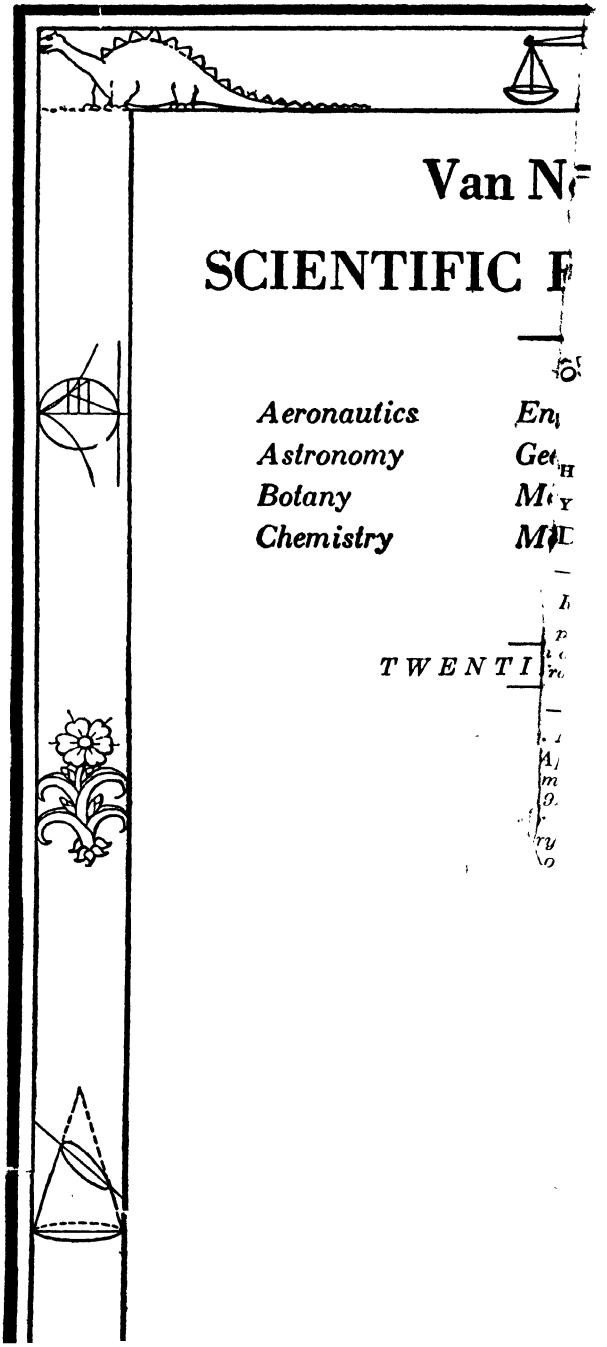
UNIVERSAL
LIBRARY

OU_170987

UNIVERSAL
LIBRARY

Van Nostrand's
SCIENTIFIC ENCYCLOPEDIA

In the manufacture of this book, the publishers have observed the recommendations of the War Production Board and any variation from previous printings of the same book is the result of this effort to conserve paper and other critical materials as an aid to war effort.



Van N

SCIENTIFIC

Aeronautics *En*
Astronomy *Ge*
Botany *M*
Chemistry *M*

TWENTI

Checked 1969

1938

COMPANY, INC.

eserved

art thereof may
ny form without
m the publisher.

March 1938
ril 1941, May 1942
ber 1943, December 1943
44 June 1944
1944, October 1944
1945, April 1945
ber 1945

CONTRIBUTING EDITORS

Richard M. Field, Ph D
Professor of Geology, Princeton University

Warren K Green, Ph D
Professor of Astronomy, Amherst College

Arthur W. Lindsey, Ph D
Professor of Zoology, Denison University

Frederick T. Morse, M E , E E
Associate Professor of Mechanical Engineering, University of Virginia

R. Sterling Mueller, B S , M D
Instructor in Surgery, College of Physicians and Surgeons, Columbia University
Surgeon, Roosevelt Hospital

Lloyd L Small, Ph D
Professor of Mathematics, Lehigh University

Edward S C. Smith, S B , A M
Professor of Geology, Union College

Ralph K Strong, Ph D
Professor of Chemistry, Rose Polytechnic Institute

LeRoy D. Weld, Ph D
Professor of Physics, Coe College

R. M Whelden, Ph D
Research Associate, Massachusetts Institute of Technology
Member, Haskins Laboratory, Inc , Schenectady

CONSULTING EDITORS

Robert H. Baker, Ph D , D Sc
Professor of Astronomy, University of Illinois

Hempstead Castle, Ph D
Assistant Professor of Botany, Yale University

C. W. Cunningham, B S C E
Instructor in Civil Engineering, College of the City of New York

Herbert O. Elftman, Ph D
Assistant Professor of Zoology, Columbia University

Erich Hausmann, E E , ScD
Thomas Potts Professor of Physics, Polytechnic Institute of Brooklyn

Adolf Knopf, Ph D
Sterling Professor of Geology, Yale University

J. Charles Rathbun, Ph D
Associate Professor of Civil Engineering, College of the City of New York

Edgar P. Slack, S B M S.
Associate Professor of Physics, Polytechnic Institute of Brooklyn

Hugh S. Taylor, D Sc , LL D , F R S
David B Jones Professor of Chemistry, Princeton University

John Turkevich, Ph D
Assistant Professor of Chemistry, Princeton University

Volney H. Wells, Ph D.
Associate Professor of Mathematics, Williams College

PREFACE

VAN NOSTRAND'S SCIENTIFIC ENCYCLOPEDIA covers the basic sciences of chemistry, physics, mineralogy, geology, botany, astronomy and mathematics; the applied sciences of navigation, aeronautics and medicine; and the three branches of engineering—civil, mechanical and electrical. In the treatment of these principal fields, many of the special sciences are included. The responsibility for each science has been left largely in the hands of a single author, to gain a unity impossible when many men contribute. However, although the responsibility rested largely in the one scientist of note, nevertheless in each field a number of men have worked with the author, and a still larger group have consulted in an advisory capacity with the authors and publishers.

In this Encyclopedia over ten thousand terms of scientific interest are arranged alphabetically and an extensive system of cross-indexing has been developed to enable the reader to find all of the facts that bear directly on each included topic. By this system, every term explained in this book is printed in bold face (black face) type wherever it is used significantly in the course of the articles on other terms. This makes it possible to turn readily to every article that has a bearing on the particular topic in which the reader is interested, as well as to obtain all supplementary information relative to any particular subject. Wherever bold face type appears within an article, the word or term appearing in this type is described in its alphabetical position. This gives to the user a very comprehensive treatment of each term if these references are consulted.

Naturally there are limits in the compiling of any one-volume book. These limits necessarily restrict the length of the article and the size of the illustration. However, the comprehensiveness of the book is noteworthy both in the scope of the terms covered and the breadth of the treatment in the individual article. The meticulous care of the authors, their advisors and their helpers, together with their systematic cross-referencing has contributed in great measure to the inclusion of so much material within the covers of one book.

A feature of this Encyclopedia is the progressive development of the discussion of each topic, beginning with a simple definition expressed in the plainest terms and progressing to a final reflection of the more detailed scientific aspects of the topic treated. Articles dealing with simple concepts are, of course, treated in simple terms throughout the Encyclopedia, but those of a highly technical nature may be of value both to the inquiring layman and to the trained technician by a selection of their reading from the earlier or later portions of such an article.

The authors and the publishers will appreciate the indulgence of the reader for omissions. The exercise of judgment in the selection of material was unavoidable and it was necessary to maintain a limit of difficulty beyond which it was impractical to go in attempting to cover so broad a field within the physical confines of one useful volume.

Grateful acknowledgment is hereby given to the many who were consulted by the authors and by the publishers and who gave unstintingly of their time in the development and production of this work.

January, 1938

Van Nostrand's Scientific Encyclopedia

A

AA. An Hawaiian term introduced into geological nomenclature by C. E. Dutton, in 1883, and signifying the jagged, scoriaceous, blocky and exceedingly rough surface of some **basic** lava flows. (R M.F.)

AARD-VARK. Mammalia, Tubulidentata. *Orycteropus.* African animals of peculiar form, including an Ethiopian and a South-African species. All are ant-eaters, feeding exclusively on ants and termites. The southern species has been called the **ant-bear.** (A.W.L.)

AARD WOLF. Mammalia, Carnivora. An African species, *Proteles cristatus*, superficially like the striped hyena. (A.W L)

AASVOGEL. South-African **vultures.** The name was applied by the Dutch colonists and means carrion-bird. (A W L)

ABACA. The **sclerenchyma** bundles from the sheathing leaf bases of *Musa textilis* (**Manila hemp**), a plant closely resembling the edible banana plant. These bundles are stripped by hand, after which they are cleaned by drawing over a rough knife. The fiber bundles are now whitish and lustrous, and from six to twelve feet long Being coarse, extremely strong and capable of resisting tension, they are much used in the manufacture of ropes and cables. Since the fibers swell only slightly when wet, they are particularly suited for rope which will be used in water. Waste manila fibers from rope manufacture and other sources are used in the making of a very tough grade of **paper**, known as manila paper. The fibers may be obtained from both wild and cultivated plants, the latter yielding a product of better grade. The cultivated plants, propagated by seeds, by cuttings of the thick **rhizomes** or by suckers, are ready for harvest at the end of three years, after which a crop may be expected approximately every three years. (R.M.W)

ABALONE. Mollusca, Gastropoda *Haliotis* Marine species, some of them common on the coast of California The broad shallow shell has a richly colored iridescent inner surface and is used in jewelry. (A W L.)

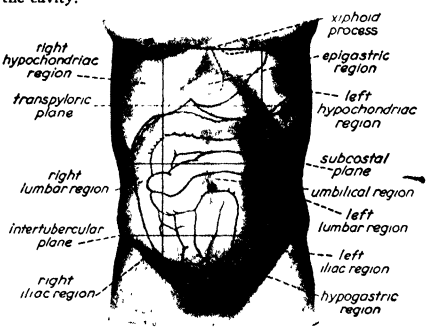
ABAMPERE. The abampere, formerly called the "electromagnetic unit current," is the fundamental unit of the **c.g.s.** (centimeter-gram-second) electromagnetic system of **electrical units.** If a current of this magnitude flows in a circular loop of 1 centimeter radius in a vacuum, the resulting magnetic field has an intensity, at the center of the circle, of 2π **oersteds**; which would be the same as 1 oersted per unit length of wire An equivalent statement is that if a current of 1 abampere flows in a straight wire across a magnetic field of 1 oersted intensity, at right angles to the magnetic intensity, the resulting lateral thrust, or "electric motor effect," is equal to 1 dyne for each centimeter of length of the wire. The (absolute) **ampere** is defined as one-tenth of the abampere. (L D W)

ABCOULOMB. Electric and Magnetic Units.

ABDOMEN. The abdomen is the posterior division of the body in many **arthropods** It is the posterior portion of the trunk in **vertebrates.** In the vertebrates this region of the body contains most of the alimentary tract, the excretory system, and the reproductive **organs** It contains part of the **coelom** and in mammals is separated from the thorax by the **diaphragm.**

The abdominal cavity of the human body is subdivided into the abdomen proper and the pelvic cavity.

The walls of the abdominal cavity are lined with a smooth membrane called the peritoneum, which also provides partial or complete covering for the organs within the cavity.



Planes of subdivision of the abdominal cavity and outline tracing of the liver, stomach, and intestine in relation to the anterior abdominal wall.

The oblique position of the stomach and the high position of the transverse colon are largely due to the fact that the subject was fixed in the horizontal position.

(Cunningham, Textbook of Anatomy, Oxford Press)

The abdomen proper is bounded above by the diaphragm, below it is continuous with the pelvic cavity, posteriorly it is bounded by the spinal column and the back muscles, and on each side by muscles and the lower portion of the ribs In front the abdominal wall is made up of layers of fascia and muscles. The surface of the abdomen is divided into sections The mid-section above the navel between the angle of the ribs is known as the epigastric region, that portion around the navel, as the umbilical; below the navel and above the pubic bone, as the hypogastric region It is further divided into right and left upper quadrants on each side above the navel, and right and left quadrants on each side below the navel The lumbar region extends on either side of the navel posteriorly.

The principal organs of the abdominal cavity are the **stomach, duodenum, jejunum, ileum,** and **colon** or large intestine, the **liver, gall bladder** and biliary system, the **spleen, pancreas** and their blood and lymphatic vessels, **lymph-glands,** and **nerves.**

The pelvic portion of the abdomen contains the urinary bladder, uterus, Fallopian tubes, and ovaries in the female, the sigmoid colon and rectum, and a portion of the small intestine. (A W L., R S M)

ABERRATION OF LIGHT. The apparent change of the direction of an object due to the velocity of an observer is known as the aberration of light. This must

not be confused with **parallax**, which is an apparent change of position of a distant object due to a real change in position of the observer

If a **telescope** is pointed at a source of light, assumed stationary relative to the telescope, we may suppose that the **quanta** or corpuscles of light which enter the telescope tube centrally will travel along the axis of the tube to the eye of the observer If, however, the telescope is in motion in any direction not along its own length and remains parallel to the original direction, the light quanta will no longer follow the axis but will reach the eyepiece to one side of the axis by an amount proportional to the distance traveled by the telescope while the light is traversing the length of the tube If the observer wishes to observe the image of the distant object in the center of the eyepiece, the telescope must be tilted forward in the direction of motion

If β is the angle between the direction of the source and the axis of the readjusted telescope, c is the velocity of light, and v is the velocity of the telescope and observer, then it may be shown that the angle α through which the telescope has been tilted is given by $\sin \alpha = \frac{v}{c} \sin \beta$ The effect of aberration of light was first observed by the English astronomer Bradley in 1726 while searching for the **stellar parallax** He found that the maximum value of aberration due to the **orbital** motion of the earth about the sun is about 20″5 This value is known as "the aberration angle" or "the constant of aberration"

In 1871 the English astronomer Airy conceived the idea of filling a telescope tube with water to see whether the consequent reduction in the velocity of the light traversing the tube would have any effect on the constant of aberration Since light travels only ¾ as fast in water as in air or vacuum, the value of the aberration angle should be expected to be 27″3 Airy found, however, that filling the tube with water had no effect on the value of the aberration constant This surprising result has occasioned much discussion, and is ultimately connected with the **Michelson-Morely experiment** and the theory of **relativity**

All accurate observations of the positions of the stars must be corrected for the effect of aberration The effect is usually discussed under two headings annual aberration, and diurnal (or daily) aberration Of these two the annual aberration is by far the greater and is that effect which was first observed by Bradley, i e, is due to the motion of the earth about the sun The apparent displacement of a star will be parallel to the **ecliptic** and will effect the celestial **longitude** by amounts varying from 20″5 for a star in the plane of the ecliptic (celestial **latitude** = 0) to zero for a star at the pole of the ecliptic The diurnal aberration is due to the rotation of the earth about its axis and is parallel to the **equator** It produces a change of 0″32 in the **right ascension** of stars on the equator (**declination** = 0) and diminishes with increasing declination to zero for a star at the pole of rotation of the **celestial sphere** (W K G, L D W)

ABFARAD. Electric and Magnetic Units.

ABHENRY. Electric and Magnetic Units.

ABIOGENESIS. The origin of living matter or living organisms from non-living material

The ancients believed that living things, such as insects and mice, sprang from decaying organic matter or even from mud in situations where they were sometimes seen in large numbers Careful experiments finally showed that such highly organized creatures were produced only by others like themselves but the discovery of microorganisms again raised the question In the experiments conducted by Pasteur and other scientists, it was at last proved that thoroughly sterilized materials gave rise to no living things unless they were later contaminated Modern biology admits the possibility that an exceedingly simple type of living substance may arise from nonliving materials but recognizes that living things as we know them are too complex to develop abruptly in this way Even the origin of simple living substance has not actually been demonstrated (A W L)

ABLATION. From the Latin *ab* and *latio*, carried from, refers to the wasting away of the surfaces of rocks or **glaciers**, but principally used in the latter connection Ablation deposits are the masses of **detritus** left after surface melting of glacial ice (E S C S, R M F)

ABOHM. Electric and Magnetic Units; Ohm.

ABORAL OR APICAL SYSTEM. Part of the nervous system of the **echinoderms** Unlike most nervous tissue it is developed from the middle germ layer (A W L)

ABORT. This term has two common meanings in medical science It means, (1) To check a disease or a condition during its early stages, and (2) To expel the **fetus** during the first four or five months of pregnancy (R S M)

ABORTION. The expulsion of the **fetus** during the first half of **pregnancy**, which is always incompatible with the life of the fetus Various descriptive terms are used to indicate the type of abortion as (1) Accidental, (2) Artificial or induced, i e, intentional, (3) Criminal that is, induced illegally, (4) Habitual, or where it occurs repeatedly with successive pregnancies in the same person, (5) Incomplete, or where only a portion of the products of conception are expelled, (6) Therapeutic, an abortion induced by a doctor as a protection to the life or health of the mother It is commonly done when the mother has advanced **tuberculosis**, **kidney** or **heart disease**, and finally (7) Threatened abortion, that is, the appearance of hemorrhage or labor pains early in pregnancy, which may or may not develop into an actual abortion (R S M)

ABRASION. Abrasion is the wearing away or removal of the surface layer of a solid object by moving it in contact with an abrasive surface (Speeds of approximately 5,000 feet per minute are commonly used) The characteristic of a surface designed for abrasion is one of roughness (to the required degree), hardness, and toughness Abrasion is particularly suitable as a means of finishing a piece of material, the size of which must be held to close limits, and where the final finishing operation requires the removal of a microscopically thin layer of material Abrasion is also useful in the final finishing of surfaces too hard to be dimensioned otherwise, as, for instance, hardened metallic surfaces The roughness, or grain, of the abrasive surface may vary between the extreme limits of roughness required for coarse grinding, and the fineness required for finishing the sharp edge of cutting tools Natural abrasives are materials such as sand, garnet, and emery, and these are frequently affixed by means of a binder, such as glue, to sheets of paper or cloth for hand use Corundum, an excellent abrasive, also exists in a natural state, but has been largely superseded by manufactured abrasives of a similar, but superior nature, such as Carborundum, Alundun, Crystolon, etc These manufactured abrasives are obtained in granular form as **alumina** or **silicon** carbide in the electric furnace For most grinding purposes these grains are bonded together with a vitrified glass-like binder to form the grinding wheels of commerce. (F T M)

ABSAROKITE. A geologic term proposed by Iddings in 1895 for a **porphyritic basalt** containing **phenocrysts** of **olivine** and **augite** in a ground mass of smaller **labradorite** crystals Type locality, Absaroka Rane, Yellowstone Park. (R M F)

ABSCESS. A localized collection of **pus** in some tissue of the body, formed by some infectious process The abscess cavity is surrounded by a wall of inflamed tissue which serves the purpose of walling off the infectious process from the rest of the body

The signs of abscess formation in the body are increase in size of the part, local heat, redness, pain and tenderness The contents of an abscess are made up of white **blood** cells and the causative organism, together with cellular debris produced by disintegration of the **tissue** cells.

The most common organisms causing abscess formation are either the **Staphylococcus** or **Streptococcus**, although almost any organism may do so Abscesses may be single or multiple, and may be found in any organ or tissue in the body They are treated surgically by incision and drainage at the proper time (R S M)

ABSCISSA OF A POINT. Rectangular Coordinates in a Plane.

ABSCISSION LAYER. The shedding of leaves by flowering plants and certain woody plants is generally a consequence of a definite development of a specialized layer of **cells** located at the base of the petiole of the **leaf** The specialized cells, recognizable long before leaf fall occurs, are first distinguished by their dense **cytoplasmic** content, and form a distinct transverse zone The cells of this zone, exclusive of the vascular elements, separate from one another and round off as the result of a gelatinization of the primary walls or **middle lamellae** As a consequence only the vascular elements hold the leaf to the stem The breaking off of the leaf may be due in part to the elongation of cells in the peripheral layers of the abscission zone The sealing off of the leaf-scar is effected in the first place by lignification (See **Lignin**) and suberization (See **Suberin**) of the walls of the exposed cells and later by the formation of a layer of cork continuous with the periderm covering the stem The exposed **xylem** elements in the scar become occluded by wound-gum or **tyloses** or both, and the **phloem** elements become compressed and lignified

Actual dropping of the leaf may be due to the inability of the vascular strands to withstand the slightest mechanical disturbance On the other hand, the retention of leaves so general in the oaks and beeches may be explained by the fact that abscission layers are only imperfectly formed In the case of the grape vine, the brambles, and the shingle oak, however, this failure on the part of the plant to shed its leaves is the result of a complete absence of any differentiated abscission tissue and the ultimate loss of leaves is merely the result of a break which occurs somewhere near the base of the petiole

A similar process occurs in the falling of fruit, inflorescence stalks, and even of branches of considerable size (R M W)

ABSINTHE Artemisia.

ABSOLUTE HUMIDITY. Humidity.

ABSOLUTE MAGNITUDE. The apparent brightness of a star, or any other luminous object, depends both upon the intrinsic brightness of the object and also upon its distance from the observer In the case of the stars the apparent brightness, expressed as **stellar magnitude**, may be determined by any one of the standard methods of stellar **photometry** In case the distance of the star is known the intrinsic brightness may be immediately calculated Conversely, if we have any method available for determining the intrinsic brightness of a star independently of a knowledge of the distance, this distance may be computed from the ratio between the apparent and intrinsic brightness

The absolute magnitude of a star is the apparent brightness, expressed on the magnitude scale, that a star would have if it were situated at a distance of ten **parsecs** from the sun or, in other words, if the **stellar parallax** of the star were one-tenth of a second Analytically, the absolute magnitude, M, of a star is connected with the apparent magnitude, mg, and the stellar parallax, π'', by

$$M = mg + 5 + 5 \log \pi''$$

On this scale we find the sun, with apparent magnitude $-26\ 72$ and parallax $.206265''$, to have an absolute magnitude of $4\ 85$ **Antares** with parallax $.''009$ and apparent magnitude $1\ 22$ is found to have an absolute magnitude of $-4\ 0$ On the basis of these absolute magnitudes and the defining relation of the magnitude scale, we find the ratio brightness of Antares to the sun to be 3470 or the star Antares is actually 3470 times as bright as the sun (W K G)

ABSOLUTE TEMPERATURE. Absolute Zero; Temperature Scales.

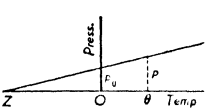
ABSOLUTE VALUE OF A REAL NUMBER. Number.

ABSOLUTE ZERO. A temperature at which bodies would possess no heat whatever Prior to the discovery of the dynamic character of heat, no significance could be attached to a zero of temperature save that of a point arbitrarily chosen, such as the melting point of ice, from which temperatures might be reckoned both ways But when it became known that heat is the kinetic energy of random molecular motion, it was at once possible to visualize, if not to realize, a condition of "absolute cold," merely by supposing the **molecules** of a substance to have come to rest relative to each other

It has been customary to define the measure of **temperature** in such a way that a linear relation exists between the temperature θ and the pressure p of a gas (hydrogen) kept at constant volume, thus

$$p = p_0 + a\theta \qquad (1)$$

in which p_0 is the pressure at the arbitrary zero of temperature This relation is represented by the straight line in the accompanying figure The slope of this line, expressed by the constant a, corresponds to the change in pressure for each unit of temperature change (degree) Experiment shows that when the centigrade scale is used, this change is 0.0036606 of the pressure of the gas at the zero of that scale, viz, the melting point of ice, so that $a = 0.0036606 p_0$ Equation (1) may accordingly be written



Relation between temperature and pressure of a gas at constant volume

$$p = p_0 + 0.0036606 p_0\theta = p_0(1 + 0.0036606\theta) \qquad (2)$$

Equation (2) now implies the possibility of causing the pressure to vanish altogether by reducing the temperature until the factor $1 + 0.0036606\theta = 0$, that is, until $\theta = -273\ 18°$ C, $-459\ 72°$ F (corresponding to Z in the figure) Since gas pressure depends upon the translatory motion of molecules, it follows that for the pressure to vanish, all such motion must cease Hence we may suppose that the centigrade temperature $-273\ 18°$ C is the absolute zero, so far as translatory thermal energy is concerned The lowest temperature so far experimentally attained was calculated to be within $0.005°$ of absolute zero **Thermometry.** (L D W)

ABSORBENT COTTON. Absorbent cotton is prepared from the fibers of the **cotton** plant These fibers are treated in such a way as to remove the natural waxy substances and the small amount of mineral matter present Subsequent washing yields the product known commercially as absorbent cotton, which can absorb as much

as eighteen times its own weight of water, and which has many commercial and medical uses (R M W.)

ABSORPTION. This term has the widest significance in science and technology In the organic world it denotes the process by which materials enter the living substance of which the organism is composed Substances including food and oxygen are taken into special organs by ingestion and respiration but they must pass through the outer surface of the **cells** to become an integral part of the organism by absorption The nature of the process is considered under **osmosis**

The absorption of gases plays an important part in engineering It is the frequent cause of **corrosion** by condensate (due to the high content of dissolved oxygen) Gaseous absorption is the basis of the absorption system of **refrigeration** In this system a gas (or vapor) is absorbed in a suitable medium and is then separated by distillation, followed in some cases by liquefaction under pressure The principles involved in the absorption of gases in liquids are treated in the article on **Solutions** and **Solubility**, and in the article on **Dissolving** The adsorption of gases (as well as liquids and solids) is a related phenomenon that is treated in the article on **Adsorption**

The quantity of heat absorbed by a substance is calculated from **specific heat** and **temperature** The capacity of surface to absorb radiant heat is measured by its absorptivity (**Thermal Radiation**)

The absorption of mechanical energy by **dynamometers**, which convert the mechanical energy to heat or electrical forms, has lead to the use of the term "absorption dynamometers" to distinguish these machines For the absorption of radiation see **Absorption Coefficient** (E T M, A W I)

ABSORPTION COEFFICIENT. A quantity used to express the rate at which a substance absorbs radiation passing through it When light, x-rays, or other **electromagnetic radiation** enters a body of matter, it experiences in general two types of attenuation Part of it is subjected to **scattering**, being reflected in all directions without essential change of character, while another portion is absorbed by being converted into other forms of energy The scattered radiation may still be effective in the same ways as the original, but the absorbed portion ceases to exist as radiation or is re-emitted as secondary radiation Strictly therefore we have to distinguish the true absorption coefficeint from the scattering coefficient, but for practical purposes it is sometimes convenient to add them together as the total attenuation or extinction coefficient

Accurate measurements upon radiation which has traversed various thicknesses of matter has established that any infinitely thin layer perpendicular to the direction of propagation cuts down the flux density by a fraction of its value proportional to the thickness of the layer, and that the flux density after having penetrated the medium to a distance x is

$$I = I_0 e^{-ax},$$

in which I_0 is the flux density upon entrance into the medium (i e, for $x = 0$) For true absorption, the constant a is the absorption coefficient (commonly designated by μ) For scattering, which obeys the same law, a is the scattering coefficient And for the total attenuation, including both, it is the extinction coefficient, which is the sum of the absorption and the scattering coefficients

Another way of expressing the absorbing effect of a substance is to specify the "half-value layer," which is that thickness of the substance which will reduce the flux density to one-half its original value, so that $I = \frac{1}{2} I_0$ This thickness is equal to $0.6931/a$ Thus if the absorption coefficient of copper for certain x-rays is 13 5 cm^{-1}, the half-value layer for these rays is 0 0513 centimeter thick For many purposes it is convenient to use the mass absorption coefficient, which is the absorption coefficient of the substance divided by its density

In general the absorption coefficient of a medium varies characteristically with the wave length of the radiation, as illustrated by the absorption of x-rays in aluminum, tabulated below

Wave Length (X-units)*	Absorption Coefficient (cm^{-1})
100	0 45
200	0 72
300	1 45
400	2 95
500	5 30
600	8 70
700	13 50
800	20 40
900	28 10
1000	38 00

(L D W)

* An X-unit is 10^{-11} cm See **X-rays.**

ABSORPTION SPECTRUM. The **spectrum** of radiation which has been filtered through a material medium When white light traverses a transparent medium, a certain portion of it is absorbed, the amount varying, in general, progressively with the frequency, of which the **absorption coefficient** is a function Analysis of the transmitted light may, however, reveal that certain frequency ranges are absorbed to a degree out of all proportion to the adjacent regions, that is, with a distinct selectivity These abnormally absorbed frequencies constitute, collectively, the "absorption spectrum" of the medium, and appear as dark lines or bands in the otherwise continuous spectrum of the transmitted light The phenomenon is not confined to the visible range, but may be found to extend throughout the spectrum from the far infrared to the extreme ultraviolet and into the x-ray region

A study of such spectra shows that the lines or bands therein accurately coincide in frequency with certain lines or bands of the emission spectra of the same substances This was formerly attributed to **resonance** of electronic vibrations, but is now more satisfactorily explained by **quantum theory** on the assumption that those quanta of the incident radiation which are absorbed are able to excite atoms or molecules of the medium to some (but not all) of the energy levels involved in the production of the complete emission spectrum

A very familiar example is the spectrum of sunlight, which is crossed by innumerable dark lines—the **Fraunhofer lines**—from which so much has been learned about the constitution of the **sun**

A noteworthy characteristic of selective absorption is found in the existence of certain anomalies in the refractive index in the neighborhood of absorption frequencies, discussed under **Dispersion** (L D W)

ABSORPTIVITY Thermal Radiation.

ABUTMENT. A **bridge** abutment is a **masonry** or **concrete** structure which functions both as a **pier** and as a **retaining wall** It must support the end of the bridge and hold the abutting earth in position The simple abutment consists of a **footing**, a main stem, a bridge seat and a back wall The footing transfers the loads to the supporting soil, consequently the area in contact with the soil must be large enough to insure a safe bearing pressure The main stem must be large enough to withstand safely the combined effects of the bridge loads, its own weight and the pressure of the soil back of the abutment The bridge seat is the surface which supports the end **bearings** of the bridge The back wall supports the earth above the bridge seat A type of retaining wall called a wing wall sometimes forms a part of the abutment The wing walls are

usually attached to both ends of the main stem and are used to retain the side slopes of the ground at the end of the abutment (C W C)

ABVOLT. Electric and Magnetic Units.

ABYSSAL FAUNA. The animals found in the depths of the ocean below six hundred fathoms The abysses are characterized by darkness, low temperature, great pressure, and the absence of plant life due to the lack of light Grotesque form and the extensive development of light-producing organs are frequent among abyssal animals (A W L)

ABYSSAL ROCKS. Proposed by Brogger as a general term for deep-seated **igneous** rocks, or those which have crystallized from **magmas** far below the surface of the earth, very slowly and under great pressure **Granite** is a typical abyssal rock The term **Plutonic** is synonymous (R M F)

ACACIA. Leguminoseae tribe Mimosae A very large genus of trees and shrubs, particularly abundant in Africa and Australia The small flowers are aggregated into ball-like or elongate clusters, which are quite conspicuous The leaves are rather diverse in shape, quite commonly they are dissected into compound pinnate forms, in other instances, especially in Australian species, they are reduced even to a point where only the flattened petiole (See **Leaf**), called a phyllode, remains This petiole grows with the edges vertical, a fact which some have been led to construe as a protective adaptation against too intense sunlight on the surface Several species, particularly those growing in Africa and tropical Asia, yield products of commercial value For example, from *Acacia Senegal* gum arabic is obtained, and from *A catechu*, a brown or black dye called cutch Many species are valuable timber trees Certain tropical American species are of particular interest because of the curious pairs of thorns, which are united at their base These thorns are often hollowed out and used as nests by species of stinging ants (R M W)

ACANTHITE. Argentite.

ACANTHOCEPHALA Worms with recurved spines at the anterior end, parasitic in the intestines of vertebrates They are usually regarded as a class of roundworms (**Nemathelminthes**) (A W L)

ACANTHUS. Acanthaceae Acanthus is a small genus of Mediterranean plants largely grown for ornamental purposes The flowers are white or various shades of red The leaves of these plants are the source of the more or less conventionalized architectural design called the acanthus (R M W)

ACARINA. The order of **Arachnida** which includes the **mites** and **ticks** (A W L)

ACCELERATION. The rate of change of the velocity with respect to the time is called acceleration It is expressed mathematically by $\frac{dv}{dt}$, the vector derivative of the velocity v, with respect to the time, t If the motion is in a straight line whose position is clearly understood, it is convenient to treat the velocity v, and the acceleration $\frac{dv}{dt}$ as scalars with appropriate algebraic signs, otherwise they must be treated by vector methods.

Acceleration may be rectilinear or curvilinear depending upon whether the path of motion is a straight line or a curved line A body which moves along a curved path has acceleration components at every point One component is in the direction of the tangent to the curve and is equal to the rate of change of the velocity at the point The second component is normal to the tangent and is equal to the square of the tangential velocity divided by the **radius of curvature** at the point. This normal component which is directed toward the center of curvature also equals the square of the **angular velocity** multiplied by the radius of curvature The acceleration due to gravity is equal to an increase in the velocity of 32 2 feet per second at the earth's surface and is of prime importance since it is the ratio between the weight and the **mass** of a body For examples of acceleration in both curved and linear motion, see **Kinematics.** (C W C, L D W)

ACCELERATORS, RUBBER. Rubber and Accelerators.

ACCELEROMETER. The accelerometer is an instrument for determining the acceleration of the system with which it moves Work in accelerometry is becoming increasingly important as means of transport continue to provide higher motive speeds for the use of mankind The principal instrument in this field of work is the accelerometer It has been used in airplane work to study the stresses that the airplane structure undergoes, and to determine how long these stresses last The records can also be used to study pilots' ability, especially in landings and acrobatic maneuvers Other uses for this instrument are the study of the oscillations of automobile springs, the pickup and braking power of automobiles, the side load on tires or rails when rounding curves, and study of vibrations of various sorts The accelerometer should have a natural period of vibration which is considerably higher than that of any shocks it may experience In addition, it should give a graphic, easily interpreted record, and it should be rugged, strong, and accurate Not all these characteristics can be met by one design, and accelerometers suitable for measuring the accelerations produced in certain flight maneuvers are unsatisfactory for measuring landing shock accelerations One style of the accelerometer is the seismograph type Unfortunately, this instrument records displacements against an axis of time sequence, and accelerations are not read directly The slope of the displaced curve is the rate of change of displacement with time, in other words, the velocity If the velocity is determined and plotted, a similar measurement of slope gives the rate of change of velocity with time, and this is the acceleration Thus the record of a seismograph type of accelerometer must be differentiated twice in order to obtain accelerations, for

$$v = \frac{ds}{dt}$$

$$a = \frac{dv}{dt}$$

$$\text{Hence} \quad a = \frac{d^2s}{dt^2}$$

While this type of instrument has its certain uses, it has been superseded for most accelerometry work by more practical designs (F T M)

ACCESSORY NIDAMENTAL GLAND. A gland of the female reproductive system in the **squids** and allied species (A W L)

ACCOMMODATION. The power of altering the focus of the **eye** so that divergent light rays may be brought to a point on the retina (R S M)

ACCOUCHEMENT. Confinement, or delivery of a baby, by an **obstetrician** or **midwife** (R S M)

ACCOUCHEMENT FORCÉ. Delivery (See **Obstetrics**) accomplished or aided by the hand or instruments. (R S M)

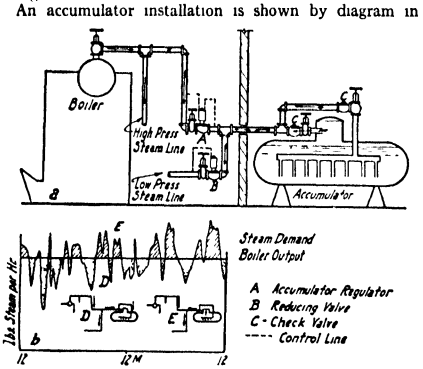
ACCOUCHEUR. An **obstetrician** or **midwife** (R S M)

ACCUMULATOR. An accumulator is a device for receiving and storing energy at a slow and uniform rate, and from which it may be discharged much more rapidly, thus providing an increase of power over short periods

The electrical accumulator is the well-known storage **battery** Two principal types are the lead storage battery, made up of electrodes having active materials of lead peroxide and sponge lead immersed in dilute sulphuric acid, and the Edison type having electrodes of nickel hydrate and iron oxide immersed in an electrolyte of caustic potash solution In the process of charging the battery, electric energy is stored by a chemical transformation of the material on the plates which is effected by the passage of current through the battery from an external source This process is reversed during the discharge period, when power can be delivered at several times the rate used during charging The storage battery is rated on its **ampere-hour** capacity For example, a 120 ampere-hour battery will give a continuous discharge of 12 amperes for 10 hours Theoretically, the product of amperes times hours should be constant for any rate of discharge, but actually the ampere-hour capacity is less at higher discharge rates (See **Electrochemistry**, also **Reactions Involving Oxidation-Reduction**)

The steam accumulator is an effective means for smoothing out irregular steam demand into a uniform boiler output Its operation is based upon the fact that the heat contained in water in a liquid form varies with the pressure of the water Thus in a tank of water under pressure with the water at the saturation temperature, a decrease of pressure on the tank will be accompanied by a release of some of the heat energy held by the water, and a consequent **flashing** of a portion of the water into steam This process can be continued with the production of steam at ever decreasing pressures until the lower pressure limit is reached Since the heat required to evaporate a pound of water is much more than the heat of the liquid at the commonly used pressures, only 20% to 40% of the weight of water in a charged accumulator tank can be converted into steam

An accumulator installation is shown by diagram in



The Ruths steam accumulator

the accompanying figure The irregular steam demand is assumed to be that of an industrial process using considerable quantities of low pressure steam, while the desired boiler output is shown as the straight line The accumulator must absorb steam during the valleys which occur below the steady boiler output line and supply steam during the peaks The direction of steam flow when charging the accumulator is shown at *D*, while at *E* is the flow diagram for accumulator discharging

The hydraulic accumulator is a hydraulic machine consisting of vertical cylinders with weighted pistons or plungers under which a certain amount of water can be stored, and is, consequently, available for doing work at the pressure yielded by the weighted piston The accumulator feature is obtained by virtue of the fact that while the water may be discharged rapidly, giving large hydraulic **power** for short periods of time, it may be refilled by a comparatively small and low powered pump working a much longer time

Another type of hydraulic accumulator is the pumped storage plant, now being looked on with considerable favor by electric power systems for the economic carrying of variable load As employed in conjunction with steam generating stations, steam turbine driven centrifugal pumps raise water from a lower to an upper pool with off-peak power During the peak-load periods this water is released to the lower pool through a hydraulic turbo-generator as rapidly as is needed to give the required power The hydraulic storage of power of this nature is essentially a high head development, low head equipment and hydraulic losses being too expensive In favorable locations the overall efficiency of conversion and storage may not need to be greater than 50% in order to justify the project (F T M)

ACETALDEHYDE Acetaldehyde (CH_3 CHO) is a colorless, odorous liquid, boiling point 20° C, miscible with water, alcohol, or ether in all proportions Acetaldehyde reacts with many chemicals in a marked manner, (1) with ammonia-silver nitrate ("Tollen's solution"), to form metallic **silver**, either as a black precipitate or as an adherent mirror film on glass, (2) with alkaline **cupric** solution ("Fehling's solution") to form **cuprous** oxide, red to yellow precipitate, (3) with rosaniline (fuchsine, magenta), which has been decolorized by **sulfurous** acid ("Schiff's solution"), the pink color of rosaniline is restored, (4) with **sodium** hydroxide, upon warming, a yellow to brown resin of unpleasant odor separates (This reaction is given by aldehydes immediately following acetaldehyde in the series, but not by **formaldehyde**, **furfuraldehyde** or **benzaldehyde**), (5) with anhydrous **ammonia**, to form aldehyde-ammonia (CH_3 CHOH NH_2), white solid, melting point 97° C, boiling point 111° C, with decomposition, (6) with concentrated **sulfuric acid**, heat is evolved, and with rise of temperature, paraldehyde (($C_2H_4O)_3$ or CH_3 $CH<^{OCH(CH_3)}_{OCH(CH_3)}>O$, colorless liquid, boiling point 124° C, slightly soluble in water, is formed, (7) with acids, below 0° C, forms metaldehyde $(C_2H_4O)_x$ white solid, sublimes at about 115° C without melting but with partial conversion to acetaldehyde, (8) with dilute **hydrochloric acid** or dilute **sodium** hydroxide, aldol (CH_3 CHOH CH_2 CHO) slowly forms, (9) with **phosphorus** pentachloride, forms ethylidene chloride (CH_3 $CHCl_2$), colorless liquid, boiling point 58° C, (10) with ethyl **alcohol** and dry hydrogen chloride, forms **acetal**, 1,1- di-methoxyethane (CH_3 $CH(OC_2H_5)_2$), colorless liquid, boiling point 104° C, (11) with **hydrocyanic acid**, forms acetaldehyde cyanhydrin (CH_3 CHOH CN), readily converted into alpha-hydroxypropionic acid (CH_3 CHOH COOH), (12) with sodium hydrogen **sulfite**, forms acetaldehyde sodium bisulfite (CH_3 CHOH SO_3Na), white solid, from which acetaldehyde is readily recoverable by treatment with sodium carbonate solution, (13) with **hydroxylamine** hydrochloride forms acetaldoxime (CH_3CH NOH), white solid, melting point 47° C, (14) with phenyl**hydrazine**, forms acetaldehyde phenylhydrazone (CH_3 CH N NH C_6H_5), white solid, melting point 98° C, (15) with magnesium methyl iodide in anhydrous ether (**"Grignard's solution"**), yields, after reaction with water, isopropyl alcohol (($CH_3)_2$CHOH), a secondary alcohol, (16) with **semicarbazide**, forms acetaldehyde semicarbazone (CH_3 CH N NH CO NH_2), white solid, melting point 162° C, (17) with **chlorine**, forms trichloroacetaldehyde ("chloral") (CCl_3 CHO), (18) with **hydrogen**

sulfide, forms thio-acetaldehyde (CH_3 CHS or $(CH_3$ CHS$)_3$) Acetaldehyde stands chemically between ethyl **alcohol** on the one hand—to which it can be reduced—and **acetic acid** on the other hand—to which it can be oxidized These reactions of acetaldehyde, coupled with its ready formation from **acetylene** by mercuric sulfate solution as a catalyzer, open up a vast field of organic chemistry with acetaldehyde as raw material Acetaldehyde is also formed by the regulated oxidation of ethyl alcohol by such a reagent as sodium dichromate in sulfuric acid (chromic sulfate also produced) Reactions (1), (3), and (16) above are most commonly used in the detection of acetaldehyde (R K S)

ACETALS. Organic compounds of the general formula $RCH(OR')(OR'')$ They are formed by the reaction of **aldehydes** with **alcohols** in the presence of small amounts of acids or certain inorganic salts They are stable toward alkali, are volatile and insoluble in water but are decomposed into aldehyde by the action of acids The last reaction is often used as a source of aldehydes (R K S)

ACETANILIDE. Aniline.

ACETIC ACID AND ACETATES. Acetic acid ($H\ C_2H_3O_2$ or $CH_3\ COOH$) is a colorless liquid, melting point 16.6° C, boiling point 118° C, miscible with water, alcohol, or ether in all proportions Acetic acid solution reacts with alkalis to form acetates, e g, **sodium** acetate, **calcium** acetate, similarly, with some oxides, e g, **lead** acetate, with carbonates, e g, **sodium** acetate, **calcium** acetate, **magnesium** acetate, with some sulfides, e g, **zinc** acetate, **manganese** acetate **Ferric** acetate solution, upon boiling, yields red precipitate of basic ferric acetate Acetic acid solution attacks many metals, liberating hydrogen and forming acetate, e g, magnesium, aluminum, zinc, iron Acetic acid is an important organic substance, with alcohols forming **esters** (acetates), with **phosphorus** trichloride forming acetyl chloride ($CH_3\ CO\ Cl$), which is an important reagent for transfer of the acetyl (CH_3CO-) group, forming **acetic anhydride**, also an acetyl reagent, forming **acetone** and calcium carbonate when passed over a suitable **catalyzer** (**barium** carbonate) or when calcium acetate is heated, forming **methane** (and sodium carbonate) when sodium acetate is heated with sodium hydroxide, forming mono-, di-, tri-**chloroacetic** (or **bromoacetic**) **acids** by reaction with chlorine (or bromine) from which **hydroxy-** and **amino-**, **aldehydic-**, **dibasic acids**, respectively, may be made, forming **acetamide** when **ammonium** acetate is distilled Acetic acid dissolves sulfur and phosphorus, is an important solvent for organic substances, and causes painful wounds when it comes in contact with the skin Normal acetates are soluble, basic acetates insoluble The latter are important in their compounds with lead, copper ("verdigris") Acetic acid is made (1) by destructive distillation of wood Dilute acid is obtained in the aqueous distillate, recovered by neutralization with **calcium** hydroxide, and then evaporation and recovery of calcium acetate, (2) from calcium or sodium acetate, acetic acid of high strength is made by distillation with concentrated **sulfuric acid**, (3) by the action of bacteria on dilute ethyl alcohol, containing the proper food materials for the bacteria, dilute acetic acid (vinegar) is produced The vinegar contains, besides acetic acid and water, the materials characteristic of the alcohol and the process used, (4) by the reaction of acetaldehyde and air over a suitable catalyzer Acetic acid is used as has been suggested by its reactions, (1) in the preparation of many organic substances, notably, **cellulose acetate**, as a non-inflammable photographic film and also as a textile fiber, (2) in the preparation of many acetates and basic acetates and carbonates (white lead in conjunction with carbon dioxide), (3) as a weak, moderately cheap acid, (4) as a solvent when concentrated, for organic chemicals, (5) in pharmaceutical preparations, dyeing, rubber, artificial leather

Esters (acetates of various alcohols) of note are

Methyl acetate (CH_3COOCH_3), boiling point 57° C

Ethyl acetate ($CH_3COOC_2H_5$), boiling point 77° C

Glycol monoacetate ($CH_3COOCH_2\ CH_2OH$) boiling point 182° C

Glycol diacetate ($CH_3COOCH_2\ CH_3COOCH_3$) boiling point 190° C

Glyceryl monoacetate (monoacetin) ($CH_2OH\ CHOH\ CH_2OOCCH_3$) decomposes upon heating

Glyceryl diacetate (diacetin) ($CH_2OH\ CHOOCCH_3\ CH_2OOCCH_3$), melting point 40° C, boiling point 176° C at 40 mm pressure

Glyceryl triacetate (triacetin) ($CH_2OOCH_3\ CHOOCCH_3\ CH_2OOCCH_3$), melting point —78° C, boiling point 259° C

Glucose pentacetate ($C_6H_7(OH)(COOCH_3)_5$), melting point 113° C, sublimes

Cellulose triacetate ($C_6H_5(OH)_2(COOCH_3)_3$)

Cellulose tetracetate ($C_6H_6(OH)(COOCH_3)_4$), softens at about 150° C

Cellulose pentacetate ($C_6H_5(COOCH_3)_5$)

Cetyl acetate ($CH_3COOC_{16}H_{33}$), melting point 22° C, boiling point 200° C at 15 mm pressure

Phenyl acetate ($CH_3COOC_6H_5$), boiling point 195° C

Acetates may be detected by formation of foul-smelling cacodyl (poisonous) on heating with dry arsenic trioxide (R K S)

ACETOACETIC ACID ESTER. This is an important organic liquid of the formula $CH_3(CO)CH_2 \cdot COOC_2H_5$, which is used as a starting point for the synthesis of **ketones** of the type $CH_3(CO)CHR'R''$ and acids of the type $R'R''CHCOOH$ where R' and R'' are hydrocarbon **radicals** The ethyl ester of acetoacetic acid is made by treating ethyl acetate (See **esters**) with sodium (R K S)

ACETONE. Acetone ($CH_3\ CO\ CH_3$) is a colorless, odorous liquid, boiling point 56° C, miscible in all proportions with water, alcohol, or ether Acetone reacts with many chemicals in a marked manner, (1) with **phosphorus** pentachloride, yields acetone chloride ($(CH_3)_2CCl_2$), (2) with **hydrogen chloride** dry, yields both mesityl oxide ($CH_3COCH\ C(CH_3)_2$), liquid, boiling point 132° C, and phorone ($(CH_3)_2C\ CHCOCH\ C(CH_3)_2$), yellow solid, melting point 28° C, (3) with concentrated **sulfuric acid**, yields mesitylene ($C_6H_3(CH_3)_3$ (1,3,5), (4) with **ammonia**, yields acetone amines, e g, diacetoneamine ($C_6H_{13}ONH$), (5) with **hydrogen cyanide**, yields acetone cyanhydrin ($(CH_3)_2CHOH\ CN$), readily converted into alpha-hydroxy acid ($(CH_3)_2CHOH\ COOH$), (6) with sodium hydrogen **sulfite**, forms acetone sodium bisulfite ($(CH_3)_2COH\ SO_3Na$), white solid, from which acetone is readily recoverable by treatment with sodium carbonate solution, (7) with **hydroxylamine** hydrochloride, forms acetoneoxime ($(CH_3)_2C\ NOH$), (8) with **phenylhydrazine**, yields acetonephenylhydrazone ($(CH_3)_2\ NNHC_6H_5$ H_2O), solid, melting point 16° C, anhydrous compound, melting point 42° C, (9) with **semicarbazide**, forms acetonesemicarbazone ($(CH_3)C\ NNHCONH_2$), solid, melting point 189° C, (10) with magnesium methyl iodid in anhydrous ether (**"Grignard's solution"**), yields, after reaction with water, trimethylcarbinol ($(CH_3)_3COH$), a tertiary alcohol, (11) with ethyl thioalcohol and hydrogen chloride dry, yields mercaptol ($(CH_3)_2C(SC_2H_5)_2$), (12) with **hypochlorite**, **hypobromite**, or **hypoiodite** solution, yields chloroform ($CHCl_3$), bromoform ($CHBr_3$) or iodoform (CHI_3), respectively, (13) with most reducing agents, forms isopropyl alcohol ($(CH_3)_2CHOH$), a secondary alcohol, but with **sodium** amalgam forms pinacone ($(CH_3)_2COH\ COH(CH_3)_2$), (14) with **sodium** dichromate and sulfuric acid, forms **acetic acid** (CH_3COOH) plus **carbon dioxide** (CO_2) When acetone vapor is passed through a tube at a dull

red heat, **ketene** ($CH_2:CO$) and **methane** (CH_4) are formed. Acetone is made (1) by heating **calcium** acetate at 400° C., calcium carbonate being simultaneously formed, (2) by passing **acetic acid** vapor over a heated catalyzer, e.g., **barium** carbonate, **manganese** carbonate, (3) by fermentation of **starch** by specific bacteria, normal-**butyl alcohol** being simultaneously produced, and acetone is formed in the water condensate (approximately 0.5 per cent acetone) in the destructive distillation of wood, and in the urine of persons having **diabetes**. Acetone may be detected by the addition of acetic acid and sodium nitroprusside (trace). The appearance of a violet color in the interface between this solution and a layer of ammonium hydroxide indicates acetone. Acetone is used (1) as a solvent, e.g., for **acetylene**, (2) as a solvent for **cellulose** and glyceryl esters in the manufacture of celluloid, smokeless powders, airplane dopes, varnishes, (3) in the preparation of **chloroform, iodoform, sulfonal**. (R.K.S.)

ACETOPHENONE. Aldehydes, Ketones and Related Compounds.

ACETYL CHLORIDE. Chlorine.

ACETYLENE. Acetylene, ethyne (C_2H_2 or $CH:CH$) is a colorless gas, of characteristic odor, moderately poisonous, boiling point —84° C., density 1.17 grams per liter at 0° C. and 760 mm. (specific gravity 0.91, air equal to 1.00), slightly soluble in water or alcohol, very soluble in acetone (300 volumes of acetylene in 1 volume acetone at 12 atmospheres pressure), burns when ignited in air with a luminous sooty flame, requiring a specially devised burner for illumination purposes, forms an explosive mixture with air over a wide range (about 3% to 80% acetylene), explosive when compressed to 2 or more atmospheres, but safe when dissolved in acetone, of high fuel value (1455 British thermal units per cubic foot). Acetylene reacts (1) with **chlorine**, to form acetylene tetrachloride ($C_2H_2Cl_4$ or $CHCl_2\cdot CHCl_2$) or acetylene dichloride ($C_2H_2Cl_2$ or $CHCl:CHCl$), (2) with **bromine**, to form acetylene tetrabromide ($C_2H_2Br_4$ or $CHBr_2\cdot CHBr_2$) or acetylene dibromide ($C_2H_2Br_2$ or $CHBr:CHBr$), (3) with **hydrogen chloride** (bromide, iodide), to form ethylene monochloride ($CH_2:CHCl$) (monobromide, monoiodide), and 1,1-dichloroethane, ethylidene chloride ($CH_3\cdot CHCl_2$) (dibromide, diiodide), (4) with water in the presence of a **catalyzer**, e.g., mercuric sulfate, to form **acetaldehyde** ($CH_3\cdot CHO$), (5) with **hydrogen**, in the presence of a catalyzer, e.g., finely divided nickel heated, to form **ethylene** (C_2H_4) or **ethane** (C_2H_6), (6) with metals, such as copper or nickel, when moist, also lead or zinc, when moist and unpurified. Tin is not attacked. Sodium yields, upon heating, the compounds C_2HNa and C_2Na_2. (7) With ammonio-**cuprous** (or **silver**) salt solution, to form cuprous (or silver) acetylide (C_2Cu_2), dark red precipitate, explosive when dry, and yielding acetylene upon treatment with acid, (8) with **mercuric** chloride solution, to form trichloromercuric acetaldehyde ($C(HgCl)_3\cdot CHO$), precipitate, which yields with hydrochloric acid acetaldehyde plus mercuric chloride. Acetylene is made by reaction of **calcium** carbide and water, calcium hydroxide being simultaneously formed, and is formed when the gas in a Bunsen burner burns at the base of the burner; and when hydrogen is passed through a carbon **arc** (about 7% acetylene in the exit gas). Acetylene may be detected by the formation of explosive copper acetylide. Acetylene is used (1) as a fuel with oxygen for high temperature flames, (2) as an illuminant, (3) in the manufacture of acetaldehyde, from which a variety of chemicals is prepared, (4) in the manufacture of chloro-derivatives. (R.K.S.)

ACETYLSALICYLIC ACID. A **drug** commonly known as "aspirin" or "empirin." (See **Salicylic Acid.**) It is used for relief of milder forms of pain, especially joint and muscle pains. It also tends to reduce fever. It does not harm the heart, contrary to popular opinion. This drug is used in massive doses in acute rheumatic fever. (R.S.M.)

ACHENE. An achene is a single-seeded **fruit**, which does not split when mature, and which has the seed free from the ovary wall except at the point of attachment. (R.M.W.)

ACHEULEAN. Paleontology of Man.

ACHILLES, TENDON OF. In man the prominent tendon at the back of the ankle, extending from the muscle of the calf to the heel. Technically it is the tendon which attaches the gastrocnemius muscle to the calcaneum or heel bone. The name derived from human anatomy is used in relation to other vertebrates. (A.W.L.)

Tendon of Achilles.

ACHLORHYDRIA. Absence of **hydrochloric acid** in the **stomach.** This may occur in older people and in certain diseases, as **cancer** of the stomach, pernicious **anemia** and certain wasting diseases. (R.S.M.)

ACHOLIA. Absence or lack of secretion of **bile.** (R.S.M.)

ACHRAS SAPOTA. Sapodilla. Sapotaceae. A large tree native to the forests of Central and tropical South America, the fruit of which is an edible berry. Its greatest value is in its **latex** product, which yields chicle. The chicle-gathering industry is centered in Yucatan and Central America. The tapping is done in the rainy season. The tapper climbs to a height of 30–50 feet, and with a machete cuts a series of connecting zig-zag diagonal gashes in the bark as he descends. At the bottom of this series of cuts he attaches a cup, into which the latex flows. The crude substance is collected, boiled down to eliminate much of its water and the coagulated product pressed into twenty to twenty-five pound blocks. This substance, chicle, varies in quality from the best grade, which is milk white in color, to pinkish or darker grades, which have received less care in preparation. Each tree yields about 2½ pounds of chicle during one season and may be tapped every six years. The blocks of chicle are shipped largely to the United States, where they are melted and cleaned, flavored and sweetened, and then marketed as the familiar chewing gum. This use of the latex of the Sapodilla is not new, since the Aztecs and their predecessors knew of it and used it. When first introduced into the United States it was tried as a rubber substitute, but proved unsuitable. (R.M.W.)

ACHROIT. Tourmaline.

ACHROMATISM. Chromatic Aberration.

ACICULUM. A strong internal **seta** found in the **parapodia** of annelid worms. (A.W.L.)

ACID ANHYDRIDES. Acids, Carboxylic.

ACIDOSIS. A condition occurring in the body in which **acids** are absorbed or form in excess of their elimination or **neutralization**. The alkali-reserve of the body is disturbed, the first step being a decrease in amount of bicarbonate (See **carbon**) in the **blood**. A similar but opposite condition results from excess formation or ingestion of **alkalies**, or from prolonged loss of acid from the stomach. The resulting condition is known as alkalosis. In this condition the alkali-reserve is increased over the normal limit.

Ordinarily, excess acid or alkali formed or taken into the body does not cause either of these conditions. This

is due to the ability of the body to protect itself automatically by preserving the acid-base **equilibrium** This is accomplished by several mechanisms In general the balance is maintained by elimination, oxidation, excretion and neutralization The bufter substances in the blood—the **salts, hemoglobin** and **protein**—act to lessen the change toward increased acid or alkali **concentration** Further, there is a reserve of alkali (alkali-reserve) to take care of any excess acid This reserve of alkali consists of sodium bicarbonate, di-potassium phosphate and protein salts Acidosis only occurs when the buffer substances and alkali-reserve are depleted This occurs only during serious disorders

Excess acid or alkali can be eliminated by the kidneys and by the respiratory mechanism through its power to throw off greater or lesser concentrations of **carbon dioxide** Neutralization of acid occurs with **ammonia** formed by the body **metabolism** These are all normal bodily processes and the mechanism of equilibrium can still be maintained in abnormal conditions without producing an acidosis or alkalosis unless certain adverse factors enter into the picture

Acidosis may occur in many diseases, usually those of serious nature They are (1) starvation or inadequate intake of water or food, especially **carbohydrates**, during acute **infections**, (2) after prolonged **anaesthesia**, (3) in **diarrheal** and vomiting diseases of children, (4) in severe untreated **diabetes**, (5) in advanced **kidney** and **heart disease**

Alkalosis may result from (1) prolonged vomiting with excess loss of **hydrochloric acid** from the stomach, (2) prolonged increase in the respiratory rate as is seen in certain disorders and in higher altitudes, (3) excess taking of alkalies by mouth as might occur in the treatment of **ulcers** of the stomach and in other conditions This may also occur through prolonged use of alkali products by the laity due to the pernicious advertising of these products on the radio and in advertisements for treatment of imaginary and non-existent "acid conditions" and indigestion (R S M)

ACID ROCK. A term applied to **igneous** rocks which contain more **quartz** than **feldspar** (orthoclase) According to A Holmes an igneous rock which contains 66% of **silica** is said to be acidic The term is gradually going out of use Since the geologist uses acid in a different sense from the chemist, Clarke has proposed persilicic for igneous rocks which are relatively rich in silica (R M F)

ACIDS, BASES AND SALTS. These are chemical compounds classified as **electrolytes** Acids are electrolytes which furnish **hydrogen ions**, e g, $HCl \rightarrow H^+ + Cl^-$ Bases are electrolytes which furnish **hydroxyl ions**, e g, $NaOH \rightarrow Na^+ + OH$ Salts are electrolytes which furnish neither hydrogen nor hydroxyl ions, e g, $NaCl \rightarrow Na^+ + Cl^-$ Salts are formed by the combination of equivalent weights of an acid and a base, a process called neutralization The result is the formation of a salt and the combination of the hydrogen and hydroxyl ions to form water $HCl + NaOH \rightarrow NaCl + H_2O$

Water as an electrolyte occupies a unique position in that it furnishes both hydrogen ions and hydroxyl ions in equal amounts In pure water the concentration of each of these ions is 10^{-7} moles per liter The product of the hydrogen times the hydroxyl concentration is always constant and equal to 10^{-14} When the hydrogen ion concentration is greater than 10^{-7} due to the presence of an acid, the hydroxyl ion concentration becomes less than 10^{-7} and the solution is said to be acidic When the hydroxyl ion concentration is greater than 10^{-7} due to the presence of a base the hydrogen ion concentration adjusts itself to a value less than 10^{-7} Thus the hydrogen ion concentration is a measure of the acidity or basicity of a solution It is usually defined by stating the pH which is the negative logarithm of the hydrogen ion concentration (in moles per liter) The process of neutralization, whereby an acid and a base in **solution** react to form a salt—actually hydrogen ion of the acid and hydroxyl ion of the base react to form water leaving the **cation** of the base and the **anion** of the salt by recombination—is discussed elsewhere See **Reactions Involving Recombination of Ions**

Upon evaporation of the solvent, the salt is obtained as such, frequently as crystals, sometimes with, sometimes without water of crystallization See **Reactions Involving Water**

A salt can be defined as "a system built from oppositely charged ions which do not neutralize each other" (Kilpatrick, 1935) In this sense **hydrochloric acid** (H^+Cl^-) and **sodium** hydroxide (Na^+OH^-) are salts Acids are those salts whose cation is hydrogen ion, H^+ (probably acid (H_3O^+) dissociating to proton (H^+) plus base (H_2O)), and bases those whose anion is hydroxyl, OH^- (probably acid (water) dissociating to proton (H^+) plus base (OH^-)) A salt (1) when dissolved in an ionizing solvent, e g, sodium chloride in water, is a good conductor of electricity, and (2) when in the solid state forms a **crystal** lattice, e g, sodium chloride crystals possess a definite lattice structure for both sodium cations (Na^+) and chloride anions (Cl^-), determinable by examination with x-rays

A broader definition than that confined to solutions is demanded in some fields of chemistry, for example, in high temperature reactions of acids, bases, salts In the formation of metallurgical **slags**, at furnace temperatures, **calcium** oxide is used as base and **silicon** oxide and **aluminum** oxide, as acids, and calcium aluminosilicate is produced as a fused salt Sodium carbonate and silicon oxide when fused react to form the salt sodium silicate with the evolution of carbon dioxide In this sense

[Oxide of any element functioning as a metal, that is, as a base] plus [Oxide of any element functioning as a non-metal, that is, as an acid] yields [Salt]

Iron and **sulfur** when heated react to form the salt ferrous sulfide In this sense

[Metal] plus [Non-metal] yields [Salt]

Salts are, therefore, prepared (1) from solutions of acids and bases by neutralization, and separation by evaporation and crystallization, (2) from solutions of two salts by precipitation where the solubility of the salt formed is slight, e g, **silver** nitrate solution plus sodium **chloride** solution yields silver chloride precipitate (almost all as solid) and sodium nitrate as sodium cations and nitrate anions in solution (recoverable as sodium nitrate solid by separation of silver chloride and subsequent evaporation of the solution), (3) from fusion of a basic oxide (or its suitable compound—sodium carbonate above) and an acidic oxide or its suitable compound—ammonium **phosphate** since ammonium and hydroxyl are volatilized as ammonia and water, thus

ammonium sodium hydrogen phosphate $Na{-}P^{5+}O_4$ (NH_4, H)

yields sodium **metaphosphate** $Na{-}P^{5+}O_3$ upon heating) (4) from reaction of a metal and a non-metal

Reactions of acids as such in solution without decomposition of anion, are dependent upon the presence of hydrogen cation (H^+) and the anion of the acid

Reactions of bases as such in solution without decomposition of cation, are dependent upon the presence of the cation of the base and hydroxyl anion (OH^-)

Reactions of salts as such in solution, without decomposition of cation or anion, are dependent upon the presence of the cation and the anion of the salt

Acids in general (exceptions are common) attack metals, **oxides, carbonates, sulfides, sulfites,** with the for-

mation of a salt and, in the respective instances, hydrogen, water, **carbon dioxide, hydrogen sulfide, sulfur dioxide** (R K S)

ACIDS, CARBOXYLIC, AND RELATED COMPOUNDS (Acid Anhydrides, Lactones, Lactides). Carboxylic **acids** (containing carboxyl group—COOH) are of wide variety as to constitution, physical properties, methods of preparation, and uses, well illustrated by reference to some of the particular acids, such as formic, acetic, stearic, oleic, benzoic Several hydroxy acids (containing hydroxyl group, —OH, and carboxyl group, —COOH) are found in important natural materials Such acids are tartaric, citric, malic, lactic The ionization constants of some organic acids and of **phenol,** which constants indicate the relative strength of these acids, are as follows, arranged in decreasing acidic strength

Acid	Ionization Constant of Acid
Trichloroacetic	2×10^{-1}
Dichloroacetic	5×10^{-2}
Oxalic	4×10^{-2}
Malonic	2×10^{-3}
Chloroacetic	2×10^{-3}
Phthalic	1×10^{-3}
Tartaric	1×10^{-3}
Salicylic	1×10^{-3}
Citric	8×10^{-4}
Malic	4×10^{-4}
Formic	2×10^{-4}
Lactic	1×10^{-4}
Benzoic	7×10^{-5}
Succinic	7×10^{-5}
Acetic	2×10^{-5}
Carbonic	3×10^{-7}
Hydrocyanic	7×10^{-10}
Phenol	1×10^{-10}

Acids that are insoluble or slightly soluble in water may usually be titrated after dissolving in alcohol, and the amount of sodium hydroxide standard solution required to neutralize a given weight of the acid is characteristic, and an indication of the particular acid involved

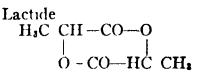
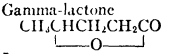
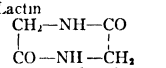
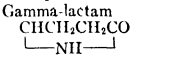
Substituted chloro-, bromo-, iodo-, amino- and cyano-, thio-, phospho-, acids will be found under the elements **chlorine, bromine, iodine, nitrogen, sulfur, phosphorus,** respectively

Primary **alcohols** or **aldehydes,** upon **oxidation,** yield the corresponding carboxylic acids, and methyl **ketones** yield acetic acid, among other products Regulated reduction of carboxylic acids yields the corresponding aldehydes or primary alcohols

When the sodium or calcium salt of carboxylic acids is heated with **sodium** hydroxide or **calcium** oxide the **hydrocarbon** containing one less carbon atom than the acid is formed, e g , sodium acetate yields **methane,** sodium benzoate yields **benzene**

Acid **anhydrides** and acid or acyl **chlorides** are important organic reagents, e g , acetic anhydride ($(CH_3CO)_2O$), benzoyl chloride (C_6H_5COCl)

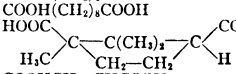
When hydroxy- or amino acids lose water or ammonia, respectively, characteristic reactions occur, as follows

Hydroxy- or Amino Acid	Acid	Product
Alpha-hydroxy	$CH_3CHOHCOOH$	Lactide 
Beta-hydroxy	$CH_3CHOHCH_2COOH$	Unsaturated acid $CH_3CH{=}CH\,COOH$
Gamma-hydroxy	$CH_3CHOHCH_2CH_2COOH$	Gamma-lactone 
Alpha-amino	$CH_2NH_2\,COOH$	Lactim 
Beta-amino	$CH_2NH_2\,CH_2\,COOH$	Unsaturated acid $CH_2{=}CH\,COOH$
Gamma-amino	$CH_2NH_2\,CH_2\,CH_2\,COOH$	Gamma-lactam 

SELECTED REPRESENTATIVE CARBOXYLIC ACIDS

	Acid	Formula	Melting point (°C)	Boiling Point (°C)
1	Carbonic	$(HO)_2CO$		
2	Formic	H COOH	8 5	100 5
3	Acetic	CH_3 COOH	16 6	118
4	Propionic	C_2H_5 COOH	−22	141
5	Normal-butyric (butanoic)	C_3H_7 COOH	− 8	163
6	Iso-butyric	$(CH_3)_2CH$ COOH	−47	154
7	Valeric (pentanoic)	C_4H_9 COOH	−59 appr	187
8	Caproic (hexanoic)	C_5H_{11} COOH	9	202
9	Heptanic (oenanthylic)	C_6H_{13} COOH	17	260 appr.
10	Caprylic (octanoic)	C_7H_{15} COOH	16	237
11	Nonanoic (pelargonic)	$C_8H_{17}COOH$	12	254
12	Capric	C_9H_{19} COOH	31	269
13	Undecylic (undecanoic)	$C_{10}H_{21}COOH$	30	228 (160 mm)
14	Lauric	$C_{11}H_{23}$ COOH	48	225 (100 mm)
15	Tridecylic (tridecanoic)	$C_{12}H_{25}COOH$	51	236 (100 mm)

SELECTED REPRESENTATIVE CARBOXYLIC ACIDS—*Continued*

	Acid	Formula	Melting Point °C	Boiling Point °C
16	Myristic	$C_{13}H_{27}COOH$	58	250 (100 mm)
17	Pentadecylic	$C_{14}H_{29}COOH$	52	257 (100 mm)
18	Palmitic	$C_{15}H_{31}COOH$	64	340 appr dec.
19	Margaric (heptadecanoic)	$C_{16}H_{33}COOH$	60	227 (100 mm)
20.	Stearic	$C_{17}H_{35}COOH$	69	383
21	Nondecylic	$C_{18}H_{37}COOH$	66	
22	Arachidic	$C_{19}H_{39}COOH$	75	
23	Behenic	$C_{21}H_{43}COOH$	83	
24	Lignoceric	$C_{23}H_{47}COOH$	80	
25	Cerotic	$C_{25}H_{51}COOH$	78	
26	Melissic	$C_{29}H_{59}COOH$	90	
27	Acrylic	$CH_2{=}CH\,COOH$	12	142
28	Crotonic (alpha)	$CH_3\,CH{=}CH\,COOH$	72	185
29	Iso-crotonic (beta)	$CH_2{=}CHCH_2COOH$	15	172 dec.
30	2-Methylacrylic	$CH_2{=}C(CH_3)\,COOH$	15	162
31	Vinylacetic	$CH_2{=}CH\,CH_2\,COOH$	−39	163
32	Angelic (2-methycrotonic)	$CH_3\,CH{=}C(CH_3)\,COOH$		
33	Oleic	$CH_3(CH_2)_7CH{=}CH(CH_2)_7\,COOH$	14	286 (100 mm)
34	Linoleic (linolic)	$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$	−18	230 (16 mm)
35	Linolenic (3 double bonds)	$C_{17}H_{29}COOH$		
36	Propargylic acid (proprolic)	$CH{\equiv}C\,COOH$	9	144 dec.
37	Furoic (pyromucic)	$C_4H_3O\,COOH$ (2)	131	231
38	Benzoic	C_6H_5COOH	122	249
39	Phenylacetic	$C_6H_5CH_2COOH$	77	265
40	Diphenylacetic	$(C_6H_5)_2CHCOOH$	148	
41	Triphenylacetic	$(C_6H_5)_3CCOOH$	265	
42	Cinnamic (Beta phenylacrylic)	$C_6H_5CH{=}CHCOOH$	133	300
43	Ortho-toluic	$CH_3C_6H_4COOH$ (2)	102	259
44	Meta-toluic	$CH_3C_6H_4COOH$ (3)	110	263
45	Para-toluic	$CH_3C_6H_4COOH$ (4)	177	275
46	Oxalic	$COOH\,COOH$ { anhydrous / crys $2H_2O$	189 / 101	150 subl.
47	Malonic	$COOHCH_2COOH$	136	dec
48	Succinic	$COOH(CH_2)_2COOH$	185	235
49	Glutaric	$COOH(CH_2)_3COOH$	97	304 dec
50	Ad pic	$COOH(CH_2)_4COOH$	151	265 (100 mm)
51	Pimelic	$COOH(CH_2)_5COOH$	103	272 (100 mm)
52	Suberic	$COOH(CH_2)_6COOH$	140	
53	Sebacic	$COOH(CH_2)_8COOH$	135	295 (100 mm)
54	Camphoric	 Dextro / Inactive	187 / 202	
55	Fumaric (Trans-ethylene dicarboxylic)	$COOHCH{=}CHCOOH$	287	290
56	Maleic (Cis-ethylene dicarboxylic)	$COOHCH{=}CHCOOH$	130	135 dec.
57	Ortho-phthalic (ortho-benzene dicarboxylic)	$C_6H_4(COOH)_2$ (1,2)	191	dec
58	Meta-benzene dicarboxylic (isophthalic)	$C_6H_4(COOH)_2$ (1,3)	330	subl.
59	Para-benzene dicarboxylic (terephthalic)	$C_6H_4(COOH)_2$ (1,4)	subl	
60	1,2,3-Benzenetricarboxylic (hemimellitic)	$C_6H_3(COOH)_3$ (1,2,3)	190	
61	1,2,4-Benzenetricarboxylic (trimellitic)	$C_6H_3(COOH)_3$ (1,2,4)	216 dec	
62	1,3,5-Benzenetricarboxylic (trimesic)	$C_6H_3(COOH)_3$ (1,3,5)	350 subl	
63	1,2,3,4-Benzenetetracarboxylic (prehnitic)	$C_6H_2(COOH)_4$ (1,2,3,4)	237 dec	
64	1,2,3,5-Benzenetetracarboxylic (mellophanic)	$C_6H_2(COOH)_4$ (1,2,3,5)	238	
65	1,2,4,5-Benzenetetracarboxylic (pyromellitic)	$C_6H_2(COOH)_4$ (1,2,4,5)	264	
66	Benzenehexacarboxylic (mellitic)	$C_6(COOH)_6$	dec.	
67	Glycollic (hydroxyacetic)	$CH_2OH\,COOH$	65 appr	dec.
68	Lactic (alpha-hydroxypropionic)	$CH_3CHOHCOOH$		122 (14 mm)
	sarcolactic	dextrolaevo	18	
	paralactic	dextro	25	

(*Continued on next page*)

SELECTED REPRESENTATIVE CARBOXYLIC ACIDS—*Continued*

	Acid	Formula		Melting Point (°C)	Boiling Point (°C)
69	Beta-hydroxypropionic (hydrocrylic)				dec
70	Alpha-hydroxybutyric	$CH_3CH_2CHOHCOOH$		42	260
71	Beta-hydroxybutyric	$CH_3CHOHCH_2COOH$			130 (14 mm)
72	Gamma-hydroxybutyric	$CH_2OHCH_2CH_2COOH$		−17	
73	Alpha-hydroxystearic	$C_{16}H_{33}CHOHCOOH$		92	
74	Glyceric (2,3-dihydroxypropionic)	$CH_2OHCHOHCOOH$			
75	Tartaronic (2 hydroxypropandioic)	$COOHCHOHCOOH$		158 dec	
76	Malic (2-hydroxysuccinic)	$COOHCH_2CHOHCOOH$	Dextrolaevo	133	150 dec
			Laevo	100	140 dec
77	Tartaric (2,3-dihydroxysuccinic)	$COOHCHOHCHOHCOOH$			
	Racemic		Dextrolaevo	205	
			Dextro and laevo	170	
	Mesotartaric		Inactive	140	
78	Arabonic	$CH_2OH(CHOH)_3COOH$		89	
79	Gluconic	$CH_2OH(CHOH)_4COOH$			
80	Glycuronic	$CHO(CHOH)_4COOH$			
81	Mucic	$COOH(CHOH)_4COOH$		206 dec	
82	Saccharic	$COOH(CHOH)_4COOH$		(lactone)	
83	Citric (hydroxytricarboxylic)	$COOHCH_2C(OH)(COOH)CH_2COOH$		153	
84	Ricinoleic	$C_{17}H_{32}(OH)(COOH)$		4	
85	Mandelic	$C_6H_5CHOHCOOH$		118	dec
86	Salicylic	HOC_6H_4COOH (2)		159	
87	Gallic	$(3,4,5)(HO)_3C_6H_2COOH$		235 dec	
88	Glyoxalic (glyoxylic)	$CHO\ COOH$		dec	
89	Pyruvic	$CH_3COCOOH$		9	165 dec
90	Acetoacetic	CH_3COCH_2COOH			100 dec
91	Levulinic	$CH_3COCH_2CH_2COOH$		33	246
92	Mesoxalic	$COOH\ CO\ COOH\ H_2O$ or $COOH\ C(OH)_2\ COOH$		120	(RKS)

SELECTED REPRESENTATIVE ACID ANHYDRIDES

	Acid Anhydride	Formula	Melting Point (°C)	Boiling Point (°C)
1	Acetic	$(CH_3CO)_2O$	−73	140
2	Propionic	$(C_2H_5CO)_2O$	−45	165 appr
3	Normal-Butyric	$(C_3H_7CO)_2O$	−75	198
4	Iso-Butyric	$((CH_3)_2CHCO)_2O$	−53	182
5	Benzoic	$(C_6H_5CO)_2O$	43	360
6	Cinnamic	$(C_6H_5CH\ CHCO)_2O$	135	
7	Succinic	$(CH_2CO)_2O$	120	261
8	Malic	$(CHCO)_2O$	57	202
9	Glycollic	$(CH_2OHCO)_2O$	130	
10	Lactic	$(CH_3CHOHCO)_2O$	260 dec	
11	Salicylic	$(HOC_6H_4CO)_2O$	200 appr	dec

LACTONI AND LACTIDE (HYDROXYACID ANHYDRIDES)

1	Butyrolacetone (gamma)	$CH_2CH_2CH_2CO$ (O)		206
2	Lactide (dilactide)	$H_3C\ CH—CO—O$ / $O—CO—HC\ CH_3$	125	255

RKS

ACIDS, INORGANIC See **Individual Acid.**

ACINIFORM GLANDS. The glands of **spiders** which produce the silk used to enclose the prey (AWL)

ACMITE—AEGIRITE. Acmite is a comparatively rare rockmaking mineral, usually found in nephelite **syenites** or other **nephelite** or **leucite** bearing rocks, as phonolites. Chemically it is a **soda-iron** silicate, and its name refers to its sharply pointed **monoclinic** crystals. Bluntly terminated crystals form the variety aegirite, named for Aegir, the Icelandic sea god

Acmite has a hardness of 6 to 6 5, specific gravity 3 5,

vitreous luster, color brown to green, transparent to opaque

The original acmite locality is in Norway Greenland furnishes fine specimens United States localities are Magnet Cove, Arkansas, and Libby, Montana, where a variety carrying **vanadium** occurs (E S C S)

ACNE. A chronic infection of the **sebaceous glands** in the skin The exact cause of this disease is not exactly known It is usually first seen in certain susceptible individuals with the onset of **puberty** Because of its occurrence at this time many observers believe that the primary cause of this disease lies in a disturbed function of some of the endocrine **glands** In some cases correction of this disturbance has caused a disappearance of the acne It usually disappears on reaching adult life, although in certain individuals the disease becomes chronic It is most often seen in people with oily skins The external opening on the skin of the sebaceous gland becomes narrowed, the sebaceous material cannot escape and the retained material serves as a source of irritation, secondarily infecting the surrounding tissue Some forms of acne are caused by **drugs** such as **bromides** and **iodides** when taken by susceptible individuals Acne may cause permanent scarring It is most successfully treated by **X-rays** and **ultra-violet rays** or sunlight, although vaccines, local treatment of the skin, glandular and hygienic methods are also useful in certain cases It is not contagious (R S M)

ACOELA. An order of free-living flatworms in which the alimentary tract is without a cavity (A W L)

ACOELOMATA. Animals without a **coelom** The term is applied especially to the flatworms, nemertine worms, and roundworms, these animals have attained the mesoderm in which the body cavity develops but it remains a more or less continuous mass with small spaces if any (A W L)

ACONINE. Alkaloids.

ACONITE. A **drug** obtained from the dried root of *Aconitum napellus* This drug was formerly used in the treatment of various **fevers** but is now seldom used (R S M)

ACONITINE. Alkaloids.

ACONTIA Filaments bearing stinging cells in **sea anemones** They can be shot out through the mouth or through special pores when the animal is stimulated (A W L)

ACOUSTICS. In the broader sense, acoustics is the physics of **sound**, treated in all its aspects Commonly, however, the term is restricted to a study of the transmission of sound through various media or in various enclosures or conduits, including the effects of reflection, refraction, interference, diffraction, and absorption

Of especial importance is the acoustics of buildings and auditoriums Sound from a source within an enclosure tends to build up to a maximum of intensity, limited only by leakage (as through open doors or windows) and by the dissipation of the energy through air viscosity and absorption It is thus much easier to make one's self heard in a small, closed room than out of doors In a large enclosure, an important factor is "reverberation," that is, the re-echoing of sounds among the various exposed solid surfaces, which, if too protracted, may impair the distinctness of audition Sabine defines the "reverberation time" as the period in which the intensity falls to one millionth of its steady value after the source is suddenly silenced He obtained an empirical formula for the time in seconds, as follows $T = 0.164V/a$ Here V is the volume of the room in cubic meters, while a is the sum of the equivalent absorptions of the various exposed surfaces, each equal to the product of the area of the surface in square meters by its "acoustic absorptivity" (ratio of absorbed to incident sound energy) Sabine found the absorptivity of plaster to be 0.033, glass 0.027, wooden floor 0.061, linoleum 0.120, etc, and the absorption of an audience to be 0.44 square meter per person (equivalent to 0.44 square meter of a perfect absorber), of each empty wooden seat 0.008 square meter, of each upholstered seat 0.30 square meter, etc It is thus possible to predict by Sabine's law the reverberation time of an auditorium before it is built, and to judge whether it will be good for piano music (for which the best value is about 1.1 seconds) or for speaking (for which a smaller value is desirable) Another factor in auditorium acoustics is concerned with "focusing" the sounds from the stage upon the audience by means of properly shaped walls and ceiling, a problem which Sabine studied by means of photographs of sound waves in small model enclosures

The investigation of such problems as the passage of sound through simple tubes, or tubes having branches, or through cavities of various shapes, such as musical instruments or resonators, reveal certain remarkable analogies to the theory of alternating current circuits Thus we encounter the property known as acoustic impedance, with its components, acoustic resistance and acoustic reactance, the latter being dependent upon the acoustic inertance (analogous to inductance) and acoustic compliance (sometimes called acoustic capacitance) These correspond to analogous properties of alternating current circuits, in which the electric impulses may be compared to acoustic waves with electricity as the medium The acoustic resistance, inertance, and compliance depend, respectively, upon the viscosity, the density, and the elasticity of the medium It is an interesting fact that by causing sound to pass through a suitably designed conduit, such as the two-branched or shunted "Quincke tube," certain frequencies may be suppressed, much as electric oscillations are suppressed by electric wave filters This effect is due to the interference of wave trains following different routes (I D W)

ACRASPEDOTE A medusa without a **velum**, such as the common **jellyfishes** (A W L)

ACRIDINE. Pyridine and Related Compounds

ACRIFLAVINE An acridine (See **Pyridine and Related Compounds) dye**, reddish yellow in color, which is used in dilute solution in the treatment of infected or contaminated wounds It possesses germicidal and antiseptic properties and, when used in the proper dilution, will not injure body tissues In weak solutions it is also used for irrigation of diseased body cavities, as, for instance, the urinary **bladder** when **cystitis** is present (R S M)

ACROCYST. A chamber formed of the **blastostyle** of some species of **hydroids**, in which the eggs develop (A W L)

ACRODONT. Dentition.

ACROLEIN Aldehydes, Ketones, and Related Compounds

ACROMEGLIA OR ACROMEGALY. A chronic disease due to overfunction of a part of the **pituitary gland** This usually occurs in adult life The head becomes enlarged, the lips thicken, the nose enlarges and the chin becomes prominent, giving a lion-like appearance to the face The other portions of the body involved in this disease are the short and flat bones The hands and feet enlarge so rapidly in the acute stage that the patient is forced to change to larger shoes and gloves every month or so (R S M)

ACRYLIC ACID. Alcohols and Ethers.

ACTINIUM. Symbol Ac A radioactive element, and also a series of radioactive elements See **Radioactive Changes**

ACTINOLITE. The term for a **calcium-iron-magnesium amphibole**, the formula being $Ca_2(Fe,Mg)_5(OH)_2(Si_4O_{11})_2$, but the amount of iron varies considerably It occurs as bladed crystals or in fibrous or granular masses Its hardness is 5–6, specific gravity 2 9–3 2, color green to greyish green, transparent to opaque, luster vitreous to silky or waxy Iron in the **ferrous** state is believed to be the cau.e of its green color Actinolite derives its name from the frequent radiated groups of crystals Actinolite is found in **schists**, often with **serpentine** and in **igneous** rocks probably as the result of the alteration of **pyroxene** The schists of the Swiss Alps carry actinolite It is also found in Austria, Saxony, Norway, Japan, and Canada in the provinces of Quebec and Ontario In the United States actinolite occurs in Massachusetts, Pennsylvania, Maryland, and as a **zinc-manganese** bearing variety in New Jersey (E S C S)

ACTINOMYCOSIS. A disease of man and certain domestic animals caused by a **pathogenic fungus** known commonly as the ray fungus This infectious fungus was first recognized to be a vegetable **parasite** by Bollinger in 1877 It is found in the **pus** caused by the disease, in the form of small whitish or yellowish granules varying in size from a fraction of a millimeter to one or two millimeters in size

The disease is not contagious and to acqu're it direct implantation of the parasite within the body is necessary

This infection is characterized by formation of fibrous tissue and multiple abscesses

The disease is a serious one and may last months or years The mortality is high The treatment is chiefly surgical when possible (R S M)

ACTINOMYXIDA. Sporozoa.

ACTINON. Symbol An A radioactive element of the actinium series. See **Radioactive Changes**

ACTINOZOA. Anthozoa.

ACTINULA A larval form of **hydroid**, resembling a **polyp** with a short stalk. (A W L)

ACTION. In certain discussions of dynamics there is need of an expression for the product of twice the mean total **kinetic energy** of a system of particles, during a specified interval of time, by the duration of the interval This product is called the "action" Mathematically, it is expressed by

$$S = 2\int_{t_0}^{t} E_K dt,$$

in which E_K is the kinetic energy and t_0 and t are the times of beginning and ending of the interval The c g s unit of action is the erg-second The well known "Planck's constant h" is the common designation for the elementary quantum of action

Maupertuis enunciated a law, known as the "principle of least action," which states that when a dynamic system is left to itself, unaffected by outside forces, so that its total energy cannot alter, any spontaneous change within the system takes place in such fashion that the action has the least possible value during the interval covered by the change (L D W)

ADAMANT. The term adamant was used by Theophrastus about 300 B C to mean **lodestone** Chaucer as well as other medieval writers used it similarly There seems to have been some confusion as to the exact nature of adamant, some regarded it as referring either to lodestone or **diamond** or to a mythical substance combining the properties of both Curiously enough there is a rare variety of bort (black diamond) which is magnetic, due to the mechanical admixture of particles of **magnetite** Whether this sort of black diamond was known to the ancients is wholly a matter of conjecture

The long continued association of the idea of hardness with the word adamant has led to our modern usage of the term as well as the derived, adamantine, **referring** to the lu.ter of substances of high refractive indices. (E S C S)

ADANSONIA DIGITATA. Baobab Bombaceae A tree of tropical Africa, the baobab has an extremely large trunk (the diameter sometimes exceeding thirty feet), but does not attain great height The natives often excavate the light, easily worked wood and use the hollow so formed for shelter The large fruit has a mucilaginous pulp which is often eaten, and the bark yields a fiber used for making cloth and rope (R M W)

ADAPTABILITY. A property of living matter through which it makes adjustments to its environment It is accomplished chiefly through four fundamental properties irritability, conductivity, contractility, and secretion The first enables it to receive impressions from surrounding factors Through the second all parts of the living body are in communication with the parts capable of receiving stimuli from without The last two are the more common means of response Contractility is the source of movement by which spatial adjustments of the body in relation to its surroundings are accomplished, and secretion is a means of producing special substances, such as digestive fluids, involved in the animal's reactions

Adaptability is expressed in all of the actions of an organism, and in a more permanent way in the **adaptation** of the individual and species to its mode of life (A W L)

ADAPTATION. The process of modification of the living organism to adjust it to the conditions of its environment Also an inherited character that enables the organism to meet certain environmental conditions

All living things are adapted for a mode of life characteristic of their kind, under equally characteristic environmental conditions They receive from previous generations a heritage (See **Heredity**) that fits them for this mode of life, and all characters in the hereditary complex that are of definite use are adaptive Wings, for example, are an essential flight adaptation, and fins or some similar appendage are commonly found as adaptations for swimming Other characters such as the colors and patterns of butterfly wings are usually of no apparent value and may be called non-adaptive or incidental

Regardless of its adaptive heritage, however, each individual encounters some fluctuations in its environment to which it must adjust itself The resulting changes in its body are adaptive, no less than its inherited structures They are the acquired characters of biological literature, and have also been called individual adaptations Human beings commonly experience two fine examples of this kind of adaptation in the calluses formed by the skin in response to friction, and the deposition of pigment, or tanning, as a protection against excessive ultraviolet light

The relation of adaptations of both kinds to individual life is evident in any living thing Beyond this field they are of great importance in theories of **evolution**, the one as the extensive result of evolutionary processes of the past and the other as a possible factor in the accomplishment of changes of evolutionary significance. (A W L)

ADAPTIVE (RADIAL) EVOLUTION. Fossil Invertebrates and Fossil Reptiles.

ADAPTIVE RADIATION. A principle of evolutionary development formulated by Henry Fairfield Osborn It assumes that a limited stock of animals in a restricted area tends to become broken up in the course of time into species adapted to various special habitats. Thus, as originally applied to the **mammals**, the ances-

tral stock is supposed to have been a small walking species with generalized teeth and omnivorous habits From it the running and jumping species, burrowers and fliers, and species adapted to eat flesh or to eat vegetation are supposed to have evolved

Although originally applied to the mammals the principle has been found to apply equally well to other groups, such as the insects In some cases divergent or branching evolution has been noted, as well as radiating development from a common central stock (A W L)

ADDAX. Mammalia, Artiodactyla An **antelope,** *Addax nasomaculatus*, of northern Africa and Arabia (A W L)

ADDER Reptilia, Serpentes A term loosely applied to various **snakes**, both poisonous and non-poisonous Among the poisonous species are the resplendent adders of Asia, which are near the American coral snakes, and the deadly **crait** and rai-samp of India, also known as the blue adder and banded adder, respectively Australia also has two poisonous species, the death adders (*Acanthophis*), and the deadly puff-adder, *Bitis arietans*, s found throughout Africa In North America the last name is applied to the harmless hog-nosed snakes, although spreading adder is perhaps more commonly used (A W L)

ADDICT One who makes a habit of taking a narcotic **drug** The term may also apply to the taking of any drug habitually The narcotics chiefly used by addicts are **morphine, heroin,** and **cocaine** (R S M)

ADDISON'S DISEASE A chronic insufficiency of the **adrenal glands** that develops in the third or fourth decade of life, marked by depression, mental and physical apathy, disturbances of the digestive tract, pigmentation of the skin, and very low blood pressure The disease is gradual, with progressive exhaustion and debility until an intercurrent infection produces death

At autopsy, **tuberculosis** of the adrenal glands is the most common finding, although other diseases of the adrenal glands may be present

Treatment is supportive, although certain glandular (See **Gland**) extracts seem to be of use (R S M)

ADDITION. Addition is one of the fundamental operations with **numbers,** by which two or more numbers are combined to give a number, the result is called the sum

Addition of numbers is subject to several fundamental rules or so-called laws the commutative and associative laws, and in combination with **multiplication,** the distributive law

The commutative law for addition of numbers is expressed by the formula

$$a + b = b + a$$

for any two numbers a and b, in words, the sum of any two numbers is the same in whatever order they are added A similar statement applies to the sum of more than two numbers

The associative law for addition of numbers is expressed by

$$(a + b) + c = a + (b + c)$$

or any three numbers a, b, c; in words, the sum of any three numbers is the same in whatever manner they are grouped This is easily extended to more than three numbers

The absolute value of a positive number is the number itself, and the absolute value of a negative number is its numerical value regardless of algebraic sign

To add two numbers having like signs, add their absolute values and prefix the common sign

To add two numbers having unlike signs, take the difference of their absolute values and prefix to it the sign of the number having the larger absolute value (L L S)

ADENINE. Alkaloids.

ADENITIS. Inflammation or infection of glandular tissue The term generally is applied to inflammation of the **lymph** glands Cervical adenitis is inflammation of the glands of the neck, axillary adenitis is inflammation of the glands of the **axilla;** inguinal adenitis is inflammation of the glands of the groin, mesenteric adenitis is inflammation of the glands in the mesentery of the small intestine The infection can be local, originating in the glands or by drainage into the glands from a nearby inflammation, or it can accompany a systemic disease (R S M)

ADENOIDS An increase in the normal lymphoid tissue in the nasopharynx (See **Pharnyx**) It is sometimes referred to as the third tonsil The condition usually accompanies enlargement of the tonsils The exact cause of this condition is not known, although heredity and acute infectious diseases play a part in its development The disease, usually occurring during childhood, is easily recognized when fully developed, by the dull facial expression, inability to blow the nose, mouth breathing, snoring and nasal twang to the voice It is usually accompanied by frequent head colds, nose bleeds, and ear trouble If not corrected, mental deficiency may develop, together with various reflex **neuroses** and habit formations The treatment is surgical removal and is usually done at the same time as tonsillectomy (R S M)

ADHESION. This term is used both in anatomy and in physics

In anatomy adhesion refers specifically to an abnormal adherence of parts of the body, either directly, surface to surface, or by bands of connective **tissue** This most commonly occurs as a result of inflammation, as in **joints,** where adhesions between the lining membranes (**synovial** membranes) can produce stiffness and pain In the peritoneal cavity following various degrees of peritoneal infection, bands or adhesions can occur between the peritoneal coats of organs or intestines These occasionally cause untoward symptoms requiring operative interference In the chest, as a result of various types of **pleurisy,** adhesions often form between the **pleura** covering the lung and the lining of the interior of the chest cavity

In physics, the terms adhesion and cohesion designate intermolecular forces holding matter together The tendency of matter to hold itself together or to cling to other matter is one of its most characteristic properties Adhesion and cohesion are merely different aspects of the same phenomenon, which is apparently of the nature of an intermolecular attraction We speak of cohesion as an interaction between adjacent parts of the same body and as acting throughout the interior of its substance, while adhesion refers to a similar interaction between the closely contiguous surfaces of adjacent bodies

There is reason to believe that as two neutral molecules or atoms approach each other, their mutual potential energy reaches a minimum value at a certain equilibrium distance, so that work would be necessary either to push them closer or to pull them farther apart, because of forces which are probably electrical The distribution of molecules, ions, or atoms in a solid is determined by this type of equilibrium, and the regular spacing of crystal structure and the architecture of the molecule itself are dependent upon it Any force tending to diminish the equilibrium distance meets with the rapidly increasing reaction of compressive elasticity, while any force tending to increase it is opposed by cohesion, which increases at first and then rapidly diminishes toward zero as the point of fracture is reached

The behavior of bodies which are aggregates of crystals or of fibers is complicated by the friction and the adhesion of the adjacent particles, so that the ultimate

strength of a material is not a safe measure of its true cohesion A filament of spun quartz may be much stronger when freshly drawn than later when crystallization replaces its initial cohesion by the adhesion between separate crystals, and yarn is not nearly so strong as the cotton or wool fiber composing it

Adhesion increases with closeness of contact This explains why one must bear down with a pencil to make a mark on paper, why fine dust adheres more firmly than coarse sand, and why a liquid or a gum usually sticks to a solid better than another solid does

Cohesion in liquids is usually less, and in gases it is always much less, than in solids Aside from the pressure in liquids due to external causes, there is presumably a very great internal or intrinsic pressure, due to intermolecular attraction, but not capable of direct measurement by means at our disposal The clearest evidences of its existence are the work required for thermal **expansion** and the phenomenon of **surface tension** (R S M , L D W)

ADIABATIC PROCESSES. Changes in matter which take place without transfer of heat When heat is imparted to or withdrawn from a body of matter, the body generally experiences changes of temperature, pressure, and volume, and sometimes a change of state These changes severally involve the absorption or the release of energy, which may be regarded respectively as positive and negative energy increments, and the algebraic sum of which is equivalent to the quantity of heat supplied or withdrawn If the body in question could be provided with perfect thermal insulation, so that no heat could enter or leave it, then any change requiring energy, which might take place within the body, would necessarily be effected at the expense of energy yielded by other internal changes But a rise of temperature might be caused by heat generated in compression Processes of this sort, unaccompanied by any transfer of heat across the insulating boundaries of the body, are said to be adiabatic

For an ideal gas, the pressure and the volume maintain, during an adiabatic expansion or compression, a relationship in which the pressure changes proportionately more with volume than for an isothermal change This adiabatic relation, for a very slow change, is represented by the formula $pv^{\gamma} = \text{constant}$, in which γ is the ratio of the **specific heat** of the gas at constant pressure to that at constant volume (for air, about 1 41) Corresponding formulas are readily obtained for pressure and temperature and for volume and temperature by utilizing the **ideal gas law** Adiabatic processes, though hardly realizable in practice, are often considered in thermodynamic reasoning (L D W)

ADIPOCERE. Waxy matter formed by the chemical transformation of bodies protected from air by burial in moist places or by submergence in water Grave wax (A W L)

ADIPOSE FIN. A fleshy **fin** without supporting spines, occurring behind the dorsal fin in some fishes (A W L)

ADIPOSIS. An excessive accumulation of fatty tissue in the body This condition is usually caused by overindulgence in food, especially in cases where heredity, disinclination to exercise, or faulty glandular mechanisms —especially disturbances of the **pituitary** or **thyroid gland**—make the subject particularly susceptible to this condition (R S M)

ADJUTANT. Aves, Ciconiiformes *Leptoptilus* A name applied to stork-like birds (**Aves**) of several species They occur in Africa and the Oriental region where they are valuable as scavengers From at least one species the soft downy feathers known as marabou are secured (A W L)

ADMITTANCE. Admittance is the reciprocal of impedance In **alternating current circuits** impedance is equal to the square root of the sum of the squares of resistance and reactance (F T M)

ADOBE. An extremely fine-grained wind-blown **clay** particularly characteristic of the arid and semi-arid south-western United States, Mexico and South America Used by the south-western Indians and Mexicans for huts and buildings from pre-historic times (R M F)

ADOLESCENCE The period between **puberty** and maturity, usually between the ages of twelve and twenty years (R S M)

ADRENAL GLAND (Suprarenal Gland) One of the **glands** of internal secretion The two adrenal glands are small, triangular structures situated on the upper portion of each kidney just below the diaphragm They are composed of two portions the internal portion, called the medulla, and the outer portion, called the cortex Each portion has a separate secretion and function **Adrenalin** is secreted into the blood stream by the medullary portion This medullary portion of the gland is derived from the same embryonic **cells** that form the sympathetic **nervous system.** Adrenalin, when secreted, stimulates this nervous system and the reverse is also true, that is, stimulation of this nervous system also causes additional adrenalin to be poured forth into the system Fear, anger, excitement, sudden physical exertion, etc , are stimulating factors, both to the sympathetic nervous system, and in turn to the secretion of adrenalin

The cortex of the gland secretes a substance or substances whose functions are not known This portion is linked up with the other glands of internal secretion (**pituitary** and **thyroid**) and has to do with **reproductive** functions (R S M)

ADRENALIN (EPINEPHRINE) ($C_6H_3(OH)_2CH$-$OHCH_2NHCH_3$) One of the secretions of the **adrenal glands** It is usually used either by local application or by hypodermic in 1 1000 solution

Normally a sufficient amount of this substance is secreted by the gland to maintain normal tone of the blood vessels During exercise and especially with fear, anger, danger or sudden muscular activity, the glands are stimulated and larger amounts are discharged into the blood stream This stimulates the sympathetic nervous system with the following results blood pressure is increased quickly and markedly, respirations are quickened and deeper, and smooth muscle is contracted These actions are favorable for muscular exertion but unfavorable for digestion, as may easily be understood The same reaction is seen when adrenalin is given hypodermatically

It is used medically to increase the blood pressure and restore tone to the blood vessels Adrenalin is the most rapidly acting circulatory stimulant of marked power, but owing to its transient action, it is used only in emergencies It is used in cases of failure of the normal heart as may occur following electric shocks, etc , where it is given in dilute solution into the heart blood Adrenalin is sometimes used to shrink mucous membrane as of the nose, throat, when congestion is present It is sometimes used to control bleeding from an oozing surface, through its action of constricting blood vessels

A common use for adrenalin, which is specific, is to prevent or treat foreign **protein** reactions, as are seen when serum is given to a sensitive person, and in **hives,** hay fever and **asthma.** In the latter diseases, its action is often dramatic and the attack is usually aborted temporarily at least (See **Hormones.**) (R S M)

ADSORPTION. Adsorption is a type of adhesion which takes place at the surface of a solid or a liquid in contact with another medium, resulting in an ac-

cumulation or increased concentration of molecules from that medium in the immediate vicinity of the surface. For example, if freshly heated charcoal is placed in an enclosure with ordinary air, a condensation of certain gases occurs upon it, resulting in a reduction of pressure; or if it is placed in a solution of unrefined sugar, some of the impurities are likewise adsorbed, and thus removed from the solution. Charcoal, when activated (i.e., freed from adsorbed matter by heating) is especially effective in adsorption, probably because of the great surface area presented by its porous structure. Its use in gas masks is dependent upon this fact.

When **colloidal** hydroxides, notably **aluminum** hydroxide, are precipitated in a solution of acidic **dyes,** that is, those containing the groups —OH or —COOH, the dye adheres to the precipitate, yielding what is termed a lake. The dirt that adheres to the hands results from the unequal distribution of the dirt between the surface flesh of the hands and the air or solid with which the flesh comes in contact. Water is frequently ineffective in removing the dirt. The efficacy of soap in accomplishing its removal is due to the unequal distribution of dirt between flesh and soap "solution," this time favoring the soap and leaving the hands clean.

According to the Gibb's adsorption law, adsorption of the type here described occurs whenever an increase in concentration of the medium would result in a decrease of the interfacial surface energy, that is, the potential energy per unit area of contact between adsorbing body and medium. This is in accord with the principle of least energy. The reverse effect (negative adsorption) is observed when the surface energy would be decreased by a decrease in concentration. Both types occur in appropriate circumstances. Heat resulting from the transformation of energy which takes place in these processes is called heat of adsorption. At a given fixed temperature, there is a definite relation between the number of molecules adsorbed upon a surface and the pressure (if a gas) or the concentration (if a solution), which may be represented by an equation, or graphically by a curve called the adsorption isotherm.

The degree of adsorption depends upon (1) the composition of the adsorbing material, (2) the condition of the surface of the adsorbing material, (3) the material to be adsorbed, (4) the temperature, and (5) the pressure (if a gas). A notable case in point is carbon. Of the finely divided varieties of carbon there are important sugar charcoal, bone black or animal black, blood charcoal, wood charcoal, coconut-shell charcoal, activated carbon. The temperature of preparation of adsorbent charcoal is an important factor, high temperatures being deleterious, and the removal (or non-removal) of gases by passing steam over the heated carbon, which operation increases the adsorptive power. Bone black is used for removing the coloring matter from raw sugar solutions. Fusel oil is removed from whiskey and poison gases from air by adsorption with the proper form of carbon. By cooling carbon in a vacuum to the temperature of liquid air, the concentration of residual gas is greatly decreased. Dewar (1906) found that five grams of charcoal (presumably coconut-shell charcoal) at the temperature of liquid air reduced the pressure of air in a one-liter container from 1.7 millimeters to 0.00005 millimeter. This is now a standard method for the production of a high vacuum, as in the **neon** lighting tube. Travers (1906), using **carbon dioxide** gas, and animal charcoal, found that the concentration of gas divided by the third power of the concentration of adsorbed gas is a constant. In other cases the power to which the concentration of adsorbed gas must be raised is approximately 3 to 2.

Besides carbon, other important adsorbents in use are infusorial or diatomaceous earth, fuller's earth, clay, and silica gel. All surfaces that behave indifferently towards non-electrolytes have the ability to adsorb **electrolytes.**

Adsorption plays an important role in the process of **dyeing,** and in contact catalytic processes such as the conversion of **sulfur dioxide** to trioxide, and of **nitrogen** plus **hydrogen** to **ammonia.** In the case of insoluble organic acids (containing —COOH group) and substances containing hydroxyl (—OH) groups on the surface of water, the film is oriented so that the —COOH or —OH groups are attracted into the surface of the water, while their hydrocarbon ends project away from the surface of the water showing no tendency to dissolve (Langmuir).

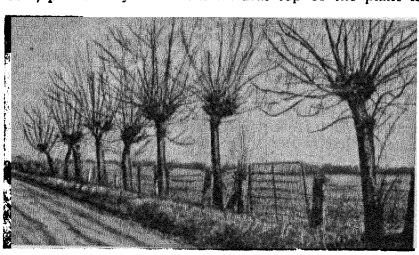
The heat of adsorption, or wetting in this case, of starch by water is 29 **calories** per gram of dry starch. The heat of adsorption of various vapors and adsorbents has been measured. Since increase of temperature reduces adsorption, the adsorption process is accompanied by the evolution of heat. It appears that the heat liberated for a given volume of liquid filling the capillary spaces of a given adsorbent is practically constant. The heat of adsorption of hydrogen is, on **nickel, palladium, platinum, copper,** 11,700, 18,000, 13,800, 9,500 calories respectively per gram mol (2 grams) of hydrogen; and of carbon monoxide on platinum 35,000 calories per gram mol (28 grams) of **carbon monoxide;** and of **ethylene** on copper 9,500 calories per gram mol (28 grams) of ethylene.

Occlusion is a type of adsorption, or perhaps more properly absorption, exhibited by metals or other solids toward gases, in which the gas is apparently incorporated in the crystal structure of the solid. Palladium thus occludes extraordinary quantities of hydrogen, with the liberation of much heat. (L.D.W., R.K.S.)

ADULARIA. **Feldspar.**

ADULT. A full-grown animal. In species with a pronounced **metamorphosis** the last stage is known as the adult or in insects as the imago. Sexual maturity is characteristic of most adults but some are without sexual functions and in some species reproduction may take place in an earlier developmental stage. (A.W.L.)

ADVENTITIOUS BUDS. **Buds** which appear elsewhere than in the leaf axils or above them. They may appear anywhere in the internode, or on roots or even on leaves, and develop either naturally or as a result of injury. The dense bunches of buds, which frequently appear on burls or in witches brooms, may be adventitious. The buds which appear at the tops of thistle **roots,** particularly when the natural top of the plant is



Pollarded trees (*Catalpa*). Numerous branches developed from adventitious buds when the stem was cut.

cut off, are adventitious. So also are the buds which develop on the leaves of the Begonia and **Bryophyllum.** The practice of pollarding, or cutting off the branches of a tree in such a way as to leave only the main trunk or perhaps the stumps of a few large branches, results in the development of dense groups of adventitious buds. These grow into adventitious branches which in certain willows may be long and supple and so useful in manufacturing wicker furniture. The habit of forming adventitious buds on roots is of material value, since in

consequence it is possible to propagate many plants by means of root cuttings

Adventitious roots also exist They may appear from the stem where they arise in the **pericycle**, or from other tissues of the plant The roots which appear on slips or stem cuttings are adventitious (R M W)

ADVENTITIOUS ROOTS. Adventitious buds.

AEOLIAN DEPOSITS. Sediments and **sedimentary** rocks which are largely, if not entirely, composed of wind-blown material Desert sands are typical aeolian sediments, characterized by relatively uniform, well-rounded particles whose surfaces are usually covered with microscopic pits due to their mutual bombardment during transportation This pitting gives each sand grain a frosted appearance Wind-blown sediments frequently show characteristic **cross-bedding**, ripple marks (miniature dunes) and wind-faceted pebbles (**glyptoliths**) Further evidence of their origin is the absence of fossils Aeolian deposits are usually largely composed of **quartz** sand An important fine-grained wind-blown deposit is **Loess** Extensive desert deposits are also composed of **gypsum**, salt, etc Due to the high degree of oxidation, desert sands that contain ferro-magnesian minerals are often red, due to the formation of the relatively insoluble **iron** oxide (R M F)

AERATION. Aeration is an artificial method in which water and air are brought into direct contact with each other The purpose of aeration is to release certain dissolved gases, which often cause water to have obnoxious odors or disagreeable tastes It is also used to furnish oxygen to waters which are deficient in this element Aeration may be accomplished in many ways One method consists of spraying the water into the air The same result may be obtained by allowing the water to flow through a series of reservoirs whose water surfaces are at different elevations

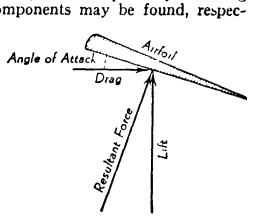
The principle of aeration is used in the treatment of sewage by a method known as the activated **sludge** process The **sewage** is allowed to flow into an aeration tank where it is mixed with a predetermined volume of sludge Compressed air is introduced which agitates the mixture and furnishes oxygen which is necessary for certain biological changes which take place (C W C, F T M)

AERENCHYMA. Spongy tissue occurring chiefly in the stems of many aquatic or marsh plants This tissue is formed by the **phellogen** layer, and in many cases results from the separation of the cell walls, leaving extensive intercellular spaces, as in *Decodon* Such porous tissue gives great buoyancy to the stem and so helps keep the leaves up in the air and permits gas diffusion within the plant The term aerenchyma is frequently applied to any loose porous tissue found in plants, as for example that occurring in **lenticels.** (R M W)

AEROBE OR AEROBIC BACTERIA. Most species of **bacteria** can grow only when there is available to them free oxygen These are called aerobic bacteria (Compare **Anaerobe**) (R M W)

AERODYNAMICS. That branch of physics which treats of the forces exerted by air or other gases upon bodies exposed to them, especially those forces arising from the relative motion of gas and exposed body The most important practical applications are found in the bracing of structures against wind, in the construction of wind-driven machinery and sailing vessels, and in the design of aircraft

It was shown by Langley and other early experimenters that when a smooth, plane surface is exposed normally to a current of air, it experiences a force which is proportional to the square of the wind velocity V and very nearly to the area s of the plate, as expressed by the formula $F = ksV^2$ It is not possible to calculate this force theoretically with accuracy, since so much depends upon the manner in which the air is deflected around the plate The experiments of Langley indicated, however, that if the wind velocity is expressed in miles per hour, s in square feet, and the force in pounds, k has a nearly constant value of about 0 003 If the surface is not plane, the force depends upon its curvature, as is well illustrated by a common type of **anemometer.** For a surface turned obliquely, the resultant force varies with the **angle of attack** (angle between wind direction and surface) This force may be divided into two components, one in the wind direction and the other at right angles to it, called respectively the drag and the lift These components may be found, respectively, by multiplying sV^2 by a drag coefficient and a lift coefficient which must be determined by experiment for each modification of surface form It is thus necessary to set up model airfoils, representing actual propeller blades, airplane wings, etc, in an experimental **wind tunnel** and to measure the forces exerted upon them In this way the best shapes for maximum ratio of lift to drag, etc, are worked out and the type of design known as streamlining is perfected



Components of wind force on an airfoil

When an airplane is flying, there are four resultant forces acting upon it which must be kept in equilibrium They are (1) the weight of the plane and cargo, (2) the total lift on all surfaces, (3) the traction of the propeller, and (4) the total drag on all surfaces (1) and (2) are vertical forces, (3) and (4) are horizontal forces Each pair must form a couple and the two couples must together have zero resultant torque if the plane is to maintain an unchanging flight This equilibrium is accomplished by adjustment of the speed and the angles of attack of the various control surfaces (L D W)

AERODYNAMIC EFFICIENCY. There is no single, rigid, and definite meaning ascribed to this term However, in general, it might be said that aerodynamic efficiency measures the ratio of the useful effect on a body exposed to air in motion as compared to the total effort required or to the undesirable reactions unavoidably incurred Thus, one automotive vehicular shape would be more efficient than another when it transported, for example, five persons with equal comfort at the same speed but with less expenditure of power to overcome wind resistance than the other Or, again, the aerodynamic efficiency of an **airfoil**, such as that employed in an airplane wing, can be measured by the ratio of the lift created to the drag entailed in creating this lift (see **Aerodynamics**) (F T M)

AEROLITE. Meteorite.

AERONAUTICAL ENGINES. An aeronautical engine is any engine which, by virtue of design or adaptation successfully meets the special requirements of the propulsion of aircraft These special requirements are

1 Weight Low weight per horsepower developed
2 Reliability This applies especially in aviation, but is not to be disregarded in aerostation (See **Aeronautics**)
3 Stamina Aircraft engines must be able to deliver continuously at least 75% of their full power without overheating or excessive wear

4 Frontal Area. A minimum frontal area should be presented to the windstream
5 Rotative Speed The rotative speed cannot be increased above about 2000 rpm without adding reduction gearing because of the poor efficiencies of propellers operated at high speeds
6 Ability to continue functioning when placed in other than normal horizontal position, and when subject to accelerations as during acrobatic flying
7 Compensation for changes of atmospheric conditions at altitudes equal to the highest altitude at which the airplane can be flown
8 Balance Freedom from shaking and vibrating forces
9 Thermal Efficiency This affects the amount of fuel that needs to be carried

It has not been possible to achieve the best in all these requirements in any single engine, but many available aeronautical engines exhibit an excellent combination of many of them While most aeronautical engines are especially designed and built for the service, there are conversions or adaptations of other types, such as automobile engines, which have apparently proved successful In general, however, these conversions are characterized by relatively higher weights per horsepower than for straight aeronautical designs, although they fulfill the other requirements to a fair degree Owing to the comparative rarity of airships, the airship engine is here accorded only passing notice The blimps are powered by the smaller stock airplane type engines, but special engines are usually designed and built for dirigibles

One of the most important requirements of the airplane engine is the necessity for achieving all the other requirements with due regard to keeping the weight at a minimum Generally speaking, reliability, stamina, balance, etc, are opposed to low weight per horsepower, so that the design of an aeronautical engine becomes a compromise between the other desirable features and weight The low weights of today's engines are achieved by the use of special alloy metals, careful designing, and extensive testing The larger engines will be lighter per unit output than the smaller ones, because the weight of auxiliaries, such as magnetos, carburetors, and the like, does not vary directly, in proportion to output, but is nearly as much in small engines as in large ones The weight of large aeronautical engines is usually between 1½ and 2 pounds per horsepower The smaller sizes weigh between 2¾ and 3¼ pounds per horsepower The weight of automotive conversions may be in the neighborhood of 4 to 6 pounds per horsepower. As there must be a horsepower for at least every twenty-five pounds of airplane weight, it can easily be seen that the engine is no small part of the weight of an airplane As a matter of fact, twenty-five pounds per horsepower would represent an airplane greatly underpowered, judged from modern standards Fifteen pounds per horsepower is more nearly an average figure for the small sportsman or trainer type of airplane, ten to twelve pounds per horsepower for the high speed transports, and as low as six to seven pounds per horsepower for high performance military airplanes This requirement of lightness has lead to the perfection of the internal combustion engine of the Otto cycle type as the leading aeronautical engine While Diesel and steam types of prime movers both have successfully flown aircraft, and may become very important to the aircraft of the future, the gasoline engine is preeminent in this field at the present time Its commanding position is principally due to its superiority in weight per horsepower developed In many other points it is inferior, as it uses a type of fuel that has high fire and explosion hazard, it requires auxiliaries which are delicate and easily thrown out of adjustment, and suffers a loss of output at increasing altitude These disadvantages, however, only serve to emphasize the importance attached to weight.

Reliability in the Otto engine may readily be secured, but usually only at the expense of increasing the weight, and to secure the maximum possible reliability, the weight would be prohibitive Hence the aircraft engine cannot be entirely reliable, although manufacturers have been able to achieve remarkable results in this direction Airplanes acting as public carriers should, for night schedules, be multi-motored, and able to maintain altitude with one motor out This feature is of less importance in daytime flying, as the pilot, confronted with engine trouble, will usually be able to select an emergency field and land safely, an achievement practically impossible at night The sparking plug element of the ignition system is one of the less perfect components of an engine, but the whole electrical ignition system is such that it is deemed best to duplicate it, so common practice on standard engines is to have two spark plugs in each cylinder, and two independent sources of voltage to these plugs It has not been expedient from the standpoint of cost or weight to duplicate all the auxiliary systems of the gasoline engine

Unlike the automobile engine, which may operate over long periods of time at only 25% to 35% of full power output, the aeronautical engine must deliver its "cruising" power steadily, and be able to deliver full power for a period of several minutes' duration The airplane engine is called on for a full power output, during the period of take-off, and climb to some altitude at which the pilot feels it safe to throttle back The throttled power output, however, is rarely less than 65% full power for cross-country work, and it is not usually possible to maintain altitude in an airplane with the power output less than 50% of rated For these reasons, a high degree of stamina, which involves special attention to the cooling and lubricating systems, as well as to the wearing parts, must be incorporated in aeronautical engines

The parasitic drag of an aeronautical power plant is dependent on its cooling system Between 25% and 35% of the heating units in the fuel must be passed through the cylinder walls in order to keep them cool enough, and this heat must ultimately be dissipated to the atmosphere If this is done by extending the outside surface of the cylinder to form fins and moving an airstream across them, the more effective the cooling, the greater the parasite drag involved If a liquid cooling medium is interspersed between cylinder and atmosphere, as is the case in liquid cooled engines, the engine may be completely enclosed in a well streamlined fuselage or nacelle, but a radiator must be placed in the windstream at some point, and becomes a source of drag The radiator resistance of very large engines is less than the drag of air cooled engines of equivalent power, and hence the liquid cooled engine is favored for high speed, high powered airplanes Special low drag types of radiators are employed on high speed racing planes, where neither engine drag nor radiator drag can be tolerated These surface radiators, however, are altogether too fragile and expensive to be considered for any other service than the special one of high-speed racing, wherein the working life of the aircraft may not extend beyond a test period and a world-breaking record flight over a measured mile or similar short course

A most serious defect of the internal combustion engine is its decrease in volumetric efficiency and developed power when it is supplied with air of decreasing density Such is the case when an airplane climbs steadily It eventually arrives at an altitude where the decrease in engine horsepower leaves no excess power over that required to maintain horizontal flight, and no further climb is possible The airplane is then said to have reached its "ceiling" This ceiling varies from 10,000-20,000 feet above sea level, depending upon the horsepower, weight, and wing area of an airplane It may, however, be increased several thousand feet by supercharging the engine Since flight at high altitudes

(i.e., stratosphere flight) holds forth much of promise for the aeronautical industry of the future, the supercharged internal combustion engine, or an external combustion cycle, such as the steam cycle, will be favored types.

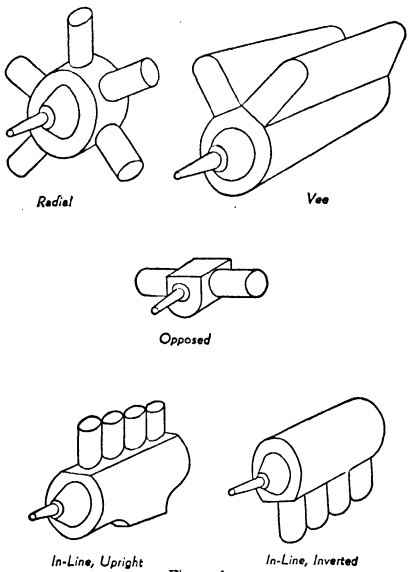


Figure 1.
Aeronautical engine cylinder arrangement.

The average thermal efficiency of the aeronautical engine is 25% at full rated power, and individual engines depart only slightly from this value. The gasoline tanks must hold sufficient gasoline to provide .09 of a gallon for each horsepower used per hour.

Practically all cylinder arrangements that have been used for internal combustion engines are to be found in aircraft practice, but many of them are seldom seen. The more common cylinder arrangements are shown in Figure 1. The radial arrangement of cylinders is probably used more than any other at the present time. The radial aeronautical engine is always air cooled. In fact, one of the principal advantages of the radial arrangement is the presentation of each cylinder, individually, to the cooling airstream, whereas in-line arrangements, while presenting a lower frontal area, have problems of cooling introduced by the fact that only the front cylinder meets an undisturbed airstream. The radial engine has a short cylindrical crankcase to which are attached, with axes radial to the crankcase, cylinders to the number of three, five, seven, or nine. The cylinders are evenly spaced around the circumference of the crankcase. The crankshaft, which passes through the center of the crankcase, has a single throw and is supported on two main bearings and one thrust bearing. The front end of the crankshaft protrudes from the crankcase and on it is mounted the propeller hub. Through gearing, the crankshaft drives the valve lifting cams, the magnetos, the oil pump, and many other needed accessories. A radial engine of the four-cycle type must be built with an odd number of cylinders because it fires on alternate cylinders, and the four-stroke cycle requires two full revolutions before all cylinders have fired. Thus, in a seven cylinder engine, in which the cylinders are numbered consecutively 1, 2, 3, . . . 7, the firing order is 1-3-5-7-2-4-6. Radial engines using six and fourteen cylinders have been built, but they are really twin threes of twin sevens, and their crankshafts have two throws. Since some cylinders of a radial engine must project from the lower part of the crankcase, no integral oil sump is possible, but rather the oil is withdrawn from the lower part of the crankcase by a sump pump and delivered to an external oil tank where it is stored and cooled, and from which it is taken by the pressure oil pump and delivered back to the bearings and other parts of the engine. The piston and connecting rod arrangement is interesting in that there is one master rod which bears upon the crankshaft, while the remaining cylinders have articulated connecting rods, that is, they bear upon pins in the big end of the master connecting rod. All this is clearly shown in Figure 2, in which the cylinder having the master rod is vertical, a customary arrangement. Except for the connecting rods the cylinders are identical.

The in-line cylinder arrangement, in which the cylinders are mounted in a line over a crankshaft which has as many throws as there are cylinders, is used in both air and liquid cooled engines. For engines of equivalent output, the in-line engine tends to be heavier because of the longer crankcase and crankshaft, but presents a much lower frontal area and is more susceptible to streamlining than the radial type. Six cylinders in line, however, are about the maximum that can be successfully cooled, and these must be equipped with a special cowling containing air scoops and deflectors to direct cool air over the cylinders and to discharge heated air from the forward cylinders where it will not tend to heat those behind. In-line, air cooled engines are frequently made inverted, that is, having the cylinders projecting downward from the crankcase. Advantages of improved forward visibility and high thrust center are secured by inverted designs. The upright engines may

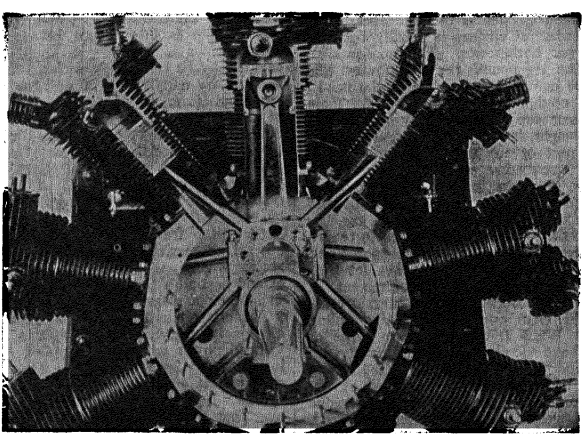


Figure 2.

have self-contained oil sumps, but inverted engines must have external oil tanks

Small two and four cylinder air cooled engines are frequently made horizontally opposed This type is essentially a light plane engine It rarely exceeds fifty horsepower, whereas the in-line engine is found up to two hundred horsepower, and the radial as high as seven hundred horsepower, in stock models The Vee arrangement of cylinders is frequently used in multi-cylinder watercooled engines, and occasionally in air cooled engines The present trend, however, is to employ liquid cooled engines only in the larger powers, omitting, of course, consideration of automobile conversions, which are water cooled, and generally less than 100 horsepower

The consistent effort of aeronautical engine designers to reduce the weight per horsepower has not left much place for the commoner materials of construction, such as cast iron In the design of aeronautical engines there is attained a high perfection of the metallurgist's art While a few small air cooled engines will have cast iron cylinders, standard practice in this field indicates the use of forged steel cylinder barrels, to which are attached cast aluminum alloy cylinder heads by bolting, screwing, shrinking, or combinations of these Questions of cooling, volumetric efficiency, and manufacturing cost dictate the use of overhead valves in these engines, consequently the cylinder heads contain the ports, valve seats, and spark plugs Aluminum bronze rings are inserted to form the valve seats as aluminum does not possess sufficient strength to resist the pounding action of the valves Pistons are aluminum alloy, and connecting rods are duralumin or drop forged alloy steel Crankcases are cast or forged aluminum, usually machined all over, while crankshafts are of special alloy steel, such, for instance, as nickel chromium steel Valves offered difficult problems as they tended to warp, leak, pit, break, and stick under the severe service conditions of aeronautical engines Engine manufacturers have, with the cooperation of parts manufacturers and metallurgists, succeeded so well in solving these problems that the latest engines produced satisfy, to a high degree, all the requirements mentioned in the introduction to this article (F T M)

AERONAUTICS Aeronautics encompasses all that pertains to the study, design, manufacture, maintenance, testing, and use of aircraft Since the term aircraft includes any machine or device for navigating the air, aeronautics is seen to be a term embracing a broad field of human activity One general method of aeronautical classification is based on the method of sustension of the aircraft, namely

1 Aviation, where lifting is obtained from the dynamic action of air in motion relative to wings
2 Aerostation, in which lift is obtained by the buoyancy of a volume of light gas

Aviation is therefore that branch of aeronautics which pertains to heavier-than-air craft, such as fixed wing **airplanes, gliders, autogiros, ornithopters, helicopters**

Aerostation is that branch of aeronautics which pertains to **airships,** free **balloons,** and captive balloons

Not included in either of the above categories is the rocket type of aircraft, which, however, has not become of sufficient importance to extend the classification to include it

The following outline will serve to give the reader an idea of the activities in the whole field of aeronautics.

A Study of aircraft, theoretical and practical
1. Education, in aviation schools and colleges Flying instruction, ground school work for mechanics and craftsmen, business and commercial studies, technological or engineering education
2 Research, in developing new aircraft types, improving present types, investigating meteorological conditions, etc
   a Governmental agencies (Army, Navy, National Advisory Committee for Aeronautics)
   b Universities
   c Manufacturers

B Design

Design of aircraft, landing fields, hangars, aircraft equipment, communication systems, etc
This activity is found mainly in factories manufacturing aircraft, but is also, to a lesser extent, carried on by individual experimenters and various government agencies

C Manufacture
1 Processing raw materials Manufacturing of special alloy metals, selection and seasoning of wood, manufacture of finishing materials, extraction of helium, etc
2 Fabricating Shaping raw materials to the final form in accordance with design drawings
3 Assembling Building the finished aircraft, hangar, radio transmitter, etc

D Testing
1 Ground testing of materials, methods, engines, etc
2 Flight testing of the aircraft structure, of instruments, of power plants, of transport schedules, and of communication systems

E Maintenance, inspection, and repair of flying equipment, and of ground equipment

F Use
1 Military Observation, bombing, pursuit patrol, direct ground offense
2 Civilian Non-commercial For personal transportation, pleasure flying, and air racing
3 Scheduled air transport
An important phase of the aeronautic industry, which acts as a public carrier of persons, mail, and cargo, on definite time schedules between specified points, and over specified routes, in so far as exigencies of weather conditions permit
4 Fixed base operation Special for hire charter trips, of both business and sporting nature
5 Miscellaneous
   a Forest patrol
   b Executive transport
   c Advertising
   d Freight transportation to otherwise inaccessible regions
   e Map photography
   f Crop dusting, etc

G Regulation and control

United States Department of Commerce, Bureau of Aeronautics Supervision of the aeronautical industry for the purpose of promoting general public safety against the hazards of aeronautical transportation, including
1 Setting up standards of design and construction of aircraft and other aeronautical equipment
2 Inspecting design and construction, and certifying equipment, i e , licensing
3 Supervising the airworthiness of aircraft
4. Examining operating personnel, pilots and mechanics, for competence and physical condition.
5 Developing and maintaining airways
6 Developing new and improved aeronautical equipment (F T M)

AESCULAPIUS The god of healing in ancient Greek mythology (R S M)

AESTIVATION Summer dormancy, the antithesis of the more familiar hibernation (A W L)

AFRICAN CRESTED RAT. Mammalia, Rodentia, *Lophiomys.* A rare species of **rat** of northeastern Africa, related to the wood-rats of North America. (A.W.L.)

AFRICAN JUMPING HARE. Mammalia, Rodentia, *Pedetes.* A south-African species with large hind legs. (See **Rodentia.**) It belongs with the **jerboas** near the true mice and not with the hares as the name suggests. (A.W.L.)

AFRICAN LEMUR. Galago.

AFRICAN SLOW LEMUR. Potto.

AFTERBIRTH. The membranes and **placenta** expelled from the **uterus** a short time after the birth of the child. (R.S.M.)

AFTERGLOW. Electrodeless Discharge.

AGAMA. A large South African **lizard** of the genus *Agama.* (A.W.L.)

AGAMONT. A single-celled animal of a generation which reproduces asexually. See also **gamont.** (A.W.L.)

AGAR-AGAR. A gelatine-like substance which is prepared from various species of red **algae** growing in Asiatic waters. The prepared product appears in the form of cakes, coarse granules, long shreds, or in thin sheets. It is used extensively alone or in combination with various nutritive substances, as a medium for culturing **bacteria** and various **fungi.** It is sometimes recommended as a mild laxative. (R.M.W.)

AGARICS. Agaricaceae. Fungi. This family of **fungi** is probably better known than any other, since it contains most of the plants commonly described by the names toadstool and mushroom, which popularly and mistakenly denote poisonous and edible fungi, respectively.

The Agarics are mostly fleshy fungi of that very definite structure, the familiar parasol-like toadstool. This is composed of convex pileus or cap, usually supported on an evident stalk. The underside of the cap shows a series of radiating plates, or gills, which are formed in agaric fungi only, and so serve to separate them from all others. The two sides of the gills are covered with the microscopic spore-bearing bodies called basidia, which are club-shaped or cylindrical cells bearing **spores,** generally four each. Agarics vary in size from delicate species with a cap a millimeter or so in diameter, supported by a slender thread-like stalk, to massive forms twelve inches in diameter: the larger species form millions of spores.

The spores float in the air for considerable distances, and finally come to rest on some solid substance. Should this be favorable for germination, the spore puts out a slender tube, which elongates rapidly and penetrates the substratum, from which it absorbs substances necessary for its continued growth. Gradually this thread-like body, known as the mycelium, spreads through extensive masses of substratum, branching frequently as it does so.

Finally there is accumulated in the mycelium a supply of reserve food sufficient for fruiting: then, if atmospheric conditions, such as moisture and temperature, be suitable, the familiar toadstool appears, it being only the reproductive stage of the fungus. Its rate of growth is often phenomenal, as is also the force it may exert in its growth. Seemingly delicate bodies not only break open the hard-packed surface of the ground, but also may push aside pebbles of considerable weight. Not infrequently whole rings of toadstools appear in a field, springing to maturity in a single night—these are the familiar fairy rings, resulting from the growing outward from a common source of the unseen mycelium, and not from the dancing of fairy forms.

When the young fruit-body first comes up it is completely enclosed in a membranous skin known as the velum. As enlargement continues this skin is broken. Often traces of the velum remain in the form of flakes on the upper surface of the cap, and as a ring or annulus around the stalk. Attempts have been made to find in these characteristics a means for separating the edible from the poisonous species. However, no reliable distinction is found here. Actually, unless one is absolutely sure of the identity of a given species, the only safe rule is complete abstinence. Classification is based on the color of the spore-masses, and also the determination of the way in which the gills are attached to the stalk, the color changes shown as a cut or broken surface dries, and various other means.

Sporophore of a mushroom, *Agaricus campestris.*

A few species of Agarics, notably *Agaricus* (*Psalliota*) *campestris,* are extensively cultivated, and justly esteemed as food. Other species are violently poisonous, particularly species of the genus *Amanita.* Yet certain Siberian people use *Amanita muscaria,* a poisonous species, to produce a form of intoxication. Another common mushroom, the Inky-cap, a species of *Coprinus,* has been used as a writing fluid, the substance of the toadstool breaking down into a fluid mass containing vast numbers of black spores. (See **Basidomycetes.**) (R.M.W.)

AGATE. Agate is a variety of **chalcedony** whose variegated colors are distributed in regular bands or zones, in clouds or in **dendritic** forms, as in moss agate.

The banding is often very delicate with parallel lines of different colors, sometimes straight, sometimes undulating or concentric. The parallel bands represent the edges of successive layers of deposition from solution in cavities in rocks.

As agate is an impure variety of quartz it has the same physical properties as that mineral. It is named from the river Achates in Sicily where it has been known from the time of Theophrastus.

Agate is found in many localities; India, Brazil, Uruguay and Germany are notable for fine specimens.

Onyx is a variety of agate in which the parallel bands are perfectly straight and can be used for the cutting of cameos. Sardonyx has layers of sard (red carnelian) alternating with lighter colored layers of onyx. (E.S.C.S.)

AGAVE. Amaryllidaceae. A large genus of plants, particularly abundant in Mexico, in which the thick rigid leaves form a basal rosette from the center of which rises the tall flower stalk. Because of the time required to store sufficient food reserves for flowering, certain species, notably *Agave americana,* are called **century plants** from the belief that they flower but once a century; actually flowering may occur in from five to fifty or more years. Once started, the flower stalk develops very rapidly, requiring immense quantities of sap. In Mexico, the flower stalk is cut off early in its formation and the stump scooped out to form a cup into which quantities of sweet sap exude. This sap is collected and fermented to form pulque, a strong drink with an unpleasant odor. Distilled pulque gives a more potent drink, mescal. From the leaves of several species, particularly *Agave sisalana* and *A. fourcroydes,* are obtained fibers. These fibers occur as **sclerenchyma** sheathes surrounding the vascular bundles in the leaves. To obtain the fibers, the leaves are cut off and the spiny tip and margin removed. Machines then beat and scrape the leaves and wash them until the clean fibers are obtained. These are then dried either in the sun or by artificial heat, and are ready for export under the name of sisal or henequen, according to the species from which they were

obtained Many species of Agave are cultivated for their ornamental value (R M W)

AGE OF THE EARTH. Chronology.

AGGLOMERATE A term proposed by Sir Charles Lyell in 1831 for coarsely graded volcanic ejectamenta similar in appearance to ordinary **conglomerates** or **breccias** An extremely thick and widespread accumulation of so-called agglomerates occurs on the borders of the Yellowstone Park These deposits, however, include numerous beds of water-laid pebbles, gravels and sands, the latter containing fossil plants of early **Tertiary** age (R M F)

AGGREGATE The solid particles which form the major portion of the volume of **concrete** are called aggregate The aggregate may be classed as fine or coarse depending upon the size of the individual particles The specifications for the concrete on any project will give the limiting sizes which will distinguish between the two classifications Fine aggregate generally consists of sand or stone screenings while crushed stone, gravel, **slag** or cinders are used for the coarse aggregate The aggregate should be strong, clean and free from clay or organic matter since the strength of concrete depends upon the strength of the individual particles as well as the efficiency of the cement and water as a binder (C W C)

AGGREGATE GLANDS Silk glands of **spiders** which produce the viscid spiral lines of the web (A W L)

AGOUTI, AGUTI Mammalia, Rodentia Large **rodents** of the genera *Dasyprocta* and *Myoprocta* found in Central and South America and the West Indies, where they live chiefly in the forests They are hunted for their flesh (A W L)

AGRANULOCYTOSIS. (Granulocytopenia, Malignant Neutropenia) This is not a distinct disease The condition may occur primarily or may accompany a number of diseases It is characterized by great and often progressive diminution in the number of **leucocytes (leucopenia)** due to exhaustion of the bone marrow cells from which the leucocytes are produced This exhaustion of the bone marrow is seen in some cases of acute infection, especially in those that are fulminating in character, this occurs in cases where there has been a history of taking or exposure to **radioactive substances** or benzene, or to one of a great number of drugs which contain the benzene ring as **"pyramidon," acetanilide,** etc This condition is uncommon, and it is thought that some other factor is present, possibly an idiosyncrasy or an **allergic** state which causes agranulocytosis to develop In women there sometimes seems to be an association with **menstruation** In many cases agranulocytosis develops without any apparent cause

Acute cases are characterized by a high fever, chills, ulceration of the mucous membranes and a marked **toxemia** Such cases usually terminate fatally within a few days The mortality is very high (R S M)

AGRICULTURAL CHEMISTRY. Agricultural chemistry is that branch of the science of chemistry which deals with the chemical processes connected with the growth of plants and animals, and the preparation of these and their products for market Since plants are dependent upon air and soil, and upon water and climate for their growth, these are matters of prime importance in connection with crop cultivation The maintenance of proper soil involves the study of the various chemical types of plant food, of fertilizers, and the effect of small percentages of various elements The cultivation of plants also necessitates battling against injurious pests and diseases The preparation of plant and animal products calls for examination of preparation methods as such, for example, in the case of milk products, butter, cheese, lactose, casein, and of the storage and transportation conditions, for example, meats, eggs, fruits, vegetables See **Soils: Fertilizers, Reactions Involving Recombination of Ions, Hydrogen Ion Concentration, Poisons; Foods; Photosynthesis; Biochemistry** (R K S)

AGUE. Recurrent chills and **fever**, usually of **malarial** origin (R S M)

AI. Sloth.

AIGRETTE. The tuft of slender feathers found on the back of the **egret** during the breeding season (A W L)

AILANTHUS. Simarubaceae Tree of Heaven, or Tree of the Gods A genus of trees having large pinnate leaves, small flowers and winged fruit One species, *Ailanthus glandulosa*, a native of China and Japan, has been extensively introduced into cities in the eastern United States, because of its ability to withstand the gas and smoke of the city, and is often found growing to large size in most unlikely habitats An objectionable feature is the unpleasant odor of the male flowers (R M W)

AILERON. The aileron is one of the three **aerodynamic** surfaces of an **airplane** which are variable in attitude at the will of the pilot, and the purpose of which is to provide the required degree of maneuverability of the aircraft The aileron is that surface which produces rotation about the longitudinal axis of the fuselage This motion is known as roll, and is necessary to correct other rolls produced unintentionally, as by gusts, and is also employed to accomplish such maneuvers as banks or sideslips, both of which require a certain degree of roll executed under the control of the pilot

The conventional type of aileron is a flap attached to a portion of the trailing edge of the **wing**, usually towards the extremities This flap is rotatable around its forward axis, upwards and downwards, and in effect changes the **camber** of the airfoil The result is a change of pressure on the wing much greater than that which could be obtained by pressure on the aileron alone The principal defect of this type of aileron is that it becomes relatively ineffective when, for safety's sake, it is needed to be most effective, that is, when the airplane approaches the stall, or is stalled With adequate control of roll during a **stall**, many serious accidents involving the tailspin could have been avoided Except for this point, the trailing edge aileron is highly satisfactory Its aerodynamic efficiency, simplicity, reliability, freedom from flutter, and balance are better than in other types, such as wing tip ailerons, spoiler ailerons, etc, which in consequence have not been widely accepted (F T M)

AIMLESS DRAINAGE. Type of drainage or stream pattern which occurs in low swampy lands Particularly characteristic of glaciated regions of low relief (R M F)

AIR. The term air is frequently used as synonymous with **"atmosphere** of the **earth"** and it is in that sense that we shall use it here The earth's atmosphere consists of a vast body of gases, vapors, and suspended matter of total mass about $5 1 \times 10^{18}$ tons, or somewhat less than one millionth part of the total mass of the earth The height to which the air extends can only be expressed in terms of the effects which it produces On purely theoretical grounds, since on the basis of the **kinetic theory** of gases we know that some molecules attain velocities great enough to escape not only from the earth but also from the **solar system**, we may say that the atmosphere of the earth extends out into space until it mingles with the interstellar gases of the **milky way** The **twilight** arch has been observed to a height of about 45 miles, **meteors** become visible about 75

miles, on the average, above the surface of the earth, and **aurora** have been observed up to about 500 miles

Most of our knowledge of the composition of air is based upon samples that have been taken at the surface of the earth There air is composed chiefly of oxygen and nitrogen (and this is probably true to a height of 70 kilometers) Air also contains a variable proportion of water vapor, and small quantities of other gases In many engineering calculations, air is considered to be composed only of nitrogen and oxygen, and the proportions assumed for such calculations are, by weight, 76 8% nitrogen and 23 2% oxygen, and, by volume, 79 1% nitrogen, and 20 9% oxygen A more complete analysis of air (without taking into consideration the variable amount of water vapor) is given below

AVERAGE COMPOSITION OF AIR

(At, or near to, the surface of the earth)

Substance	Percentage (by volume of dry air)	Percentage (by weight of dry air)
Nitrogen	78 03%	75 51%
Oxygen	20 98%	23 15%
Argon	0 94%	1 29%
Carbon Dioxide	0 03%	0 04%
Hydrogen	0 01%	0 0007%
Neon	0 00123%	0 00085%
Helium	0 0004%	0 000055%
Krypton	0 00005%	0 00014%
Xenon	0 000006%	0 000027%

Carbon dioxide is produced by the combustion of **carbon**-containing **fuels** and from the decay of organic matter Its concentration in the air would be much greater if it were not consumed by vegetation in the process of **photosynthesis,** by which oxygen is produced In this way, the steady addition to the atmosphere of carbon dioxide by the combustion of fuels, and by the breathing of men and animals, is counteracted, and the oxygen-carbon dioxide ratio of the air is maintained

The content of water vapor in the atmosphere varies greatly in amount, depending upon the locality, the season of the year, and the hour of the day, due to local and general states of the weather On account of the great importance, meteorologically and industrially, of the amount and variation of water vapor in the atmosphere, extensive studies have been made by weather bureaus and various industries

WATER VAPOR CONTENT OF NATURAL AIR

(Monthly Averages at Pittsburgh, Pa)

Month	Average Temperature (° F)	Concentration of Water in Air (Grains per Cubic Foot)	Volume of Water (Gallons per hour in air rate of 20,000 cubic feet per minute)
Jan	37 0	2 18	87
Feb	31 7	1 83	73
Mar	47 0	3 40	136
Apr	51 0	3 00	120
May	61 6	4 80	192
June	71 6	5 04	238
July	76 2	5 60	224
Aug	73 6	5 16	206
Sept	70 4	5 68	227
Oct	56 4	4 00	160
Nov	40 4	2 35	94
Dec	36 6	2 25	90

The amount of water vapor contained in the air may be expressed as the relative humidity, which is simply the fraction actually present, of the amount of water required completely to saturate the air The amount of water necessary to saturate one pound of dry air is shown by the following table

WEIGHT OF WATER NECESSARY TO SATURATE ONE POUND OF DRY AIR

Temperature (Degrees Fahrenheit)	Weight of Water (Pound)
40	00520
45	00632
50	00765
55	00920
60	01105
65	01322
70	01578
75	01877
80	02226
85	02634
90	03108
95	03662
100	04305
105	05052

The temperature of air decreases, in general, with altitude up to about 10 or 12 kilometers within the layer, known as the "troposphere," in which convection currents and storms occur (See **Winds**) Above this is the "stratosphere," a region of unknown height within which a uniform temperature of about —55° C (—67° F) obtains, and in which there are no clouds, little wind, and no storms Nearly all of the water vapor and dust are in the lower half of the troposphere, the stratosphere being very clear and excessively dry (See **Humidity**)

The various data cited above on the composition of the air are based upon samples taken at or near the surface of the earth However, it is thought that at higher altitudes, notably above 70 kilometers, there is a marked increase in the concentration of the lighter gases, and it is believed that whatever air exists above 100 kilometers consists largely of hydrogen and helium It is also thought that there is more ozone in the stratosphere than near the earth, and that it is due to the action of **ultraviolet** radiation on oxygen Through some agency, perhaps **cosmic rays** or else **electrons** from the **sun,** the upper atmosphere is much more highly ionized than the lower (See **Ionosphere**) The earth's negative charge and the electricity in the upper atmosphere give rise to a vertical potential gradient, amounting to about 1 1 volts per cm at the surface, but rapidly diminishing with altitude (See **Aurora Borealis** and **Lightning**)

By means of instruments carried up by sounding balloons and from other sources of information such as, for example, the recent stratospheric flights, it is known that the atmosphere varies greatly with altitude in many respects such as (1) density, (2) pressure, (3) temperature, (4) motion, (5) composition, (6) electrical condition, and a number of other characteristics The density, of course, is determined by the pressure, composition, and temperature The pressure decreases, of course, with increasing altitude as is shown in the following table

VARIATION OF AIR PRESSURE WITH ALTITUDE

Altitude (Feet)	Pressure (Inches of Mercury)	Pressure (Pounds Per Square Inch)
Sea Level	29 92	14 7
1,000	28 86	14 2
5,000	24 89	12 2
10,000	20 58	10 1
15,000	16 88	8 3
20,000	13 75	6 8
25,000	11 10	5 4
30,000	8 88	4 4
50,000	3 44	1 7

The standard density of air at 32° F and 14 7 pounds pressure is 081 pound per cubic foot. Its gas constant

is 53 4, and its composite molecular weight is 28 84 (FTM, RKS, LDW, WKG)

AIR-BLADDER. A pouch found in some fishes (Pisces), derived from the gut and filled with a mixture of gases, chiefly oxygen and nitrogen It regulates the buoyancy of the body Embryological development and structural relationship indicate a common evolutionary origin for the air-bladder and lungs (AWL)

AIR COMPRESSION. The compression of air by mechanical means, and the raising of it to some desired pressure above that of the atmosphere, is effected, usually, by an approximately adiabatic change of state The cycle of operation of an air compressor of the piston and cylinder form is briefly as follows Beginning with the piston ready to start on the compression stroke, the piston compresses the air until the pressure rises to slightly above the discharge pressure, when the spring-loaded discharge valve opens and the remainder of the compression stroke is a delivery of the compressed air through the discharge valve at approximately constant pressure At the end of the compression stroke, the discharge valve returns to its seat, but there is a small amount of high pressure compressed air retained in the **clearance** space between the piston and the end of the cylinder On the suction stroke of the piston this clearance air must first expand adiabatically to the suction pressure before the spring-loaded inlet valve opens The remainder of the suction stroke is then the induction of the air to be compressed in the cylinder At the end of the suction stroke the inlet valve returns to its seat, and the piston is ready for another compression stroke

If the ideal adiabatic compression were possible, the compression would be represented by the following equation showing the relation between pressure and volume

$$PV^{1.4} = \text{a constant}$$

A compression of this nature heats the air to temperatures which would interfere with reliable action of an air compressor and introduce lubrication difficulties, were there no provision for cooling the cylinder walls Therefore, in compressors we find the cylinders to be externally finned or water-jacketed so that sufficient cooling is secured to keep the temperatures from becoming excessive The extraction of heat from the cycle in this way modifies the conditions of compression away from the adiabatic to some change more nearly represented by

$$PV^n = C,$$

in which n usually lies between 1 35 and 1 4 The ratio of the temperature before and after compression is expressed by the following equation, the temperatures being degrees Fahrenheit absolute

$$\frac{T_2}{T_1} = \left[\frac{V_1}{V_2}\right]^{n-1}.$$

In compression to particularly high pressures, the temperature rise may be too great to permit the compression to be carried to completion in one cylinder, even though it is cooled as mentioned above In high pressure compressors, the compression is carried out in stages, with a partial increase of the pressure in each stage, and cooling of the air between the stages Two and three stage compression is very common where pressures of 300–1000 pounds per square inch are needed

The volume of clearance air should be made as small as possible in order to improve the **volumetric efficiency** of the compressor, since the clearance air must expand to the suction pressure before the cylinder can begin to be charged

The mechanical construction of air compressors varies with the amount of compression required Piston and cylinder compressors are usually employed for the highest pressures In small sizes these are frequently single-acting, but are made double-acting in larger sizes High pressures are also possible in centrifugal types of compressors whose action is essentially the same as that of the *pump*, and which, by multi-staging, may build up almost any desired pressure Light pressures, such as are required in draft and ventilating systems, are obtained most economically by the use of fans of the centrifugal or propeller type The chief characteristic of fans is their ability to handle large volumes of air, but the pressures rarely exceed eight or ten ounces per square inch Their action is more one of giving flow to the air rather than compression, in fact, change of density of the air is usually so small that it is negligible

There is a type of compressor intermediate between the fan and the piston types It is the rotary compressor or blower, which, operating by displacement, produces a positive air pressure, and, at the same time, is a compressor in which there are no reciprocating parts. (FTM)

AIR CONDITIONING. Air conditioning is the artificial treatment of air in buildings to render the living conditions of persons within the building more comfortable and healthful, or to ensure better conditions for the production and storage of materials Complete air conditioning involves adjustment and control of the following operations performed on the air supply of a building

1 Heating or cooling
2 Humidification or dehumidification
3 Ventilation
4 Cleaning

While portions of this complete program of conditioning were often used in past years, it has only been recently that the importance of complete air conditioning has been fully understood That a change of air in a room has beneficial effects is quite generally understood and the ventilation of buildings has been a subject of considerable study Furthermore, although it is quite obvious that dust and obnoxious fumes have no place in either industrial or domestic rooms, little has been done towards the filtering of air supplies One new and important fact brought out within recent years has given great stimulus to more scientific handling of the air conditioning problem It is that, in addition to temperature and air movement, the relative **humidity** is a very important factor in determining the comfort of the occupant of a room Experimental research of the American Society of Heating and Ventilating Engineers indicated that air conditions which yielded equal degrees of warmth to human subjects plotted as straight lines on the common psychometric chart These lines are called "comfort lines" The meaning of this fact is that a person may feel equally comfortable at two different temperatures, provided the humidity of the air at these two temperatures differs by the proper amount The reason for the influence of humidity on comfort is that the nearer to a completely saturated state the air in a room becomes, the less tendency there is for evaporation to take place from the body This evaporation plays no small part in determining hot weather comfort, and is a factor in surface cooling of the skin On the other hand, in cold weather the atmosphere in an artificially heated room is very likely to prove deficient in moisture unless some special means for increasing the moisture content is provided Some physicians believe that failure to humidify properly the air within heated buildings is an important contributing cause of the common cold during the winter season

Complete air conditioning, then, will involve the following equipment a ventilating system for giving motion and circulation to the air, a furnace or heater to raise it to proper temperature in cold weather, a refrigerator, or cooler, to temper it for hot weather comfort, a humidifier, or dehumidifier, an air washer, or filter This complete service is frequently applied to industrial buildings, theaters, auditoriums, etc, but has not been employed to any appreciable extent in homes One reason for this, of course, is the cost of such equipment for the average home Another is lack of information

on the benefits realized from an air conditioning installation; another, the widespread use of vapor or hot water heat, which is not readily converted to an air conditioning system.

It is interesting to note the reversion to the once obsolete warm air heating system, on the basis of its adaptability to partial or complete year-round air conditioning. The warm air heating system, once discredited as obsolete and inferior to other types, is returning to a position of some considerable importance through the employment of positive fan-created air circulation—eliminating many real defects in the gravity system—and the use of thermostat-operated automatic controls preventing fluctuations of temperature. Moisture can be added to the air at the furnace in the winter time, and to the required degree. The same system may be employed in the summer time, either with refrigerating coils in the return circuit, or with water sprays, or simply with the induction of air from without the building. Under any of these operating conditions, of course, the air passes through filters for the removal of dust.

Just as the air conditioning of industrial and public buildings has proven to be practical and profitable, so will, in all probability, air conditioning be an important feature in the new homes of the future. (F.T.M.)

AIRFOIL. An airfoil is any body whose shape allows it to receive a useful reaction from an airstream moving relative to it. This definition would include a great many shapes not ordinarily thought of as being airfoils, and the word airfoil is commonly associated with a body of a shape similar to that shown in Figure 1. In this figure, the cross-section of the airfoil is shown. The dimension perpendicular to this section is called the span. A great many different forms of airfoils have been used, or proposed for use, or tested. Some of them have flat lower surfaces similar to that of the figure, while some

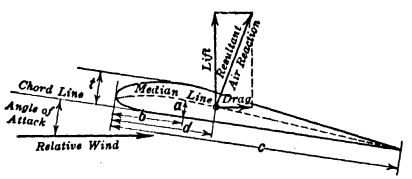


Figure 1.

Elements of an airfoil: *a*—maximum camber of the median line; *b*—location of maximum camber; *c*—chord; *d*—location of center of pressure; *t*—maximum thickness.

have convex or concave lower surfaces. Indeed, so numerous and varied are airfoils that the National Advisory Committee for Aeronautics has devised a system for cataloguing them. In this system the airfoil is described by a four digit number. The first digit represents a camber of the median line, in percentage of the cord, i.e., $\frac{a}{c}$ in the figure. The second digit is the location of the maximum camber to the nearest 10% of the cord, i.e., $\frac{b}{c}$. The last two digits give the per cent thickness. Thus for an airfoil whose dimensions are such that $a=6$, $b=27$, $c=100$, and $t=12$, the corresponding NACA number would be 6312.

When air moves relative to an airfoil with a velocity V, there is generated on the airfoil a reaction which consists of a vacuum of variable intensity over the upper surface of the airfoil, and a pressure over the lower. These forces are not uniformly distributed, as is seen in Figure 2, but are stronger near the leading edge. At any one station the forces vary with the **angle of attack**, that is, the angle with which the airfoil is presented to the wind. The resultant of the distributed forces can be considered to act through an imaginary point known as the center of pressure. The position of this center of pressure varies along the chord of the airfoil with the

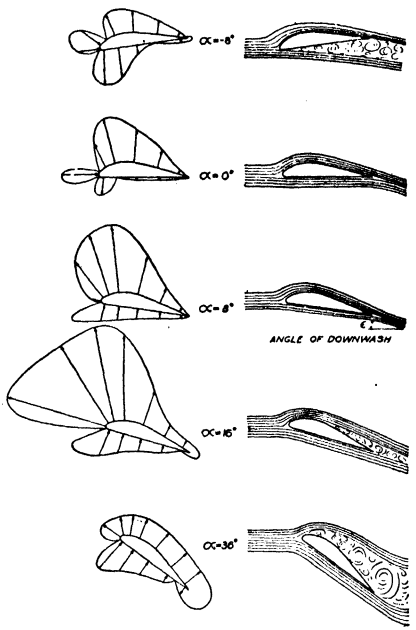


Figure 2.

Distribution of pressure on a cambered wing at different angles of attack. Sketches to the right show, approximately, the manner of air-flow at the different angles of attack.

angle of attack. The resultant air reaction is divided for convenience into two components, the lift and drag, which are, respectively, perpendicular and parallel to the windstream. (See **Aerodynamics.**) Wind tunnel experiments show that the reaction of air on an airfoil varies with the surface area (area is considered to be that projected on the plane of the chord), with the air density, with the square of the wind velocity, and with the angle of attack. If one resolves the proportionality into an equality by the use of a constant C', which will include the effect of the angle of attack, then the reaction upon the airfoil would be

$$R = C'\rho AV^2$$

Here ρ is the mass density of air, A the surface area, and V the wind velocity. When R is to be in pounds, and ρ, A, and V are given pound-foot-second units, C' is a dimensionless coefficient.

It is better, however, to use a coefficient C which is twice C' yielding the equation

$$R = \frac{C}{2}\rho AV^2$$

This is because $\frac{\rho V^2}{2}$ is the dynamic pressure, often given the symbol q. The dynamic pressure is the pressure necessary to give air of density ρ a velocity V. As the lift and drag components are much more useful in any aerodynamic study of the airfoil than is the resultant air reaction, the above discussion should be completed

with the writing of the following equations for lift and drag:

$$L = C_L qA,$$
$$D = C_D qA$$

The above coefficients of lift and drag vary with angle of attack, and Figure 3 shows typical variation The lift coefficient increases rather uniformly as the angle of attack is increased, until the stall or burbling point is

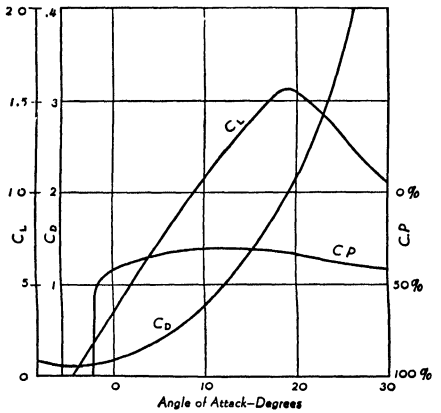


Figure 3

Common aerodynamic characteristics of a Clark Y airfoil

reached, where it breaks and decreases rapidly with further increase of angle of attack The drag coefficient evidences no burbling point, but increases parabolically with the angle of attack The variation of center of pressure with angle of attack is also shown on this figure

Curves, such as these just mentioned, are the usual means for displaying the aerodynamic characteristics of airfoils The data for these curves may be obtained from wind tunnel tests, although aerodynamic theory also enables the writing of equations representing the variations In spite of the fact that it is possible to construct a working airfoil with almost any NACA number, certain of the dimensions must be typical if reasonable performance is to be expected, for example, the second digit must be two or three for best performance This rules out a symmetrical profile The camber of the upper surface is a factor in determining the maximum lift coefficient $C_{L_{max}}$ will increase with camber up to a camber of about 25%

The means by which an airfoil moving relative to air receives a lift is explained today by two different theories One, the momentum theory, is based upon the assumption that an airfoil deflects a cylindrical stream of air of a diameter equal to the airfoil span, and that the sustention force originates in the downward momentum imparted to this mass of air as it passes the airfoil The **momentum** must be balanced by an **impulse**, and the force involved in that impulse is the lift force on the airfoil The momentum theory has been practically abandoned in favor of the circulation theory, although it yields much the same results, and is simpler

The circulation theory is based on the consideration of the actual flow around an airfoil as being made up of two components, one, a plain rectilinear flow, the other of a circumscribing one of circulatory nature The circulation flow aids the rectilinear stream over the upper surface of the airfoil, and opposes it over the lower A velocity is created over the top of the airfoil much higher than that of the rectilinear pattern, and over the bottom of the airfoil, smaller The Kutta-Joukowsky analysis of the circulation theory embodies the hypothesis that the strength of the circulation component is just sufficient to have the divided flow over the top and bottom surfaces reunite at the trailing edge of the airfoil According to **Bernoulli's theorem**, at any point in a moving air stream the sum of the static pressure and dynamic pressure is a constant Under standard conditions at sea level, the value of this constant is 14 7 pounds per square inch In the region of high velocity on the upper surface of the wing, the dynamic pressure is rather high, and there is a corresponding reduction in static pressure, and hence a vacuum is formed which results in the air reaction, or lift A very large percentage of the total lift of an airfoil is derived from its upper surface

When the angle of attack is increased to a certain point, the air no longer flows smoothly at high velocity over the upper surface, but suddenly breaks away from it, and the dynamic increment of pressure is lost through the production of a burbled air condition on the upper surface of the airfoil This restores the pressure to the full static value and results in a rapid and very material decrease of lift This burble point is usually sharply defined on the characteristic curve of lift, and occurs on most airfoils at between 15° and 20°

In general, desirable characteristics of an airfoil are as follows·

1 High maximum C_L, in order to give low landing speed for a given sized wing
2 Low minimum C_D, so that the high speed, which occurs at small angles of attack, may be the greatest possible
3 High ratio of C_L to C_D, so that an efficient, economical airplane will result
4 Minimum variation of the center of pressure, so that it will not be difficult to construct a stable airplane
5 A shape well suited to the construction of a strong, but light-weight wing, at minimum cost (F T M)

AIR HUNGER. Breathlessness or craving for air when insufficient **oxygen** is supplied to the **tissues** of the body (R S M)

AIR LIFT. An air lift is a water pumping method whereby water may be raised from a well through the medium of compressed air The drop pipe in the well is supplied at the bottom with compressed air from a small air pipe, and the effect of mixture of air and water at the bottom of the drop pipe is to bring water to the surface This is accomplished either by the water acting as pistons, trapping intermediate layers of air, the expansion of which drives the water pistons to the surface, or it may be accomplished by the mingling of air and water, forming a mixture which is sufficiently lighter than the undisturbed water in the well so that the mixture rises above the surrounding water In order for this rise to reach the surface the discharge pipe must be submerged in the water of the well an amount varying from 100% to 300% of the actual lift The **pumping efficiency** of the system is very low, but it is very suitable for handling gritty or corrosive waters (F T M)

AIR LOCK. An air lock is an airtight compartment in which the air pressure may be regulated to any desired intensity When men are required to work in regions where the air pressure is above (or below) that of the atmosphere, an air lock must be provided to permit passage of the workmen from the open atmosphere to the pressure region Thus, in the case of **caissons**, where workmen must labor under a high enough pressure to equalize the **hydrostatic** pressure existing at the bottom of the caisson, or in tunnels where flooding is avoided by forcing compressed air into it at sufficiently high pressures to hold the water back, the air lock is a feature essential to the maintenance of pressure during the admission of workmen. It is also used when enter-

ing boiler rooms of steam ships where, to supply forced draft to the boilers, the entire boiler room is sometimes held at a pressure slightly above that of the atmosphere

In construction work, the air lock is a chamber of sufficient size to hold the number of men that must be accommodated in it at one time It is provided with well braced doors having sealing-type edges and tightening locks The chamber is equipped with valves for admitting and releasing air and with safety devices to prevent excessive pressures endangering the lives of the occupants The air lock must have two airtight doors, one leading to the atmosphere, the other leading to the pressure region These doors open inward so that the pressure in the air lock tends to tighten them against the frame To enter a pressure region, a caisson for example, the workmen enter the air lock, after which the door leading to the atmosphere is tightly fastened Compressed air is then slowly admitted until the pressure in the air lock equals that in the caisson, after which the connecting door may be opened without trouble or loss of air from the working chamber After the workmen enter the caisson, the air lock door is tightly closed, after which the air lock may be opened from the outside without affecting conditions within the caisson

In contrast to air locks, the decompression chamber such as is used in deep sea diving has one door The diver, on emergence from the water, is briefly subjected to atmospheric pressure, and must be rushed to the decompression chamber and quickly subjected to pressures approximating those encountered in diving The pressure is then slowly released, the rate of decompression being such as to prevent the malady known as "the bends" Pressures in the decompression chamber are ordinarily much higher than those for which air locks need to be built (F T M)

AIR MEDICINE. Medical treatment and diagnosis as applied to aviation (R S M)

AIRPLANE. An airplane is an aircraft of the heavier-than-air type, deriving its sustension from aerodynamic reaction on the sustaining surfaces, and propelled by an air propeller which is driven from some adequate source of power The practical airplane of the present time consists of the following components

1 Wing (or wing cellule, in the case of multi-planes), to provide the required lift
2 Power unit, consisting of one or more prime movers, usually internal combustion types, attached to an air propeller by means of which a thrust sufficient to overcome the drag of the other components of the airplane is produced
3 Fuselage, or body, which is required to house the crew, passengers, and cargo, and serves as the foundation structure of the airplane The other components are usually, though not always, fastened directly to the fuselage
4 Undercarriage for supporting the airplane when on the ground or on the water
5 Controls for giving maneuverability, and allowing the pilot full control of the motion and performance of the airplane

The foregoing components are assembled in a great many different ways in the aircraft of the present time, but a very common arrangement has a single **wing**, or monoplane, attached directly to the **fuselage** and braced with **struts** The power plant (See **Aeronautical Engines**) is mounted in the nose of the fuselage with an air **propeller** bolted directly on the engine **crankshaft** The fuselage has its maximum section at the point which houses passengers and pilot, and tapers from there to a tail located some distance behind the wing The tail consists of a horizontal surface and a vertical surface, each divided into fixed and movable portions The movable tail surface, together with the **ailerons** in the **wings**, are actuated by controls operated from the cabin

When on the ground, this plane rests on two wheels carried by a short undercarriage of struts and bracing, and upon a tail skid at the rear The location of the center of gravity is such that the wheels carry most of the weight of the plane

If we were to imagine an aircraft of this type taking to the air, the operation would be somewhat as follows: The plane is at the end of a level straight runway about 2000 feet long, with the engine idling, but warmed up and ready to deliver full power The plane is heading into the ground wind, if there is one To take off, the pilot opens the throttle wide and operates the movable portion of the horizontal tail surfaces to lift the tail from the ground under the influence of the air blasts from the propeller, and hold the longitudinal axis of the airplane horizontal Meanwhile, under the influence of the propeller thrust of the wide open engine, the plane is traveling on its landing gear, with increasing speed, down the runway, being guided in a straight line with the use of the rudder, which is the movable portion of the vertical tail surfaces As the speed increases, aerodynamic reaction of lift on the wing surface builds up steadily, and after a run of from 600–1500 feet, depending on the circumstances, the lift is nearly equal to the weight of the airplane, and could readily be made to exceed it by increasing the angle of attack on the wings At this point the pilot may elect to continue the same take-off attitude until the lift equals the weight of the plane, and the plane leaves the ground naturally, by itself, or he may elect to operate the movable horizontal tail surfaces, called the elevator, and thus increase the **angle of attack**, and the lift, so that the airplane will leave the ground at some definite point

Once in the air, the plane has three degrees of freedom, and the maneuvering of the plane involves simultaneous co-ordination of controls for three basic airplane motions, the pitch, the roll, and the yaw Referring to Figure 1, the three mutually perpendicular axes about

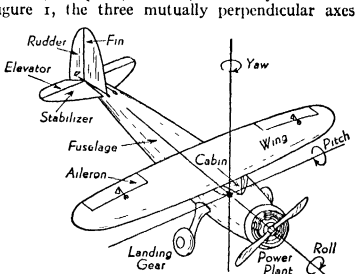


Figure 1
Axes of an airplane

which motion of an airplane takes place are the longitudinal axis of the airplane, the horizontal axis, which is parallel to the wing, and the vertical axis These intersect at a common point, which is the **center of gravity** of the airplane The rotation to the right or left around the vertical axis is called a yaw, and is obtained by the use of the rudder Motion about the lateral axis is called pitch, and is controlled by the elevator Rotation around the longitudinal axis is called roll, and is controlled by the ailerons Parts of the vertical and horizontal tail surfaces are fixed for the purpose of giving longitudinal and directional stability to the airplane, whereas lateral stability is obtained by setting the wings at a slight dihedral angle

Stability in an airplane is that ability which the airplane possesses of itself, and without aid from the pilot, of returning to a normal horizontal flight position when once displaced from that position by gusts An airfoil, alone, is unstable For instance, a slight unintentional increase of the angle of attack sets aerodynamic forces

going, which tend to increase that angle rather than to decrease it Nevertheless, stable airplanes can be built incorporating unstable airfoils through the medium of a fixed surface—a tail—placed at some distance behind the wing, or through a large amount of sweepback of the wings, a method employed in the tailless airplane If, in the conventional arrangement of the separate components of an airplane, the center of gravity of the entire airplane is placed about one-third of the wing chord aft of its leading edge, and the tail surfaces between two and three chord lengths to the rear of the wings, the airplane will likely be stable, provided, of course, that the proper relation obtains between wing area and tail area

The operation of the control surfaces, which involves their rotation around a hinge point through an angle of 10 to 20 degrees, is accomplished from the pilot's seat by connecting horns on the control surfaces to controls at the seat by cables, torque tubes, or push-pull tubes The rudder is operated by foot pedals, the ailerons and elevator by a control column having two degrees of freedom, or a column with one degree of freedom upon which is mounted a rotating wheel In the wheel type of control, turning the wheel operates the ailerons, while moving the control column operates the elevator

Most airplanes can be classed structurally as trussed types or stressed skin types The trussed structure used in the United States utilizes a triangularly framed fuselage of alloy steel or duralumin tubing, either welded or riveted at the joints This has been a very popular modern type everywhere, although the English apparently have a preference for a fuselage framing in which the compression members are wooden struts, and the tension members are wires In the truss type of fuselage the components, such as the power plant, landing gear, wings, etc , are attached to the fuselage frame by means of fittings The streamlined shape of the fuselage is formed by fairing strips attached to the fuselage As seen in Figure 2, which is the fuselage for a cabin ship,

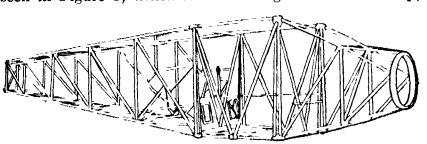


Figure 2
Welded tubular steel fuselage

the fuselage is somewhat rectangular, being composed of four longerons with suitable intermediate struts and braces in all four planes The outer covering of the fuselage is merely to give streamline shape, and hence any material which is reasonably durable, light-weight, and inexpensive, and which can be worked into the required curvatures, will do The material most frequently used is a mercerized cotton fabric finished with "dope," a solution of cellulose nitrate which is to be had in both clear and pigmented form

Stressed skin construction has no triangular framework, but rather relies upon the tube-like strength of the outer skin, which is oval or circular in cross-section, and which is made of thin sheet metal, or plywood Thin sheets of the size required to cover a fuselage would be very weak were they not reinforced at intervals with bulkheads, or diaphragms, and longitudinal stringers This construction has the advantage of a high strength-weight ratio, but is better adapted to large transport airplanes than to small one or two-place private types The attachment of fittings to the stressed skin structure is naturally much more of a problem than in the case of the trussed frame fuselage For wing structure, see **Wing.**

All parts of the airplane exposed to the air stream are subject to aerodynamic drag, the sum total of which must be overcome by the propeller thrust in order to maintain speed The drag of all parts except the wings is parasitic drag, that is, it is the drag of objects which do not create any useful lift The less this parasitic drag, the less power will be required to propel the airplane at a given speed By streamlining the struts, concealing fittings, cowling the engine, filetting wing roots and other angular intersections, retracting landing gear, etc , airplane designers have endeavored to reduce parasitic resistance and increase performance The modern air transport of the low wing **cantilever** type, with retractable landing gear, apparently has achieved the reduction of parasitic resistance to the minimum Speeds of over 200 miles per hour are thus obtained, but if materially higher speeds are wanted, some radically different type must appear, or some such expedient as stratosphere flight must be adopted, since there is but little latitude in further reduction of parasitic resistance on the conventional type of airplane

Location of the power plant in an airplane is subject to great variation The single-engined airplane of the past was almost invariably a tractor type, with the engine mounted in the nose of the fuselage The present and future may see an increasing use of pusher airplanes, in which the engine is to the rear of the cabin, as this yields a superior arrangement from the standpoint of visibility and access to the cabin It is also better from the standpoint of noise and odors For reasons of clearance, the engine of the flying boat, or amphibian airplane, is mounted atop the wing, where the propeller will be in less danger from damage by spray or wave The multi-motored installations, with two engines, usually have the engines mounted in the leading edge of the wing, one on each side of the fuselage The third engine in trimotored design is placed in the nose of the fuselage In four-motor designs, the engines have been placed equally spaced in the leading edge of the wing The National Advisory Committee for Aeronautics found by research that the placing of the engine just ahead of the leading edge of a wing, coupled with careful streamlining of the engine frame into the wing, resulted in the best aerodynamic results—that is, the propulsive efficiency was high, and the aerodynamic characteristics of the wing were but little affected

The structure for support of the airplane while at rest on the surface, or while taking off or landing, is naturally different in the case of land and water designs Undercarriage for land planes consists of two or more wheels and a skid supporting the weight of the plane, and holding it sufficiently high off the ground, so that there is no danger of contact of the rotating propeller with the ground As it is possible for the airplane to contact the ground upon landing in a very severe manner, the landing gear must be very rigid and strong, and should be provided with some means, such as pneumatic or hydraulic shock absorbers, to absorb some of the energy of the impact Whereas two wheels and tail skid, or wheel, have been common practice in the past, a great deal of attention is being given now to three-wheel landing gear, in which the third wheel is ahead of the center of gravity, and the other two behind The advantage of this arrangement is that brakes may be applied heavily to the two main wheels without any danger of turning the airplane over on its back, as was the case with the older design It has already been mentioned that advantages of performance are to be secured by retracting landing gear into the fuselage after the airplane has left the ground This is done on nearly all transport type airplanes, and on a great many sportsman planes as well where high performance at moderate power is desired Many interesting mechanically, hydraulically, or electrically operated retracting landing gears have been devised and successfully applied Every effort is made to have these retractable gear absolutely reliable, although it has been proven, in several instances, that an airplane may land on the belly of the fuselage with wheels retracted without serious injury to its occupants, and sometimes with only minor damage to the airplane

Airplanes designed to land on the water are classed as seaplanes, or flying boats The seaplane resembles a land plane with the undercarriage removed, and replaced by another of similar design, but with floats in place of wheels The flying boat is structurally quite different The fuselage, for instance, becomes a hull, and is shaped considerably like the hull of a speed boat The tail is not carried by the hull, but by special tail-carrying structural members extending backward from the wing The wing is usually above the hull, for water clearance, and the engine either in the leading edge of the wing, or mounted on a stand above it Amphibians are essentially flying boats, with retractable landing gear to enable their landing on smooth fields when necessary (F T M)

AIR PREHEATER. There are many devices of which the purpose is to heat air for some specific usage However, in speaking of air preheaters, what is ordinarily meant is the heater employed for raising the temperature of air used for **combustion** of a fuel This may occur in some industrial process such as preliminary heating of the air supplied to **blast furnaces**, but the most frequent use of air preheaters today is in connection with steam **boilers** This type of air preheater is a heating surface installed between the boiler flue gas outlet and the stack In arrangement the heating surface is composed either of tubes with flue gas inside and the air to be heated outside, or of rectangular plates spaced about one-half inch apart, leaving alternate gas and air passages The air preheater is not absolutely essential to the operation of any plant The application is chiefly justified on economic grounds, and capitalization of the annual net saving obtained by recovery of heat from the flue gas represents the maximum that should be spent for an air preheater

Two principles are employed for heat transfer in air preheaters The recuperative principle implies transfer of heat through a separating partition, such as the walls of a tube, by continuously recuperating the cool side with conduction of heat from the hot side. Regenerative heaters are those which alternately heat and cool the same mass, regenerating it thermally by passing hot spent gas over its surface Regenerative heaters are frequently used with blast furnaces, and are composed of two heating chambers in which are piled checkerworks of brick having sufficient heat storage capacity for the purpose The burned gas leaving the furnace passes through one chamber, heating up the checkerwork, while in the other chamber the heated bricks are being cooled by air passing to the combustion region When the air-heating chamber is thermally exhausted, valves shift the flow of hot gas through that chamber, and air is drawn through the hot one (F T M)

AIR PROPELLER. An air propeller, or, more accurately, air screw, is a device whereby rotative power such as that available at the shaft of a motor or engine (See **Aeronautical Engines**), may be converted into an air reaction in the nature of a thrust acting perpendicular to the plane of rotation of the propeller The air propeller has one of its principal applications and reaches its highest perfection in the propulsion of aircraft For aircraft work the propeller is usually of two or three-bladed form. A cross-section cut through the blade at any point will reveal a shape similar to that of a wing, that is, the blade is a miniature **airfoil**. Propellers for small and medium powered engines are generally of wooden construction, laminated birch and walnut being frequently employed for the purpose However, in most respects other than first cost, the wooden propeller is inferior to the aluminum alloy propeller, as the latter is aerodynamically more efficient, more durable, repairable, and adjustable to special conditions

The adjustable pitch propeller is one whose pitch may be set while the **airplane** is at rest on the ground, with the propeller stationary The standard aluminum alloy propeller with detachable blades and separate hub is one of this type The controllable pitch propeller is one whose blade pitch can be changed when the engine is running, and the aircraft in flight

The efficiency of a propeller is the ratio of the thrust horsepower actually imparted to the air to the developed output horsepower of the engine to which the propeller is attached The propulsion of an airplane in uniform horizontal flight requires the overcoming of an air drag, which is called D The propeller thrust of T pounds must equal this drag For a velocity of flight of V feet per second, and an engine brake horsepower of P, the propeller efficiency is given by the expression

$$E_p = \frac{\frac{TV}{550}}{P}$$

E_p ordinarily lies between 75% and 85% (F T M)

AIR PUMPS. The earliest air pump, constructed by von Guericke (1650), differed in no essential way from the ordinary suction water pump, and was capable of producing a vacuum of the order of one millimeter of mercury Pumps of this type held the field for two centuries, until Geissler (1855) evolved a practical means of utilizing the Torricellian principle illustrated by the vacuum above the mercury in a barometer This was also the plan followed in designing the Topler pump of 1862 The Sprengel mercury pump (1865) is quite different, utilizing the air-trap action of drops of mercury falling into a narrow funnel, after the manner of the ordinary water-jet pump used for filtering, etc These pumps were used in many pioneer researches with vacuum tubes, etc, but are far too slow and fail to give sufficiently low pressure for much modern work

Greatly improved forms of mechanical air pump have been devised in recent years Among these are pumps of the scraping vane type, in which a solid cylinder rotates eccentrically within a hollow cylinder, carrying the air around by means of a blade or vane protruding radially from one and rubbing against the other, also a rotary mercury pump by Gaede, in which air is imprisoned by spiral compartments dipping into mercury, and forced out by their further rotation Several so-called molecular pumps belong also to the mechanical class, in these the air is dragged along and expelled by the friction of a cylinder rotating rapidly inside a close-fitting casing These rapid mechanical pumps are used for many purposes directly, and also as fore pumps or backing pumps for more effective types, in which case they serve to provide a fair vacuum into which the latter may discharge the last removable traces of gas from more highly evacuated enclosures

The most efficient air pumps at present in use are those of the diffusion type In most of these the pumping agent is mercury vapor issuing from a suitable boiler, the fast-moving molecules of which carry off the gas molecules diffusing into the enclosure from a side opening, somewhat as falling raindrops clear the atmosphere of dust In Langmuir's condensation pump, the mercury vapor is prevented from entering the high-vacuum enclosure, or obstructing the diffusion, by a cold-water jacket which condenses the vapor Such diffusion pumps, with the aid of a fore vacuum, are capable of very rapid exhaustion and are used extensively in the manufacture of x-ray tubes, radio tubes, and lamp bulbs. (L D W)

AIR SCREW. Air Propeller.

AIRSHIP. The airship is that form of aircraft which derives its lifting power from aerostatic forces rather than the **aerodynamic** forces such as support the **airplane.** In other words, the lift of an airship is one of **buoyancy,** and this is derived from the difference between the density of the atmosphere and that of the

lifting gas contained by the airship. The gases most commonly used are **hydrogen** and **helium**—the two lightest known gases. Hydrogen is cheaper than helium, but helium has the very distinct advantage of being non-inflammable. The explosion hazard is reduced to a minimum in a helium filled airship. The size of an airship is determined by the volume of lifting gas required to lift the weight of the ship and the load. The lifting power of helium is approximately .07 pound per cubic foot at 32° F., standard atmospheric pressure, and that of hydrogen is 6% more. The airship is equipped with a propulsive device and controls, so that its attitude speed, altitude, and course are under the control of the pilot, whereas in the free balloon, altitude only is controllable, and velocity depends entirely upon the wind.

The requirements of navigability and **aerodynamic efficiency** have caused an effective aerodynamic shape to be given the airship. This shape is usually circular in cross-section, with a rounded nose and a tapering tail. The ratio of length to diameter varies between 5 and 8. Propulsion is obtained from **air propellers** driven by internal combustion engines which are either mounted in **nacelles** attached to the hull, or are within the hull, and drive the propellors by means of shaft and gearing extending through the skin of the hull. The latter location is considered safe only in helium filled airships.

There are three principal classifications of airships, i.e., the non-rigid, semi-rigid, and rigid. The shape of the non-rigid airship is maintained by the pressure of the lifting gas. However, the gas expands and contracts with temperature, and in the contracted state the airship would be limp (the popular name blimp is derived from a war time designation of this as the B-limp type), were it not for an air filled balloonet which is built inside the main covering. As the lifting gas expands it forces air out of the balloonet, and when the lifting gas contracts, air scoops fill the balloon by virtue of the velocity of the airship. The variable volume balloonet can also be used by the pilot to regulate the altitude of the airship by using it to compress or expand the lifting gas, so changing its density and lifting power. The balloonet is emptied for ascent, and refilled for descent. The cabin and engine installations are carried in the car or in nacelles, which are suspended below the envelope.

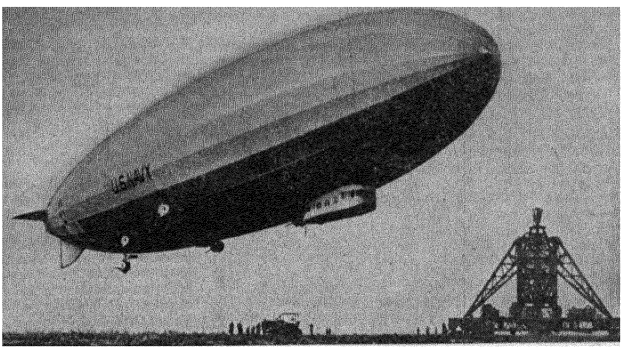


Figure 1. Dirigible Airship.

The rigid, or dirigible airship, has a complete metal framework, and its shape is, accordingly, independent of the degree of inflation of the lifting gas cells which are contained within. Fixed equipment, like power plants and living quarters, is rigidly attached to the structural frame. The semi-rigid airship resembles the non-rigid in that its shape is maintained by gas pressure, but there is a structural keel extending longitudinally from the nose to the tail, with additional structural reinforcement at the nose, and at the attachment of the control surfaces. In size, the blimps are the smallest, and the dirigibles the largest, airships.

The framework of the modern dirigible is made of girders running longitudinally connected by parallel circumferential rings. The circumferential rings must be absolutely rigid, and if the construction is not such that their shape is self-sustaining, they must be braced diametrically. One to three of the longitudinal members at the bottom of the hull are made especially heavy and rigid to form a keel. The keel serves to strengthen and integrate the ship fore and aft, provide main walkways for access to the interior of the ship, and supports heavy equipment, such as cabins, engines, and control surfaces. (F.T.M.)

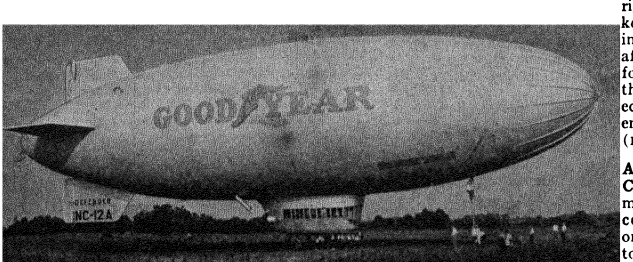


Figure 2. Semi-rigid Airship.

AIR STANDARD EFFICIENCY. The actual thermal efficiency of **internal combustion** engines depends on many indeterminate factors which render the rational computation difficult, if not impossible. An efficiency may be computed, based on certain assumptions, as follows: first, that the internal combustion engine has no mechanical friction; second, that the compression and expansion in the cylinder are those of pure air, whereas actually the expanding gases are composed of nitrogen, oxygen, steam, carbon dioxide, and carbon monoxide, and the gas compressed is never pure air; third, that the compression and expansion are **adiabatic.** This would imply a heat insulation jacket around the cylinder, but the difficulties of successful lubrication have required all practical internal combustion engines to be positively cooled. The steady flow of heat from the cylinder to the cooling system destroys the possibility of an adiabatic compression or expansion. Based on these three assumptions, thermodynamic theory can be used to yield an equation of efficiency of the cycle, and such is termed

the "air standard efficiency" The actual thermal efficiency will, of course, be considerably less than the air standard efficiency Nevertheless, the air standard efficiency is useful as a measuring stick for the various designs, and it also shows the effect, on efficiency, of varying the compression ratio The air standard efficiency of the **Otto,** or gasoline engine cycle, is given by the equation

$$E = 1 - \frac{1}{r^{k-1}}.$$

For the **Diesel cycle** it is

$$E = 1 - \frac{Rk - 1}{kr^{k-1}(R - 1)}.$$

In these formulae, the symbols have the following meanings r is the **ratio of compression**, R is the cutoff ratio, i e, roughly, the per cent of the stroke through which fuel injection occurs, k is 1 4 (F T M)

AIRY'S EXPERIMENT. Aberration of Light.

ALABASTER A fine grained variety of the mineral **gypsum,** formerly much used for vases and statuary It is usually white in color or may be of other light, pleasing tints

The word alabaster is derived from the Greek name for this substance (E S C S)

ALAGDAGA. Jerboa.

ALALITE. Diopside.

ALANINE. Aminoacids.

ALARY MUSCLES. Muscles which attach the heart of **insects** to the body wall and diaphragm (A W L)

ALBATROSS. Aves, Procellariiformes A large marine bird (**aves**) with unusual powers of flight, as is known from its habit of following ships for many hours without alighting There are several species, belonging to *Diomedea* and allied genera (A W L)

ALBEDO. The term albedo is used astronomically to indicate the reflecting power of an object Technically defined, albedo is the ratio of the radiation reflected from an object to the total amount incident upon it For example, the albedo of the moon is 0 073 which means that the moon reflects that fraction of the sunlight which is incident upon it

The value of the albedo of a planet is a measure of the quantity of **atmosphere** which surrounds the object The higher the albedo the thicker the atmospheric layer In the case of objects without atmosphere, as in the case of the moon, the albedo, combined with the color of the reflected light, may be used to make estimates of the character of the material making up the surface of the object (W K G)

ALBERTITE An oxygenated **hydrocarbon** which differs from **asphaltum** slightly in that it is not completely soluble in **turpentine,** nor can it be perfectly fused Its hardness varies from 1 to 2, specific gravity 1 097, luster pitchy, color black

It occurs as fissure filling in the **Carboniferous** rocks of Nova Scotia (E S C S)

ALBINISM. Absence of pigmentation The condition has been noted in occasional individuals of many species which are normally pigmented, including man In some cases the term is applied to a partial lack of pigment, as in the white form of certain normally yellow butterflies, in this form the black markings characteristic of the species are fully developed In contrast, the total lack of pigment in albino birds and mammals is shown by the pink eyes In these organs pigment is functionally important but the albino fails to develop it, hence the color of the blood is seen through the tissues

Albinism in man is known to be inherited as a recessive (See **Heredity**) to normal pigmentation (A W L)

ALBINO. An individual without the normal pigmentation of its kind See **Albinism.** (A W L)

ALBITE. Feldspar.

ALBUMIN. An albumin is a member of a class of proteins (see **Aminoacids, Polypeptides, and Proteins**) which is widely distributed in animal and vegetable tissues Albumins are soluble in water and in dilute salt solutions, and are coagulable by heat

The repeated appearance of albumins in the urine may indicate a diseased condition of the kidneys (See **Nephritis**) (R S M)

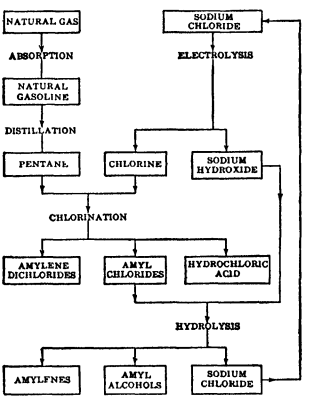
ALBUMINOIDS. Aminoacids, Polypeptides, Proteins.

ALCOHOL. This is the name of a type of chemical compounds which are discussed under the heading, **Alcohols.** Ethyl alcohol, the member of the series in most common use and of most common occurrence, is often referred to by the group named, that is, simply as alcohol It is discussed in this book under the heading **Ethyl Alcohol.**

ALCOHOLIC INSANITY Ethyl Alcohol.

ALCOHOLISM. Ethyl Alcohol.

ALCOHOLS AND ETHERS Alcohols (containing hydroxyl groups, —OH, attached to non-benzenoid



Flow sheet for amyl alcohol production from pentane of natural gas

SELECTED REPRESENTATIVE ALCOHOLS

	Alcohol	Formula	Melting Point °C	Boiling Point °C
*1	Methyl alcohol (methanol)	$H\ CH_2OH$	−98	64 5
*2	Ethyl alcohol (ethanol)	$CH_3\ CH_2OH$	−117	78 5
3	Normal-propyl alcohol (propanol)	$CH_3CH_2\ CH_2OH$	−127	98
4	Iso-propyl alcohol (dimethyl carbinol)	$(CH_3)_2CHOH$	−86	82
5	Normal-butyl alcohol (butanol)	$CH_3(CH_2)_2CH_2OH$	−90	118
6	Methylethyl carbinol	$C_2H_5\diagdown\ \diagup CHOH$ $CH_3\diagup$		99 5

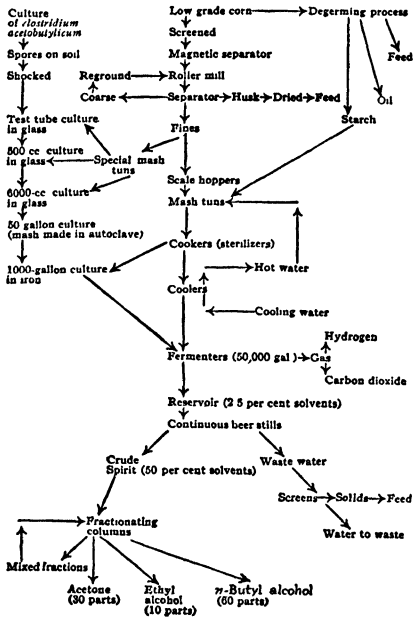
* Discussed separately under individual name

SELECTED REPRESENTATIVE ALCOHOLS—*Continued*

	Alcohol	Formula	Melting Point °C	Boiling Point °C
7	Trimethyl carbinol	$(CH_3)_3COH$	25 5	83
	Pentanols			
8	Normal-primary-amyl alcohol (pentanol)	$CH_3(CH_2)_3CH_2OH$	−78	138
9	Iso-primary-amyl alcohol (iso-butyl carbinol)	$(CH_3)_2CHCH_2CH_2OH$	−117	130
10.	Active-primary-amyl alcohol (secondary butyl carbinol)	$C_2H_5\rangle CHCH_2OH$ $CH_3\rangle$		128
11	Tertiary butyl carbinol	$(CH_3)_3CCH_2OH$	53	114
12	Methyl-normal-propyl carbinol	$CH_3\rangle CHOH$ $CH_3(CH_2)_2\rangle$		119
13	Methyl-iso-propyl-carbinol	$CH_3\rangle CHOH$ $(CH_3)_2CH\rangle$		114
14	Diethyl carbinol	$(C_2H_5)_2CHOH$		116
15	Dimethylethyl carbinol	$(CH_3)_2\rangle COH$ $C_2H_5\rangle$	−12	102
	Hexanol			
16	Normal-hexyl alcohol	$C_5H_{11}CH_2OH$	−52	156
	Heptanol			
17	Normal-heptyl alcohol	$C_6H_{13}CH_2OH$	−35	176
	Octanol			
18	Normal-octyl alcohol (caprylyl alcohol)	$C_7H_{15}CH_2OH$	−16	194
	Nonanol			
19	Normal-nonyl alcohol	$C_8H_{17}CH_2OH$	−5	215
	Decanol			
20	Normal-decyl alcohol	$C_9H_{19}CH_2OH$	47	231
21	Lauryl alcohol (normal-dodecyl alcohol)	$C_{11}H_{23}CH_2OH$	24	259
22	Cetyl alcohol (hexadecyl alcohol)	$C_{15}H_{31}CH_2OH$	49	344
23	Octadecyl alcohol	$C_{17}H_{35}$ CH_2OH	59	
24	Eicosyl alcohol	$C_{19}H_{39}$ CH_2OH	68	
25	Ceryl alcohol	$C_{25}H_{51}CH_2OH$	80	
26	Myricyl alcohol (melissyl alcohol)	$C_{29}H_{59}CH_2OH$	88	
27	Cyclohexanol	$(CH_2)_5CHOH$	24	162
28	Cycloheptanol (suberyl alcohol)	$(CH_2)_6CHOH$		185
29	Allyl alcohol	$CH_2 \cdot CHCH_2OH$	−129	97
30	Crotonyl alcohol	$CH_3CH \cdot CHCH_2OH$		118
31	Phytol	$C_{20}H_{37}CH_2OH$		145° (0 03 mm)
32	Propargyl alcohol	$CH \equiv CCH_2OH$	−17	115
33	Furfuryl alcohol	$C_4H_3O \cdot CH_2OH$		170
34	Phenyl carbinol (benzyl alcohol)	$C_6H_5CH_2OH$	−15	206
35	Diphenyl carbinol (benzhydrol)	$(C_6H_5)_2CHOH$	68	299
36	Triphenyl carbinol	$(C_6H_5)_3COH$	162	>360
37	Methylphenyl carbinol	$CH_3\rangle CHOH$ $C_6H_4\rangle$		205
38	Ethylphenyl carbinol	$C_2H_5\rangle CHOH$ $C_6H_5\rangle$		219
39	Benzyl alcohol	$C_6H_5CH_2OH$		206
40	Fluorene alcohol (diphenylene carbinol)	$(C_6H_4)_2CHOH$	156	
41	Cinnamyl alcohol	$C_6H_5CH \equiv CHCH_2OH$	33	254
42	Salicyl alcohol (Saligenin)	$C_6H_4(OH)(1)(CH_2OH)(2)$	86	subl
43	Terpineol	$C_{10}H_{17}OH$	35 appr	220
44.	Borneol (dextro-laevo) (camphol)	$C_{10}H_{17}OH$	210	subl
45	Borneol (dextro) (Borneo camphor)	$C_{10}H_{17}OH$	209	213
46	Geraniol	$C_{10}H_{17}OH$	<−15	229
47	Menthol	$C_{10}H_{19}OH$	35 appr	215
*48	Glycol (ethylene glycol, ethandiol)	$CH_2OH \cdot CH_2OH$	−17	197
49	Propylene glycol (1,2-dihydroxy propane)	$CH_3CHOHCH_2OH$		189
*50	Glycerol (propantriol)	$CH_2OHCHOHCH_2OH$	18	290
51	Erythritol	$CH_2OH(CHOH)_2CH_2OH$	126	331
52	Arabitol	$CH_2OH(CHOH)_3CH_2OH$	103	
53	Mannitol	$CH_2OH(CHOH)_4CH_2OH$	166	295 (4 mm)
54	Dulcitol	$CH_2OH(CHOH)_4CH_2OH$	188	295 (4 mm.)
55	Sorbitol	$CH_2OH(CHOH)_4CH_2OH$	110 (anhydrous)	
	Sterols			
56	Cholesterol	$C_{27}H_{45}OH$	148	<300
57.	Iso-cholesterol	$C_{27}H_{45}OH$	138	
58	Ergosterol	$C_{27}H_{41}OH$	160	

* Discussed separately under individual name.

carbon) are characterized by a wide variety of chemical reactions and uses, well illustrated by reference to



Flow sheet for butyl alcohol production from corn

particular alcohols, namely, methyl alcohol, ethyl alcohol, glycol, glycerol There are three types of alcohols, illustrated as follows (1) primary, CH_3 —CH_2OH, ethyl alcohol, methyl carbinol, (2) secondary, $(CH_3)_2$= CHOH, isopropyl alcohol, dimethyl carbinol, (3) tertiary, $(CH_3)_3$ ≡ COH, trimethyl carbinol, and characterized by the behavior upon oxidation, thus, (1) primary alcohols yield first **aldehyde**, and upon further oxidation yield **carboxylic acid**, each with the original carbon atom content, e g , CH_3CHO, **acetaldehyde**, and CH_3COOH, **acetic acid**, (2) secondary alcohols yield initially **ketone** with the original carbon atom content, e g , $(CH_3)_2CO$, **acetone**, dimethyl ketone, and upon further oxidation yield carboxylic acids or aldehydes containing fewer carbon atoms than the original alcohol, e g , CH_3COOH, acetic acid plus carbon dioxide, (3) tertiary alcohols yield no product with the original carbon atom content but yield carboxylic acids, aldehydes or ketones containing fewer carbon atoms than the original alcohol, e g , CH_3COOH, acetic acid plus carbon dioxide Upon reduction of these alcohols (as the haloid compound with magnesium in ether—**Grignard's reagent**—treated with water) the corresponding **hydrocarbons** are obtained, (1) CH_3 CH_3, ethane, methyl methane, (2) $(CH_3)_2CH_2$, propane, dimethyl methane, (3) $(CH_3)_3CH$, trimethyl methane

By loss of water, directly or by indirect reaction, alcohols form **ethers**, e g , $(CH_3)_2O$ dimethyl ether, $((C_7H_5)_2O)$ diethyl ether, CH_2-CH_2 ethylene oxide
$\quad\quad\quad

corals. Among them are the **sea-pen**, the **sea-fan**, organ-pipe coral, and precious coral

Alcyonaria are usually found in colonies The individuals are **polyps** connected together by living structures and by the hard skeletal structures They differ from the true corals in having only eight tentacles, pinnately branched (A W L)

ALDEBARAN. Aldebaran (α **Tauri**) is derived from an Arabic phrase indicating that the star is the "leader of the followers," i e, the leader of the **asterism** known as the **Hyades**, which follow the **Pleiades** in their nightly journey across the sky Astrologically, Aldebaran was a fortunate star, portending riches and honor This star was one of the four royal stars of the Persians about 3000 B C

Aldebaran is one of the smaller stars whose diameter has been measured with the stellar **interferometer**. The diameter is found to be about 33,000,000 miles, or thirty-eight times the diameter of our sun (W K G)

ALDEHYDES, KETONES, AND RELATED COMPOUNDS (Acetals, Ketenes) Aldehydes (containing —CHO group) are characterized by a wide variety of chemical reactions, well illustrated by reference to two particular aldehydes, namely, **acetaldehyde** and **benzaldehyde.** Regulated oxidation of primary **alcohols** produces the aldehyde corresponding to the alcohol used, and vigorous oxidation of aldehydes produces the corresponding **carboxylic acid**, thus, ethyl alcohol (CH_3 CH_2OH), to acetaldehyde (CH_3 CHO), to **acetic acid** (CH_3 COOH) Regulated reduction of carboxylic acids produces the corresponding aldehyde, and vigorous reduction, the corresponding primary alcohol—the reverse of the first named reactions Not only is the range of reaction of aldehydes wide, but also the range of applications, as illustrated under **formaldehyde, acetaldehyde, benzaldehyde, furfuraldehyde** The reaction with Tollen's solution, as described under formaldehyde, acetaldehyde, benzaldehyde, is commonly used to classify a substance as an aldehyde

SELECTED REPRESENTATIVE ALDEHYDES

	Aldehyde	Formula	Melting Point	Boiling Point
*1	Formaldehyde (methanal)	HCHO	−92	−21
*2	Acetaldehyde (ethanal)	CH_3CHO	−123	20
3	Propionic aldehyde (propanal)	C_2H_5CHO	−81	49
4	Normal-butyric aldehyde (butanal)	$CH_3(CH_2)_2CHO$	−99	76
5	Normal-amyl aldehyde (normal valeric aldehyde)	$CH_3(CH_2)_3CHO$		103
6	Iso-amyl aldehyde((iso-valeric aldehyde)	$(CH_3)_2CHCH_2CHO$	−51	92
7	Caproic aldehyde	$CH_3(CH_2)_4CHO$		130
8	Caprylic aldehyde	$CH_3(CH_2)_6CHO$		168 appr
9	Lauric aldehyde	$CH_3(CH_2)_8CHO$	44	185 (100 mm)
10	Acrolein (acrylic aldehyde)	CH_2 $CHCHO$	−88	52
11	Crotonic aldehyde	CH_3CH $CHCHO$	−69	102
12	Propargylic aldehyde	CH · CCHO		61
*13	Furfuraldehyde (furfural)	$C_4H_3OCHO(2)$	−39	162
14	Citral (geranal)	$C_{10}H_{16}O$		110 (12 mm)
15	Citronellal	$C_{10}H_{18}O$		206 appr
*16	Benzaldehyde	C_6H_5CHO	−56	180
17	Cinnamic aldehyde	C_6H_5CH $CHCHO$	−7	251
18	Glycol aldehyde (glycollic ald)	CH_2OHCHO	97	
19	Glyceric aldehyde	$CH_2OHCHOHCHO$	138	
20	Glyoxal (oxalic aldehyde)	CHOCHO	15	50
21	Succinic aldehyde	$CHOCH_2CH_2CHO$		202
22	Vanillin (2-hydroxy-3-methoxybenzaldehyde)	$C_6H_3(OH(2))(OCH_3)(3)$	81	
23	Benzil (yellow solid)	$C_6H_5COCOC_6H_5$	95	

* Discussed separately under individual name

SELECTED REPRESENTATIVE KETONES

	Ketone	Formula	Melting Point °C	Boiling Point °C
*1	Acetone (dimethyl ketone) (2 propanone)	CH_3COCH_3	−94	56
2	Diethyl ketone (3-pentanone)	$C_2H_5COC_2H_5$	−42	102
3	Di-normal-propyl ketone (4-heptanone)	$C_3H_7COC_3H_7$	33	143
4	Di-normal-amyl ketone	$C_5H_{11}COC_5H_{11}$	15	226
5	Methylethyl ketone (2-butanone)			
6	Methyl-normal-propyl ketone (2-pentanone)	$CH_3COCH_2CH_2CH_3$	−78	102
7	Methyl-iso-propyl ketone	$CH_3COCH(CH_3)_2$	−92	93
8.	Ethyl-normal-propyl ketone(3-hexanone)	$C_2H_5COCH_2CH_2CH_3$		124
9	Ethyl-iso-propyl ketone	$C_2H_5COCH(CH_3)_2$		114
10	Lauryl ketone (laurone)	$(C_{11}H_{23})_2CO$	69	
11	Benzophenone (diphenyl ketone)	$C_6H_5COC_6H_5$	48	306
12	Dibenzyl ketone (diphenyl acetone)	$(C_6H_5CH_2)_2CO$	34	330
13	Acetophenone (methylphenyl ketone)	$CH_3COC_6H_5$	20	202
14	Methylbenzyl ketone	$CH_3COCH_2C_6H_5$	−15	217

* Discussed separately under individual name

(*Continued on next page*)

SELECTED REPRESENTATIVE KETONES—*Continued*

	Ketone	Formula	Melting Point °C	Boiling Point °C
15	Ethylphenyl ketone	$C_2H_5COC_6H_5$	21	218
16	Diphenylene ketone (Fluorenone)	$C_6H_4COC_6H_4$	84	
17	Anthrone (9-oxyanthracene)	$C_6H_4\langle \overset{CO}{CH_2} \rangle C_6H_4$	154	
18	Cyclopentanone	$(CH_2)_4CO$		131
19	Cyclohexanone	$(CH_2)_5CO$		134
20	Cycloheptanone (suberone)	$(CH_2)_6CO$		180
*21	Camphor	$C_{10}H_{16}O$	179	209
22	Carone	$C_{10}H_{16}O$		210
23	Carvone	$C_{10}H_{14}O$		228
24	Menthone	$C_{10}H_{18}O$		207
25	Diacetyl (Dimethyl diketone, 2,3-butandione)	$CH_3COCOCH_3$		88
26	Acetylacetone (2,4-pentandione)	$CH_3COCH_2COCH_3$	−23	137
27	Benzoylacetone	$C_6H_5COCH_2COCH_3$	81	
28	Acetophenone acetone	$C_6H_5COCH_2CH_2COCH_3$		dec
29	Acetyl carbinol (alpha-hydroxy acetone)	CH_3COCH_2OH	−17	146

* Discussed separately under individual name

Ketones (containing $=CO$ group) are in several reactions similar to aldehydes, but less marked than the latter in the variety, as illustrated by reference to the commonest ketone, namely, **acetone** Regulated oxidation of secondary **alcohols** produces the ketone corresponding to the alcohol used, but vigorous oxidation ruptures the substance with the formation of two acids, one of which is found to be **acetic acid** (CH_3COOH) if a methyl ketone was used Thus, dimethyl carbinol, isopropyl alcohol ($(CH_3)_2CHOH$) to **acetone** ($(CH_3)_2CO$), to acetic acid (CH_3COOH) plus carbon dioxide (CO_2) Regulated reduction of ketones produces the corresponding secondary alcohol, and vigorous reduction the corresponding **hydrocarbon**, thus being the reverse of the first named reactions The range of applications of ketones is wide, as illustrated under acetone, **camphor** The reaction with **hydroxylamine** to form oximes of characteristic melting point, and the absence of acidic characteristics in ketones are commonly used to classify a substance as a ketone

SELECTED REPRESENTATIVE ACETALS

	Acetal	Formula	Melting Point °C	Boiling Point °C
1	Methylene dimethyl ether (methylal, dimethoxy methane)	$CH_2(OCH_3)_2$		42
2	Ethylidene dimethyl ether (1,1-dimethoxy methane)	$CH_3CH(OCH_3)_2$		64
3	Ethylidene diethyl ether (acetal, 1,1-diethoxyethane)	$CH_3CH(OC_2H_5)_2$		104

SELECTED REPRESENTATIVE KETENES

	Ketene	Formula	Melting Point °C	Boiling Point °C
1	Ketene	$CH_2\ CO$	−151	−56
2	Methyl ketene (in ether solution)	$CH_3CH\ CO$		
3	Dimethyl ketene	$(CH_3)_2C\ CO$	−98	34
4.	Diphenyl ketene	$(C_6H_5)_2C\ .\ CO$		

(R K S)

Acetals are formed by reaction of aldehydes with **alcohols** (or with **carboxylic acids**) The aldehyde is so easily obtained from acetals that the latter may, in certain cases, be conveniently used as a source of aldehyde With hydrochloric acid heated, the aldehyde and alcohol (or carboxylic acid) are readily formed Acetals are relatively stable towards alkalis

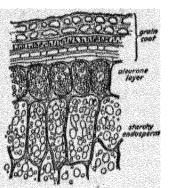
Ketenes are formed along with zinc bromide from alpha-bromo-substituted acetyl bromides by reaction with zinc, e g, dimethylbromoacetyl bromide ($(CH_3)_2C\ Br\ COBr$) yields dimethylketene ($(CH_3)_2C.CO$) Di-substituted ketenes or ketoketenes are reactive (1) with water, alcohols, ammonia, amines, phenylhydrazine, quinones, forming addition products, (2) with pyridine or quinoline forming ketene bases, (3) with olefin substances forming addition products Ketenes do not form **phenylhydrazones** or **semicarbazones** as do ketones The simplest ketene is $CH_2\ CO$, which may be considered an anhydride of acetic acid, although it is best made by passing acetone vapor through a red hot tube Carbon suboxide ($O\ C\ C\ C\ O$) is regarded as a diketene (R K S)

ALDER-FLY. Insecta, Neuroptera. A name given to the adults of a single subfamily of flies from their common occurrence on the alders bordering small streams. The larvae are aquatic. (A.W.L.)

ALDOL. Acetaldehyde.

ALEURITES (Euphorbiaceae). Tropical trees bearing small many-seeded fruits extremely rich in oil. *Aleurites triloba,* the candlenut of the orient, produces a fruit extensively used for food and for light. *Aleurites cordata,* a native of China, is the "varnish-tree." *Aleurites Fordii* yields tung, or nut oil (See **Fixed Oils**), a valuable drying agent used instead of linseed oil, especially in the preparation of waterproof varnishes. It is now widely cultivated in the southernmost parts of the United States. (R.M.W.)

ALEURONE GRAINS. Protein (See **Amino acids and Proteins**) reserves found in the seeds of several different kinds of plants. In many plants there is a special aleurone layer of definite thickness found in the **endosperm.** In **corn** the layer is a single cell in thickness and may contain a colored pigment; in **oats** it is two cells thick. In the **castor oil** plant the aleurone grains are not restricted to a single layer, but are distributed rather generally in the endosperm, and have a complex structure. (R.M.W.)



The aleurone layer in wheat. Part of a section of a wheat grain showing aleurone layer with cells filled with granules of protein.

ALEWIFE. Pisces, Teleostei. A common fish (**Pisces**) of the Atlantic coast, *Pomolobus pseudoharengus,* related to the herring and shad. It enters the streams to spawn, and is found in lakes of New York. (A.W.L.)

ALEXANDRITE. A variety of **chrysoberyl,** originally found in the **schists** of the Ural Mountains. It absorbs yellow and blue light rays to such an extent that it appears emerald green by daylight but columbine red by artificial light. It is used as a gem, and was named in honor of Czar Alexander II of Russia. (E.S.C.S.)

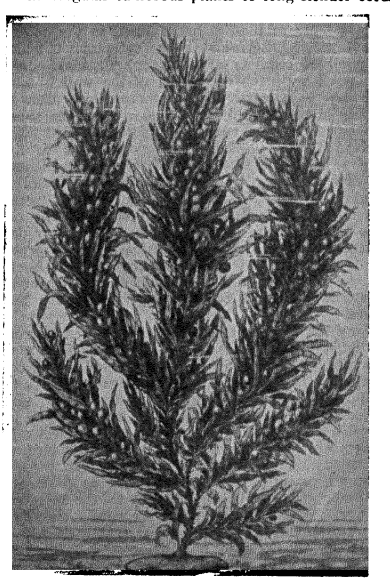
ALFALFA. *Medicago sativa.* Lucerne. A leguminaceous (See **Fruit**) plant probably native in southwestern Asia. It is an important forage plant, which has been extensively cultivated since the Roman civilization. The plant has an extremely deeply-penetrating root system, reaching down 25 feet or more, and so is admirably adapted for growing in dry lands, where resistance to drought is important. Its fragrant purplish flowers are an important source of **honey,** especially in California. (R.M.W.)

ALGAE. (Sea weeds, Pond-scums, etc.) These are **Thallophytes** characterized, with a few exceptions, by possessing chlorophyll (See **Amino acids and Proteins**), and so capable of elaborating their food by **photosynthesis.** Often the green pigment is completely concealed by other pigments, so that the plant is brown, red, or even black.

Algae are found in almost every habitat. In the oceans vast numbers of minute species float suspended in the upper levels of the water, while the shores are covered with many and varied forms from high tide level to depths of 30 feet or more. In fresh water they are equally abundant, but due to their smaller size are seldom so conspicuous as the marine forms; they occur in running water, in ponds and in stagnant, often putrid water. Many species are found only in hot springs. They are found on the surface of the ground, on the bark of trees, on rocks, and even underground to a depth of several feet. A few species have found a favorable habitat within the bodies of higher plants and animals. In fact, wherever they find support and can obtain the necessary materials for growth, there algae may be found.

Algal plants offer a wonderful diversity of forms. In size they range from unicellular microscopic plants to structures having dimensions comparable to the larger land plants. The plankton forms, those free-floating plants often so abundant in both fresh and salt water, are nearly all unicellular; other free floating forms, usually found near shore or in small fresh water ponds and streams, are multicellular organisms of various shapes, filamentous forms being especially common. Finally, attached marine forms often attain massive dimensions. The common kelp, or devil's apron, of the colder coastal waters of North America may grow to a length of thirty feet or more, and to a width of two or three feet, while related species found in the Pacific Ocean far exceed them in size, reaching lengths of 100 feet and more.

Not only do algae vary greatly in size, but they also show almost every conceivable shape. Unicellular types are often adorned with a complex but beautifully symmetrical series of arms, or bristles, which may be of service in keeping them floating in the water. The filamentous forms may be simple or very much branched; often they are delicate plants of rare beauty. Other algae grow in flat sheets or membranes, either spreading over the substratum or rising gracefully in the water. The larger forms are of coarser habit, varying from irregular tumorous plants to long slender cords



Sargassum linifolium. (From Altmanns *Morphologie und Biologie der Algen,* Gustav Fisher, Jena.)

and broad flat fronds. Plants of the genus *Sargassum,* one of the brown algae found in warm regions, have an appearance very similar to that of flowering plants. Each plant has a slender branching stem, often two feet or more in length. From this stem flat lateral branches arise, which look very much like leaves, except for their brown color. Other short lateral branches end in small

sub-spherical balls easily mistaken for fruits. Actually these structures are hollow bladders which help to keep the plant floating. Other branches, the real reproductive parts of the plant, are short cylindrical objects which might be mistaken for buds. At first the plant grows on rocks and other solid objects. It is easily broken loose, however, and floats about in the ocean currents. Thus, these plants are frequently washed up on northern beaches.

There are several systems of classification of algae, varying in details but all using the various pigments found in their cells as a basis for separation. Obviously such a classification is very artificial, but in the algae it seems to agree quite closely with natural systems based on such other criteria as the structure of the thallus or plant body, as the substances formed by the cells and stored in them, and especially as the reproductive processes which are found in the different groups.

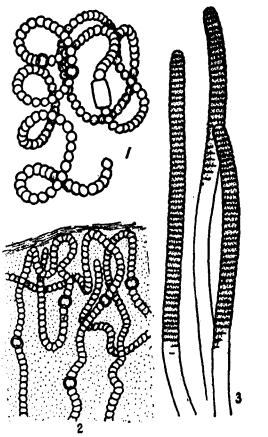
Separated according to pigments the algae fall into four large classes and several smaller ones. The four large classes are the Cyanophyceae or blue-green algae, the Chlorophyceae or green algae, the Phaeophyceae or brown algae, and the Rhodophyceae or red algae. The minor classes are the Xanthophyceae (also called the Heterokontae, because of the two unequal cilia (See **Cilium**) which characterize them), the Chrysophyceae, the Bacillariphyceae or **diatoms**, the Cryptophyceae, Dinophyceae, Chloromonadineae and Euglenineae.

The blue-green algae are characterized by having within the cell, in addition to chlorophyll, a bluish pigment, phycocyanin (See **Amino acids and Proteins**). These pigments are not localized in a definite pigment-bearing body or plastid, but diffused in the outer zone of **cytoplasm.** Surrounding the cytoplasm is a definite cell wall of cellulose (See **Carbohydrates**). In most blue-green algae the outer part of the wall is modified and becomes a soft slimy substance which often forms a layer of considerable thickness. This slime substance may be of great value as an insulation against heat and desiccation, thus enabling blue-green algae to live in what seem to be most unfavorable environments. In the central portion of the **protoplast** are found many **chromatin** bodies, which, however, are not organized into a definite nucleus. The structure of the cell of these algae, with its absence of plastids and any definite nucleus, seems to indicate a relative primitive organism, and is suggestive of the structure found in **bacteria.** Because of these similarities algae and bacteria are sometimes combined into a single group, the Schizophytes.

Many blue-green algae are single-celled organisms. The individual cells are often separate or they may be held together by the gelatinous outer wall in aggregates sometimes of considerable size. Representatives of this group are frequently observed in temporary puddles formed by a summer shower or in quiet shallow ponds in which the water often becomes very warm. Some of them are of considerable economic importance, when they appear in water supply reservoirs. In these they sometimes occur in numbers so great as to color the water and to be only too obvious to the most casual observer. Such occurrences are frequently described as "Water-blooms." Due to the products formed by the metabolism of the cells and liberated into the water, such "blooms" are real problems, for not only do these substances give to the water a distinctly unpleasant oily fishy taste and color, but several cases are recorded in which drinking of such water has been quickly fatal to live stock.

Other blue-green algae occur as simple filaments of cells. Single filaments may occur among other algae or they may exist in extensive masses covering considerable areas with a soft felt-like layer. In some genera many filaments are held together in a common gelatinous sheath. Many blue-green genera show what is called false branching. The rapid division of cells in the middle of a filament causes them to grow out laterally. Sometimes the filaments grow out as a single branch, as in *Tolypothrix*, or in pairs, as in *Scytonema*. True branching is found in a few genera.

In all the non-filamentous species the only method of reproduction is that of **cell division.** In the filamentous forms continued division may produce a filament of indefinite length. However, it eventually breaks up. This fragmentation may be due to animals feeding on cells of the filament, or to the death of certain cells. In some forms it is due to the development of cells which do not adhere tenaciously to the cells adjoining them. Specialized cells known as heterocysts are largely responsible for the last condition. They are large cells which develop from ordinary cells, and which are filled with a colorless substance. They are thought to be spore-like bodies which have generally lost the ability to function as spores.



Three species of Myxophyceae. 1, filaments of a species of *Anabaena*. 2, filaments of *Nostoc* encased in the characteristic jelly. 3, *Oscillatoria*. (1 after G. M. Smith, 2 after Fremy.)

Blue-green algae, particularly abundant in regions having a warm climate, develop elsewhere in great abundance, during the warmer seasons of the year. Besides being a source of trouble in water reservoirs, blue-green algae sometimes form unsightly stains by growing on the walls of stone buildings, especially if the latter be constantly wet. Blue-green algae are of little importance otherwise.

The green algae, or Chlorophyceae, are found in both salt and fresh water, where they often form conspicuous masses. They are characterized by a bright green color. The reserve food stored by these algae is starch, which is usually found around certain bodies known as pyrenoids, located in the **chloroplastids.**

Except that they are an important source of food for many animals, little importance can be ascribed to the green algae. They are, however, of considerable interest because of the possibility that from them the higher plants may have arisen, and because of the diversity of forms which are found within the group.

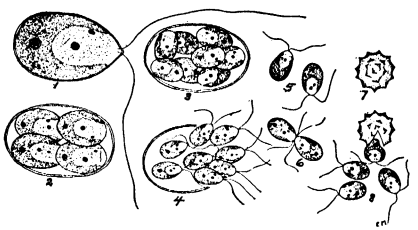
The protoplasts of the green algae are with very few exceptions enclosed within a rigid wall composed of two layers, an inner made up wholly or largely of cellulose and an outer layer of pectose (See **Carbohydrates**). Within the protoplast of the cell is located one or more conspicuous chloroplastids containing pigments approximately like those occurring in the plastids of higher plants. The chloroplastids of any single genus are usually very constant in appearance but in the different genera remarkable diversity of size and shape obtains. The primitive form seems to be the massive cup-shaped type such as occurs in many lower Chlorophyceae. The nucleus of all green algae is a definitely organized body possessing a nuclear membrane, one or more **nucleoli** and a chromatin network. Many unicellular forms have one or more cilia which persist throughout their existence. The reproductive cells of most green algae have cilia. (See **Cilium.**)

Reproduction in green algae takes place in various ways. One is a strictly vegetative process in which the colony, or filament, of cells is broken up by various external agents, after which each fragment becomes a new colony, or filament.

Asexual reproduction is another method. This commonly takes place by means of zoöspores. These zoöspores are generally formed from the protoplast of any vegetative cell, and may appear singly or in numbers by division of a single protoplast. They are expelled from the cell in a manner as yet unknown and are frequently enclosed in a delicate vesicle at the time of expulsion. The zoöspores are naked bodies, having no cell wall, and possessing apical cilia. *Vaucheria* is an exception, for its zoöspores are covered with cilia. After periods of motility varying from a few minutes to many hours, zoöspores become quiescent, withdraw their cilia, secrete a cell wall and develop to new colonies or organisms like the parent form.

Finally, many green algae possess a sexual reproduction which is often very complicated. In sexual reproduction there are formed two sets of reproductive bodies known as **gametes**, which fuse in pairs to form a **zygote**. From the zygote a new plant develops.

The great diversity of form found in the green algae makes them interesting plants to examine for lines of **evolution** which have produced the many forms existant today. Several different lines have been found. One of these includes many of the forms which remain motile throughout their existence. A relatively simple unicellular organism is the starting point for such a



Chlamydomonas. 1, mature cell; 2, four young cells formed in asexual reproduction; 3, eight gametes formed by the division of one cell; 4, gametes escaping from old cell wall; 5, free-swimming gametes; 6, two gametes conjugating; 7, resting zygote; 8, four cells formed from the zygote. Somewhat diagrammatic.

line. *Chlamydomonas* is of this type. The plant is a small spherical or oval cell enclosed in a definite cell wall and having two apical cilia. Within the protoplast there is a single massive chloroplast which has a shape like that of a soft rubber ball pushed deeply in on one side. Within the hollow of the plastid the single distinct nucleus is located. At the apex of the cell near the origin of the two cilia there is a minute red body called an eye-spot. This is a light-sensitive organ which when stimulated causes the organism to move toward or away from the light source. In the apical end there is a pair of contractile vacuoles. *Chlamydomonas* reproduces asexually by means of zoöspores. These are formed by divisions of the protoplast to form two, four or eight daughter protoplasts, contained within the wall of the original cell. This wall softens and liberates these naked cells. At once they become small replicas of the parent cell. They soon grow to the size of the original cell and again form a new group of zoöspores. In a suitable environment this is a very rapid method of reproduction. *Chlamydomonas* also reproduces sexually.

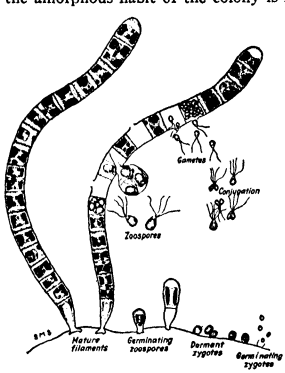
In sexual reproduction the protoplast of the cell divides to form motile bodies called gametes, which are quite like zoöspores, but smaller. On liberation from the parent cell wall, gametes from different cells unite in pairs, and form zygotes. A zygote is a resistant spore with a thick wall which enables the organism to survive periods of adverse conditions. When favorable conditions return, the contents of the zygote divide to form zoöspores, which behave as do similar spores from motile cells. The similarity of gametes and zoöspores indicates that one is derived from the other, that sex results from the transformation of asexual zoöspores into gametes.

The primitive character of *Chlamydomonas* is found in its contractile vacules, its eye-spot, its single massive plastid, and its cilia. From **Flagellates** it differs only in having a definite cell wall. Comparing other motile green algae with *Chlamydomonas* makes it possible to discover an interesting series of species of increasing complexity. First in this series is *Gonium sociale,* with colonies of four cells, and *Gonium pectorale,* with sixteen cells, held together loosely in a gelatinous matrix. All the cells of a colony are alike and any cell may form either zoöspores or gametes. All gametes are alike, but fusion occurs between gametes from different colonies. Next in the line of increasing complexity is *Pandorina,* in which a spherical colony is formed. In this genus the gametes are slightly different in size and behavior, some being small and active, while others, slightly larger, are more sluggish. This is an indication of a differentiation of sex.

Still further advance is shown by *Eudorina,* in which a colony is composed usually of thirty-two cells located in the peripheral portion of the gelatinous matrix. Each cell of the colony is like a *Chalmydomonas* cell and each is capable of reproducing asexually. But in sexual reproduction a very obvious difference in sexes is apparent. Some colonies are definitely female, the cells enlarging slightly and functioning as eggs. In other colonies, each cell divides to form sixty-four minute biciliate **spermatozoids**. Fusion between an egg and a spermatozoid produces an oöspore which gives rise to a new colony. In *Pandorina* then a very obvious distinction between sexes has appeared, but the vegetative cells remain alike. In *Pleodorina* each colony is composed of small, purely vegetative cells and larger reproductive cells. The smaller vegetative cells are formed in the anterior end of the colony. In *Volvox* we find the highest degree of differentiation exhibited in this line of motile algae. In this plant the number of cells in a colony is very great, in some species there being as many as 25,000. Of these cells only a few are reproductive, while thousands remain vegetative. Many *Volvox* colonies are so large as to be readily visible to the unaided human eye. In these the many cells form a single layer embedded in the gelatinous matrix. The center of the colony is either water or a thin gelatinous substance. The cells of the colony have the same structure as *Chlamydomonas* cells. They are joined together by fine protoplasmic strands. The beating of the cilia causes the large colony to roll rapidly about in the water, making it a fascinating object to watch. In asexual reproduction certain cells of the colony enlarge and move to the central region. There they lose their cilia, after which they divide rapidly to form new colonies which remain for some time within the parent. Often a single colony will contain a dozen or more of these small colonies. The latter are liberated by the disintegration of the parent colony. In sexual reproduction, cells in the posterior region of the colony differentiate. Some lose their cilia and become very large; these are eggs. Other cells, either in the same or different colonies, divide many times to form large numbers of minute biciliate spermatozoids. These swim to the eggs. A single spermatozoid enters an egg, its nucleus fusing with that of the egg. As a result a zygote is formed. This secretes around itself a thick wall and becomes an oöspore, capable of enduring protracted periods of unfavorable conditions. With the return of favorable conditions the thick wall of the oöspore breaks, the protoplast emerges and divides rap-

idly, forming a new colony. *Volvox* represents the climax reached in this line of evolution. There is not only a very great increase in the number of cells forming a colony, but also a distinct separation of vegetative and reproductive cells. The reproductive cells are of two kinds, eggs and spermatozoids. But every cell of the plant retains the primitive character of the individual cell.

It is possible to build up other evolutionary series of green algae in which the vegetative cells are non-motile. *Chlamydomonas* often assumes a non-motile condition; the cells become embedded in a copious gelatinous matrix and lose their cilia. This condition is known as the palmella stage. *Tetraspora* is an alga which has the appearance of the palmelloid stage of *Chlamydomonas*. Another genus, *Palmella*, normally exists as a shapeless colony of cells held together in a gelatinous matrix. Cilia are lacking, but may be developed by any cell in the colony. A ciliated cell escapes and swims about freely for a time, then settles down and divides to form a new colony. Asexual zoöspores are formed in *Palmella* and also isogametes, that is, gametes of equal size. *Palmella* shows the beginning of a non-motile habit, with a restriction of the motile stages to the reproductive cells. In *Geminella* the amorphous habit of the colony is lost; divisions take place in such a way that the resulting cells tend to exist in a single series, the individual cells being held together only by the gelatinous matrix around them. In *Ulothrix* further advance is made. In this plant the protoplast of the cell divides within the wall of the cell. But it does not escape therefrom; instead cross-walls are formed between daughter protoplasts which remain permanently joined. Repeated divisions in a single direction result in the formation of a long unbranched filament of cells. Asexual reproduction in *Ulothrix* is by zoöspores. These are very similar to the cells of *Chlamydomonas*, but each has four cilia. From each zoöspore new filaments are formed directly. Sexual reproduction is by biciliate gametes which are formed in the usual manner. Two gametes fuse to form a zygote, which on germinating produces zoöspores. In some species of *Ulothrix* the gametes are alike, while in others differences in size of the gametes produced from different cells indicate the beginning of sex differentiation.



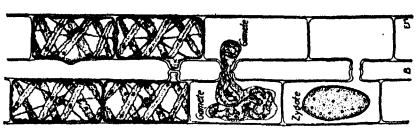
Ulothrix. Stages in development.

Other genera of algae, related to *Ulothrix*, show greater differentiation in the vegetative cells. Branching occurs in many; certain cells produce the zoöspores or gametes. Other genera, notably the marine *Ulva*, the Sea Lettuce, have cell divisions in two planes, so that extensive membranes are formed, often two meters or more in length.

The highest stage of development in this series is found in *Coleochaete*. This alga appears as small disks epiphytic on other aquatic plants. It consists of branching filaments which in some species grow out to form a flat shield-like thallus. Asexual reproduction is by biciliate zoöspores, which are formed singly from the protoplast of any cell. In its sexual reproduction, *Coleochaete* is especially interesting, exhibiting an advanced degree of differentiation of sex cells called oögamy. The eggs are formed in special cells at the tips of certain filaments. By continued growth, the vegetative cells form a layer enclosing the oögonium. From the oögonium a projection called the trichogyne grows out; in some species it remains short, but in one at least it becomes long and slender. The biciliate spermatozoids are formed singly in special cells known as antheridia. A single spermatozoid enters the egg through the trichogyne or papilla, through a soft place which forms in the wall. Following fertilization, or the union of egg and spermatozoid, the fertilized egg enlarges greatly and secretes around itself a thick wall, in which condition it remains very resistant to external changes. On germination its contents divide to produce sixteen or thirty-two cells, each of which produces a zoöspore. These give rise to new plants. In *Coleochaete* we have a highly developed end product to an advancing degree of differentiation of cells and development of sex.

Many other equally interesting lines of evolution can be found in green algae. One leads to *Vaucheria*, a branching filamentous plant in which cross walls are not formed, nuclear divisions occurring until an extensive multinucleate filament is formed. Many marine relatives of *Vaucheria*, especially abundant in tropical seas, have elaborate bodies, often thickly encrusted with lime. In the genus *Caulerpa* the thallus of some species appears to be differentiated into leaves, stems and roots; however, no differentiation of tissue occurs, the whole structure being essentially filamentous.

Another group of algae, found only in fresh water, is the Conjugales. This includes the frequently observed



Spirogyra. Stages in Conjugation.

Spirogyra, a genus having spiral chloroplastids. Sexual reproduction in *Spirogyra*, as in all the Conjugales, is by a process called conjugation. When the cells of two filaments are to conjugate they come into contact one with another. From the cells of one filament projections grow outward to meet similar projections from the cells of the other filament. These projections meet, and the walls at their tips are absorbed, leaving a tube connecting two cells of opposite filaments. Through this tube the protoplast of one cell moves into the opposite cell, where fusion occurs. Following this the zygote thus formed surrounds itself with a thick wall. This zygospore is extremely resistant to unfavorable external conditions, such as drought. After a prolonged rest period, if environmental conditions are favorable, the wall of the zygospore breaks, and a tube grows out from the protoplast within. By divisions, this tube becomes a new filament. Observation of conjugating filaments of *Spirogyra* reveal two facts: first, that when one cell of a filament conjugates with a cell of another filament, commonly all the cells of the first filament are conjugating with those of the other; second, that movement is largely from one filament to the other, so that at the end of the process one filament is composed of empty cell walls and the other filled with zygospores. This may be conceived as a sexual condition, the empty cells having been male and the cells in which the zygospores formed, female. Many related algae in the Conjugales show no indication of sexuality, the protoplasts uniting in the tube joining the two cells. No ciliated cells of any sort occur in this order.

Related to *Spirogyra* is a family containing many species whose cells are very symmetrical and beautiful

objects. This is the Desmidiaceae, a family whose members commonly occur as single cells composed of two symmetrical halves. In many species the halves are distinctly indicated by a deep constriction which leaves only a slender isthmus connecting them. Conjugation in the Desmids is essentially like that in the other Conjugales.

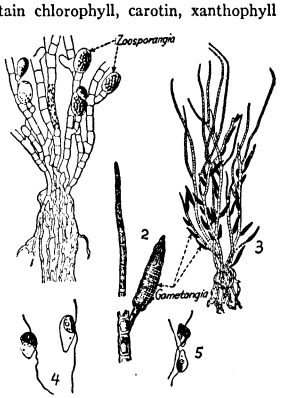
Little importance can be attached to the green algae, except that they are a fundamental source of food for fishes. Interest in them is mainly due to their remarkable diversity revealing interesting lines of development as described above and as plants from which the land flora may have developed.

The brown algae, or Phaeophyceae, are distinguished from other algae by the presence of the brown pigment fucoxanthin, which masks the chlorophyll present and which imparts to them a brown color. They are nearly all marine plants. In this group there are no very simple primitive forms, comparable to *Chlamydomonas* of the greens. The simplest forms, such as *Ectocarpus*, are branched filamentous plants.

Other brown algae are very large, with tough bodies of many often complex shapes. They are most numerous on rocky coasts, where they grow attached to the rocks and are often exposed to the severest pounding of the tides. Brown algae are found in all regions, but are especially abundant in the cold temperate and arctic waters. One genus, *Sargassum*, occurs in great abundance floating in the Atlantic Ocean, forming the Sargasso Sea, through which Columbus passed so slowly on his voyage of discovery. Probably these plants are carried by ocean currents from the shores where they grow to the Sargasso Sea, where they float endlessly. The brown algae include the largest plants of this division of the plant kingdom, many of the kelps growing 30-40 feet long, and some of the giant forms of the Pacific Ocean attaining lengths of a hundred feet and more.

All brown algae are multicellular plants. Each cell contains a single distinct nucleus and several chromoplastids which contain chlorophyll, carotin, xanthophyll and fucoxanthin (See **Amino acids and Proteins**). The presence of the latter hides the other pigments. **Photosynthesis** in brown algae, as in other plants, results in the formation of sugar. This sugar however is changed into a compound, laminarin, instead of starch, which is never found in this group of algae.

The phaeophyceae are divided into several orders. These show interesting differences in their life histories. In most of them there is a very definite alternation of generations. Plants of the sexual generation form gametes; the asexual generation forms zoöspores. The motile cells of the brown algae are quite distinct from those of the green algae, having two unequal cilia which are attached laterally and extend in opposite directions.



Ectocarpus

Ectocarpus. Stages in development. 1, Sporophyte plant; 2, 3, Gametophyte plants; 4, Two zoospores; 5, Conjugation of gametes to form zygotes. *Reprinted by permission from Textbook of General Botany*, by Holman & Robbins, published by John Wiley & Sons, Inc. (After Setchell, & Gardner.)

One of the orders of this class is the Ectocarpales, of which *Ectocarpus* is a common form. It occurs as soft brown tufts growing on other larger algae or on stones or woodwork in the water. Each plant is composed of slender branching filaments. In this genus there is a definite alternation of two generations which are indistinguishable in the vegetative condition. Plants of the sexual generation are haploid, that is, have the reduced number of chromosomes and bear gametangia. These are elongated structures composed of many small, cubical cells. Each of these cells forms a single gamete. The plants of this generation and the gametangia they bear all look exactly alike. The gametes which they produce also look very much alike. But in behavior they are different. Some are sluggish, moving but little, while others swim actively and are attracted to the sluggish ones from other plants. The active gametes are males, the others females; sometimes the female gametes are slightly larger than the males. One male gamete fuses with a female, forming a zygote. The zygote always forms an asexual plant which is **diploid**. There are two kinds of asexual plants, which look exactly alike, and also like a sexual plant. Each forms zoösporangia. One form of zoösporangium, called a plurilocular zoösporangium, is composed of many small cubical cells, each of which forms a single zoöspore. These zoöspores are liberated, swim about for a time, sink to the bottom and settle against any solid substratum and give rise to new asexual plants of the same type as that producing them. The other type of zoösporangium, often found on the same plant as the first, is composed of a single, usually much-enlarged, cell. The protoplast of this cell divides many times and gives rise to several zoöspores which are haploid. Therefore reduction division takes place in the sporangia, which produce these zoöspores. These zoöspores produce sexual plants. In some species of *Ectocarpus* the alternation of generations is not as regular as that described.

Another order of brown algae is the Cutleriales, of which the genus *Cutleria* is a well-known example. In *Cutleria* the two generations have a very different appearance, the sexual plants being much branched, and several inches tall, while the asexual plants are small lobed thalli growing prostrate on the substratum. So different are these two generations that they are often mistaken for different plants. The sexual plants are of two kinds, male and female, which differ very little. The sex organs are borne on the surface of the thallus. The male gametangia are elongate structures borne on branching filaments; the female gametangia are stouter and composed of few cells. The male gametes are minute and biciliate, the female, also biciliate, are many times larger. Many male gametes swim to a single female, one fuses with it, producing a zygote. The zygote develops into an asexual plant. The zoöspores, formed from small sac-like zoösporangia, which develop in large numbers on the upper surface of the thallus, are biciliate and very similar to gametes. They form sexual plants. In this order there is a very distinct difference in the two gametes, male and female, and a striking difference between sexual and asexual plants.

A third order is the Laminariales, which includes the largest algae known, commonly known as kelps. Some of them have a very striking appearance. *Postelsia*, for example, has a plant body composed of an erect stiff stalk often several inches in diameter. From its base many thick root-like outgrowths spread out and fix the plant firmly to the substratum. At the top of the stalk, long spreading branches are found. When the plant is seen growing in water it has much the appearance of a palm tree, whence the common name, sea palm. Another plant in this order is *Chorda filum*. Its thallus is a tough cord-like object three to eight feet long and about a quarter of an inch in diameter. It looks very much like a coarse round leather shoestring. A very common genus is *Laminaria*, which has many species of various forms, mostly large. Some of them consist

of long cord-like stalks which bear at their upper end a broad flat expansion often six to twelve feet long and 8-15 inches broad. Colloquially these are known as devil's aprons. These large plants are the asexual generation and so are diploid. The zoösporangia are formed in immense numbers on the surface of the thallus. Each zoösporangium is a cylindrical object which produces many small biciliate zoöspores. These zoöspores swim down to the sea bed, where they develop into haploid or sexual plants. The latter are minute, usually consisting of a few cells which form a branching filament. Some of the plants are male, others female. In the female plant, any cell may become a sexual cell; often the plant is only a single cell. This sexual cell is an oögonium and forms a large non-motile egg which remains in the parent plant. Any cell of the male plant may become sexual, producing minute biciliate sperms which swim to the egg and fuse with it, forming a zygote. The latter at once develops into an asexual plant. In this order, there is also a distinct alternation of generations, but the sexual generation contains the small plants, the asexual usually very large plants. The sexual cells are distinctly different: the large non-motile egg and the small biciliate sperm.

A fourth order of brown algae is the Fucales. Members of this order are tough, much-branched plants which are particularly abundant on rocky shores in regions where the water is cold. *Fucus*, the common rockweed or bladderwrack, is a common and well-known plant. In this, as in all members of this order, there is no asexual reproduction. Therefore no distinct alternation of generations can occur. A *Fucus* plant consists of a tough dichotomously branched thallus, which is attached to the rock on which it grows by a disk-shaped holdfast. In many species hollow bladders develop along the thallus and serve to keep it floating in the water. At the tips of the branches of the thallus the reproductive bodies are formed. In some species these tips are swollen to form hollow bladders, in others they are flat and little differentiated from the rest of the thallus. The reproductive cells are formed in spherical cavities which are connected with the surface by small pores. Each cavity is called a conceptacle. Numerous branching filaments rise from the lower part of the conceptacle wall. Branches of these filaments bear the sexual organs. In some species the two sexes are borne in the same receptacle, in others they occur on different plants. The male sex organs or antheridia are oval sacs. The protoplast of each sac divides to form 64 cells, each of which becomes a laterally biciliate sperm. When mature these antheridia are extruded through the ostiole or opening of the conceptacle into the water. There the wall of the antheridium bursts, liberating the sperms. Each oögonium consists of a single cell. Its protoplast divides to form eight eggs. These also are extruded from the conceptacle, while still within the wall of the oögonium, and freed by the bursting of the same. Each egg is a very large non-motile cell. Thousands of sperms are attracted to each egg and swim about it, causing it to revolve rapidly. Finally one sperm gains entrance to the egg and fertilizes it. The other sperms immediately fall away. The fertilized egg settles to the bottom, attaches itself to the substratum and at once starts to develop into a new plant. In the Fucales there is no alternation of generations. It may be that the *Fucus* plant is the asexual generation and the gametes the sexual. The gametes of the Fucales are very distinct, one being a large non-motile egg, the other a very small swimming sperm. One is tempted to arrange the various orders of brown algae in a series showing the way in which each may have evolved. However, such evolutionary relationships are purely speculative and not supported by any real evidence. It is impossible to trace the ancestry of the brown algae back to any simple ancestor, since no simple forms of brown algae are known.

Fucus. Mature plant, × 1/3. No bladders are shown. (From *Morphologie und Biologie der Algen*, Gustav Fischer, Jena.)

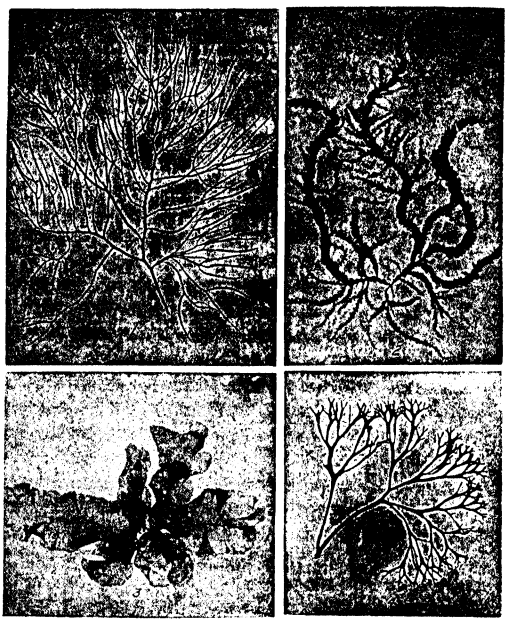
The economic importance of the brown algae, while slight, is much greater than that of the green algae. Large quantities of these plants are gathered and used for fertilizer, wherever agriculture is carried on near the coast. From the ash produced by burning the larger forms, the kelps and Fucales, iodine and also potassium are obtained. In the Orient and in some of the north Atlantic islands, some of the brown algae are used as food, both for human beings and for live stock.

The red algae or Rhodophyceae form a very large group of plants, nearly all marine, of small to medium size. They are particularly abundant in warm coastal waters and are often plants of great beauty and extremely delicate habit. The red color to which they owe their name is caused by phycoerythrin (**Amino acids and Proteins**), a red pigment which is present with the common chlorophyll-carotin group of pigments. These pigments are present in definite bodies or plastids, and not diffused through the protoplasts, as in the blue-green algae.

The forms of red algae are numerous. In many species the thallus is an extremely delicate filament. In other species the thallus is a tough, branched body six to fifteen inches long. Others are flat membranes which may be a single cell in thickness or may be many cells thick. Some are thickly covered with a calcareous deposit, so that they are hard and stony, resembling corals. No motile reproductive cells are produced by members of this group. In sexual reproduction there is always a large female cell which is fertilized by a small male cell. This sexual reproduction is a rather complicated process. The antheridia are single-celled bodies; in some species the whole cell is liberated, in others the protoplast of the antheridium is freed. In either case the male cell floats in the water, carried only by the currents. The female reproductive organ is known as the procarp. In simpler forms this consists of a swollen basal portion called a carpogonium and a long slender portion called a trichogyne. Chance brings the male cell to the surface of the trichogyne, against which it sticks. The wall of the trichogyne is dissolved, allowing the nucleus of the male cell to enter the trichogyne. This nucleus passes down the trichogyne and enters the carpogonium, where it fuses with the female nucleus. From the fertilized carpogonium asexual spores called carpospores are formed, usually at the ends of branches which grow out from the carpogonium or from cells which are formed from those surrounding the carpogonium. Into these carpospores, nuclei from the carpogonium pass. The carpospores of simpler red algae at once produce sexual plants. In most red algae, however, they produce asexual plants which may be identical with the sexual plants in appearance. These asexual plants bear reproductive cells called tetraspores, because four of them are borne in a single sporangium. Each tetraspore gives rise to a

sexual plant. So in the majority of red algae there is a distinct alternation of generations.

Of the many species of red algae very few are of any importance. In northern waters of both coasts of the



Four red algae. 1, *Agardhiella tenera;* 2, *Dasya elegans;* 3, *Grinellia americana;* 4, *Chondrus crispus.* × 1/3 (*Photographs of herbarium specimens by Naylor.*)

Atlantic, dulse, *Rhodymenia palmata,* is found. It is gathered, cleaned more or less, and dried. It is then sold as a food or a relish. Species of *Porphyra,* often called laver, are also eaten, especially by oriental people. Irish moss, or corrageen, which is *Chondrus crispus,* is another red alga which is gathered for food. It is a small much-branched plant, commonly dark red in color and with a beautiful iridescent surface. The plants are gathered, thoroughly cleaned and dried. Drying bleaches them to a creamy white color. When thoroughly dry they are bagged and sold. The powdered plant is commonly boiled in milk, flavored and sweetened, and allowed to cool. It forms a firm smooth gel known as blanc-mange. From species of red algae growing in the Pacific Ocean, **agar agar** is obtained.

The origin of the red algae and their relationships with other algae is a matter of considerable speculation. A few trace them from the blue-green algae, finding in some of the more primitive red algae "connecting links" which support this view. The same pigments are present in the two groups, and there are no ciliated reproductive cells in either. But their distinct well-developed nucleus, their chromoplastids, and their complex reproductive process set the red algae off very clearly. In view of these facts, it is perhaps more logical to derive the red algae from the green, using a form like *Coleochaete.* If there is any relationship between the red and the blue-green algae, it must be rather remote. (R.M.W.)

ALGAL REEFS. Paleobotany.

ALGEBRA. As generally understood in an elementary sense, Algebra is a branch of Mathematics which deals with the operations with **numbers** by means of general symbols, such as letters, and with some of the simpler applications of these operations.

For the historical origin of Algebra, we must go back to the time of the early Egyptians. The germs of Algebra are found in the ancient papyrus of Ahmes (about 1700 B. C.). The ancient Greeks developed elementary **geometry** to a remarkable degree, but occupied themselves very little with Algebra. It was not until the time of Diophantus (about 300 A.D.) that any Greek work in Algebra was done to amount to anything. The early Hindus, however, cultivated elementary Algebra to a surprising extent, but were little concerned with geometry.

The origin of the name "Algebra" is somewhat obscure. The Arabic mathematician *Mohammed ibn Mûsâ al-Khowârizmî* (about 825 A.D.) wrote a work entitled "*Al-jebr w'al-muqâbalah,*" which is sometimes translated as "restoration and equation," but the meaning is not exactly clear. This work treated of algebraic topics and its name is generally considered to have been the source of the name Algebra. The modern Europeans became acquainted with Algebra from the Arabs.

Some indication of the subject-matter usually considered as belonging to Algebra may be found by consulting the following topics: **Number, Algebraic Operations, Algebraic Expressions, Factoring, Fractions, Involution, Evolution, Powers and Exponents, Radicals, Identities, Equations, Solution of Equations, Linear Algebraic Equations, Quadratic Equations, Polynomial Equations, Graphs, Inequalities, Binomial Formula, Logarithms, Progressions, Variation, Permutations, Combinations, Probability, Determinants.** (L.L.S.)

ALGEBRAIC EQUATIONS. An algebraic equation is an **equation** in which both members are **algebraic functions.**

Algebraic equations in one unknown are classified into **polynomial equations** (rational integral equations), **fractional equations, radical** or irrational **equations;** polynomial equations are classified further. (L.L.S.)

ALGEBRAIC EXPRESSIONS. An algebraic expression is a symbol or combination of symbols that represents a number. If the expression consists of two or more parts connected by plus and minus signs, each of these parts with the sign preceding it is called a term. A monomial is an algebraic expression consisting of only one term, a polynomial is one consisting of more than one term; a binomial and a trinomial are polynomials of two or three terms respectively.

If two or more numbers or number symbols are multiplied together, each of them is called a factor of the product. Any factor of a product may be called the coefficient of the remaining part. (L.L.S.)

ALGEBRAIC FUNCTIONS. An algebraic function is a **function** which involves the **variable** in only the operations of **addition, subtraction, multiplication, division,** raising to **powers** with constant rational exponents, and extraction of roots (**involution**), a limited number of times.

An algebraic function may also be defined as a function $y = \phi(x)$ which satisfies an equation of the form $f(x,y) = 0$, where $f(x,y)$ is a **polynomial** in x and y.

Algebraic functions are classified into **rational functions** and irrational **functions**, and **power functions**, rational functions are further classified into sub-classes (L L S)

ALGEBRAIC NUMBERS. An algebraic number is a **number** which satisfies a **polynomial equation** in one variable with integral coefficients (I L S)

ALGEBRAIC OPERATIONS. Algebra is concerned with **numbers** and with various operations with numbers The fundamental operations of algebra are **addition, subtraction, multiplication** and **division** Two other derived operations are **evolution** (raising to a power), and **involution** (extraction of roots) (L I S)

ALGOL. Algol (β **Persei**) is one of the first **variable stars** to be recognized as such The first scientific notice of this variability was made by Montanari in 1670, but it is quite evident that the changes in the light of this star were noticed long before this time In fact, the very name Algol, which signifies "Demon star," was probably assigned to the star because of its peculiar behavior **Astrologically,** Algol was considered the most unfortunate star in the heavens

Algol is an **eclipsing binary** and is the first star of this type to be explained Because of its great brightness it has been extensively observed with all types of stellar **photometers** and the characteristics of its **light curve** are known with great precision Algol is also a **spectroscopic binary,** and, from the solution of the **orbital elements** from the light variability as well as from the spectroscopic data, the physical characteristics of the component parts may be determined (W K G)

ALIDADE Plane Table.

ALIENIST A specialist trained in neurology and psychiatry who treats mental diseases (R S M)

ALIMENTARY TRACT. The structures through which nourishment pass during the process of digestion and elimination This includes the mouth, pharynx, esophagus, stomach, the small intestine, which includes **duodenum, jejunum,** and **ileum,** and the large intestine, which includes the **cecum,** colon, rectum and **anus** (See also **Anatomy; Digestive System.**) (R S M)

ALIZARINE Dyes.

ALKALI RESERVE. Acidosis.

ALKALI ROCKS. Igneous rocks which contain a relatively high amount of alkalis in the form of soda **amphiboles,** soda **pyroxenes,** or **felspathoids,** are said to be alkaline, or alkalic Igneous rocks in which the proportions of both lime and alkalis are high, as combined in the minerals, **feldspar, hornblende,** and **augite,** are said to be calc-alkali (R M F)

ALKALIS. Acids, Bases, and Salts.

ALKALOIDS. Alkaloids are types of organic bases They are generally colorless, odorless solids, of definite melting point, which decompose upon attempted distillation, of bitter taste (poisonous), insoluble in water, soluble in alcohol, ether, chloroform, carbon tetrachloride, amyl alcohol, benzene Alkaloids are generally related to nitrogen ring compounds, e g, **pyridine, quinoline, isoquinoline, pyrrole, pyrrolidine, purine,** and are found in certain plants (*Papaveraceae, Leguminosae, Ranunculaceae, Solenaceae, Rubiaceae* (cinchona) They are powerful poisons, many possess high medicinal value, some are habit-forming Alkaloids of plants are usually found as alkaloid salts of **carboxylic acids,** e g, of malic, citric, oxalic, succinic, quinic (**cinchona** alkaloids), meconic acid, (**opium** alkaloids), in all parts of the given plant, but are generally accumulated in the fruit, seeds or bark Alkaloids react as bases to form salts (especially used for crystallization purposes are **hydrochlorides, sulfates, oxalates**), which are generally soluble in water or alcohol, insoluble in **ether, chloroform, carbon tetrachloride, amyl alcohol.** Alkaloid salts unite with **mercury, gold,** and **platinum** chlorides Free alkaloids lack characteristic color reactions but react with certain reagents, as follows, with, (1) **iodine** in **potassium** iodide solution, forming chocolate brown precipitate, (2) **mercuric** iodide in potassium iodide solution (potassium mercuriiodide), forming precipitate, (3) potassium **bismuth** iodide, forming orange-red precipitate, (4) **bromine**-saturated **hydrobromic acid** concentrated, forming yellow precipitate, (5) **tannic** acid, forming precipitate, (6) phosphomolybdic acid, forming precipitate, (7) phosphotungstic acid, forming precipitate, (8) auric chloride, forming crystalline precipitate of characteristic melting point, (9) platinic chloride, forming crystalline precipitate of characteristic melting point, (10) **picric acid,** forming precipitate, (11) **perchloric acid,** forming precipitate

It should be noted that these reagents precipitate some organic substances other than alkaloids The majority of the free alkaloids are optically active, and laevorotatory, but an appreciable number are inactive or dextrorotatory Alkaloid salt solutions are often different in sign and value of rotatory power from the free alkaloid, and the value is sometimes affected by the nature of the solvent and by the concentration Alkaloids are usually extracted from the plant material by hydrochloric or sulfuric acid This extract is then made slightly alkaline, thus precipitating the free alkaloid base, which may be separated by filtration and purified by further crystallization It was suggested by Pictet as early as 1905 that the methylation (formation of $-CH_3$ group) of hydroxyl ($-OH$) or amino ($-NH_2$) groups, occurs in the plant by means of formaldehyde (HCHO), followed by rearrangement in which the methyl group enters the ring, thus increasing the ring by one additional carbon

Pyrrole, by formaldehyde, into 1-methylpyrrole, rearranging into pyridine

Indole, by formaldehyde into 1-methylindole, rearranging into quinoline

More recently Robinson conducted the reaction of formaldehyde with 2,5-diaminopentanoic acid (CH_2NH_2 CH_2 CH_2 $CHNH_2$ COOH) obtaining 1-methyl-2-hydroxypyrrolidine plus ammonia plus carbon dioxide. (See table, p 45) (R K S)

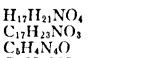
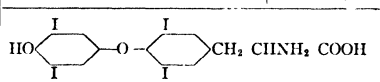
ALKALOSIS. Acidosis.

ALKYL. Radical of aliphatic hydrocarbon

ALL-OR-NONE LAW. A principle of reaction in living matter under which a structure responds to a stimulus to the maximum degree possible in its existing physiological state, regardless of the strength of the inciting stimulus Thus any stimulus capable of exciting a nerve cell at a given moment will arouse the same degree of activity in that cell First demonstrated by Bowditch for heart muscle, this principle has since been found applicable to single neurons and single muscle fibers, when stimuli similar to those occurring in nature are applied (A W L)

ALLANITE. Allanite is a rather rare **monoclinic** mineral of somewhat variable but quite complex chemical composition, perhaps represented satisfactorily by the

SELECTED REPRESENTATIVE ALKALOIDS

	Alkaloid	Formula	Melting Point °C	Boiling Point °C
1	Aconine	$C_{25}H_{39}NO_9$	132	
2	Aconitine	$C_{34}H_{47}NO_{11}$	196	
*3	Adenine	$C_5H_5N_5$	220 subl	
4	Adrenaline (active principle of the hormone of the adrenal gland)	$C_9H_{13}NO_3$		
5	Allantoin	$C_4H_6N_4O_3$	235	
6	Apomorphine	$C_{17}H_{17}NO_2$	170 decom	
7	Atropine (hydrolyzes to tropine plus tropic acid)	$C_{17}H_{23}NO_3$	118 subl	
8	Belladonnine	$C_{17}H_{21}NO_2$		
9	Brucine	$C_{23}H_{26}N_2O_4\ 4H_2O$	105 178 anhyd	
*10	Caffeine (theine) . .	$C_8H_{10}N_4O_2\ H_2O$	235 anhyd 180 subl.	
11	Cinchonidine	$C_{19}H_{22}N_2O$	207	
12	Cinchonine	$C_{19}H_{22}N_2O$	264	
13	Cocaine	$C_{17}H_{21}NO_4$	98	
14	Codeine	$C_{18}H_{21}NO_3\ H_2O$	155 anhyd	
15	Conine (2-normal propylpiperidine)	$C_3H_7\ C_5H_{10}N$	2 5	167
16	Ephedrine (1-phenyl-2-methylaminopropanol-1)	$C_{10}H_{15}NO$	40	225 appr decom
17	Ergotimine	$C_{35}H_{39}N_5O_5$	229	
18	Ergotoxine	$C_{35}H_{41}N_5O_6$	163	
*19	Guanine	$C_5H_5N_5O$	decom	
20	Homoatropine	$C_{16}H_{21}NO_3$	95 99	
21	Hydrastine	$C_{21}H_{21}NO_6$	235	
22	Hydrastinine	$C_{11}H_{13}NO_2$	116	
23	Hydroquinine	$C_{20}H_{26}N_2O_2\ 2H_2O$	172 anhyd	
24	Para-hydroxyphenylethylamine (active principle of ergot)		160	
25	Hyoscine (scopolamine)	$H_{17}H_{21}NO_4$	50 55	
26	Hyoscyamine	$C_{17}H_{23}NO_3$	107	
*27	Hypoxanthine	$C_5H_4N_4O$	150 decom	
28	Laudanine	$C_{20}H_{25}NO_4$	166	
29	Lupanine	$C_{15}H_{24}N_2O$	99	
30	Lupinine	$C_{10}H_{19}NO$	69	
31	Morphine	$C_{17}H_{19}NO_3\ H_2O$	230 decom	
32	Narcotine	$C_{22}H_{23}NO_7$	176	
33	Nicotine (1-methyl-2-beta-pyridylpyrrolidine)	$C_{10}H_{14}N_2$		246 (730 mm)
34	Novocaine (diethylaminoethyl ester of para-aminobenzoic acid hydrochloride)	$C_{13}H_{20}N_2O_2\ HCl$	156	
35	Papaverine	$C_{20}H_{21}NO_4$	147	
36	Paraconine	$C_8H_{15}N$		169
	Pilocarpine	$C_{11}H_{16}N_2O_2$	34	
37.	Piperine (hydrolyzes to piperidine plus piperic acid)	$C_{17}H_{19}NO_3$	129	
38	Protopine	$C_{20}H_{19}NO_5$	208	
39	Pseudoaconitine	$C_{36}H_{51}NO_{12}$	211	
40	Pseudoephedrine	$C_{10}H_{15}NO$	116	
41	Pseudomorphine	$C_{34}H_{36}N_2O_6\ 3H_2O$	decom	
42	Pseudotropine	$C_8H_{15}NO$	108	
43	Quinine	$C_{20}H_{24}N_2O_2$	175 anhyd	
44	Solanine (a glucoside)	$C_{32}H_{51}NO_{11}$	244 -250	
45	Strychnine	$C_{21}H_{22}N_2O_2$	268	
46	Thebaine (paramorphine)	$C_{19}H_{21}NO_3$	193	
47	Thebaine iso	$C_{19}H_{21}NO_3$	203	
*48	Theobromine	$C_7H_8N_4O_2$	290 subl	
*49	Theophylline	$C_7H_8N_4O_2\ H_2O$	269 272	
50	Thyroxine (present in the hormone of the thyroid gland)			
51	Tropacocaine	$C_{15}H_{19}NO_2$	49	
52	Tropinone (tropanone)	$C_8H_{13}NO$	41	224
53	Tropine ("tropanol")	$C_8H_{15}NO$	63	
54	Veratrine	$C_{37}H_{53}NO_{11}$	180	
*55	Xanthine	$C_5H_4N_4O_2\ H_2O$	150 decom	

(R K S)

* See **Purine and Uric Acid Compounds**

formula $Ca_2(Al,Ce,Fe)_3(Al\,OH)(SiO_4)_3$. The color of the fresh mineral is black but it is usually brown or yellowish with a coating of some alteration product, often the altered crystals have the appearance of small rusty nails It occurs characteristically in plutonic rocks like **granite, syenite** or **diorite** and is found in large masses in **pegmatites.** Localities in the United States are Essex and Orange Counties, New York, Franklin, New Jersey, Amherst County, Virginia, and Llano County, Texas The slender prismatic crystals are sometimes called orthite Allanite was named for its discoverer, T Allan Orthite was so named from the Greek word meaning straight, in reference to the straight prisms, a common habit of this mineral (E S C S)

ALLANTOIN. Alkaloids.

ALLANTOIS. A sac-like outgrowth of the hind gut of the **embryo** found only in **reptiles, birds** and **mammals.** In reptiles and birds it serves as a respiratory organ and receives waste matter, and in mammals it forms part of the **placenta** through which all interchange with the blood of the mother during embryonic development is carried out (A W L)

ALLELOMORPH. In Mendelian inheritance (see **Heredity** and **Evolution**), contrasting pairs of characters, as tall and dwarf, are known as allelomorphs (R M W)

ALLERGY. The state of exaggerated susceptibility to a substance which is harmless in similar or greater amounts to most individuals A person exhibiting this is said to be allergic to the substance causing the reaction These substances are usually of **protein** nature, although physical agents such as heat, cold, and light can provoke an allergic response The principal diseases of allergy are serum disease, serum accidents, **hay-fever, asthma, angioneurotic edema,** and **hives.** (R S M)

ALLIGATOR. Reptilia, Crocodilia A large freshwater **reptile.** Two species are known, one in China, *Alligator sinensis*, and the other, *A mississippiensis*, in the southern United States The American alligator, larger of the two, reaches a length of sixteen feet and a weight of 500 pounds It has been hunted to some extent for its skin, which makes durable leather (A W L)

ALLIGATOR PEAR. Avocado.

ALLIUM. Liliaceae A large genus whose species are found widely Some seventy-five species are found in North America, especially in the western states All are bulbous plants with flat or tubular leaves, and with spherical heads or umbels of variously colored flowers Particularly important cultivated species are the onion, *Allium Cepa*, leek, *Allium Porrum*, garlic, *Allium ursinum;* and chives, *Allium Schoenoprasum* One European species now extensively introduced in the United States is the field garlic, *Allium vineale*, which (if eaten by cows) noticeably flavors milk and butter (R M W)

ALLOCHTHONOUS. A term proposed by Gumbel in 1888 for **sedimentary** rocks whose constituents have been transported and deposited at some distance from their place of origin The bulk of the sedimentary rocks are of this type (R M F)

ALLOTRIOMORPHIC. A term proposed by Rosenbusch in 1887 for minerals in **igneous** rocks which are not bounded by their typical **crystal** faces Such minerals are said to be anhedral (R M F)

ALLOTROPES. See **Chemical Composition.**

ALLOYS. An alloy is a substance having metallic properties, consisting of two or more metallic **elements,** or of metallic and non-metallic elements, which are **miscible** with each other when molten, and have not separated into distinct layers when solid For a simple binary alloy (2 elements only), there are, apart from the formation of definite inter-metallic compounds, two opposite processes of solidification, plus their intermediate combinations

The constitution of the solidified alloy is often quite complex It may be homogeneous or very inhomogeneous, consist of a uniform mixture of microscopic crystals or may be partially separated into layers The formation of chemical compounds between the component metals complicates the study of alloy constitution The science of alloys is called metallography The method of attack of this science is through 1 Thermal analysis (study of the heat transformations of alloy on cooling), 2 Microscopic analysis (etching of the polished metal surface with chemicals and investigating the etch figures with a microscope), 3 **X-ray** analysis of the crystal structure, 4 Investigation of electrical, magnetic and mechanical properties These studies give information as to the state of the component metals in the alloys at various temperatures and permit the construction of phase diagrams

The properties of a metal are in general appreciably changed by the addition of another metal and these changes are often of great industrial importance The melting point, the formation of gas-bubble pockets, the hardness, the tensile strength, ductility, elastic limit, thermal expansion, electrical and magnetic properties are all changed by alloy formation In the case of **steel,** the commonly used alloying elements are **manganese, silicon, nickel, chromium, molybdenum, vanadium,** and **tungsten.** The effect of manganese in steel is to increase strength, and resistance to wear Steel containing 12–14% manganese is so hard and tough that it is used for railway crossings, grinding machines, safes, and the jaws of rock crushers The effect of silicon in steel is to impart magnetic properties that make the alloy suitable for use in electrical machinery, e g , in the magnetic circuits of transformers Silicon also increases resistance to corrosion "Duriron" is a steel containing 12–14% silicon which is used for chemical apparatus The effect of chromium in steel is also to impart resistance to corrosion, and to increase hardness Thus, chromium is used in the stainless steel of commerce, and steel containing 2–14% chromium is fabricated into cutting tools, files, projectiles, etc The effect of nickel in steel is to increase hardness and tensile strength Thus, steel containing 3–4% nickel is used in automobiles for crank shafts, gears, etc Larger proportions of nickel give remarkable magnetic properties, for example, permalloy, which contains 80% nickel, is widely used in telegraph cables and other electrical work Invar is a steel containing 36% nickel, which has a remarkably low coefficient of thermal expansion, and is used for measuring tapes and instrument scales Steel containing both nickel and chromium (1–4% nickel and up to 2% chromium) possesses exceptional hardness combined with great tensile strength It is used for armor plate Steels containing vanadium and chromium are well suited for forging Thus, wrenches are commonly made from a steel of this composition Moreover, frames and axles of automobiles are commonly made from a chrome-vanadium steel (up to 1% vanadium and up to 10% chromium) Chrome-molybdenum steels can readily be fabricated by welding They have very high strength, good resistance to shock, and their physical properties are radically improved by heat treatment Steel containing 6–7% molybdenum is used for high-speed cutting tools, another steel commonly used for this purpose contains 10–25% tungsten and 2–10% chromium A steel containing 70% cerium is used for cigarette lighters because it emits a spark when struck

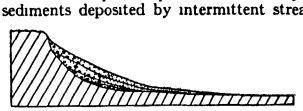
There are a great many alloys which are characterized as non-ferrous, that is, they contain no iron A few representative alloys of this character are listed below, (In several instances, their composition may vary somewhat from the figures given):

NAME OF ALLOY	COMPOSITION
Brass	Chiefly copper and zinc (copper predominating)
Bronze	Chiefly copper and tin (copper predominating)
Gunmetal	Copper 90%, tin 10%
Speculum metal	Copper 67%, tin 33%
Admiralty metal	Copper 70%, zinc 29%, tin 1%
Phosphor bronze	Copper 95%, tin 5%, phosphorus, trace
Monel metal	Copper 32%, nickel 68%
Nickel silver	Copper 64%, nickel 10%, zinc 26%
Duralumin	Aluminum 95%, copper 4%, manganese ½%, magnesium ½%
Babbitt metal	Tin 88 9%, copper 3 7%, antimony 7 4%
Wood's metal (Fusible)	Lead 26 7%, bismuth 50%, tin 13 3%, cadmium 10%
Stellite	Cobalt 50%, chromium 30%, tungsten 15%, balance is iron, carbon, manganese, and silicon
German silver	Copper 50%, zinc 20%, nickel 30%
Solder	An alloy of lead and tin
Amalgam	Any alloy of a metal with mercury

(F T M, R K S)

ALLSPICE. *Pimenta officinalis* Myrtaceae Allspice is the dried fruit of a small tree native in the West Indies and Central America The tree grows to a height of thirty or forty feet, has leathery leaves, fragrant with the oil they contain, and small white flowers borne in axillary cymes (See **Flower**) The fruits contain one or two seeds Before they are ripe the fruits are gathered, rapidly dried and marketed under the name allspice This name was given because early users thought the flavors of **cinnamon, cloves** and **nutmeg** were all found in this one spice It is used for flavoring cakes, puddings and pies (R M W)

ALLUVIAL FAN. Also termed subaerial delta Cone-shaped to delta-shaped deposits of coarsely graded **clastic** sediments deposited by intermittent streams that



Cross-section of an alluvial fan, or sub-aerial delta *Field. Laboratory Manual, Princeton University Press*

debouch from steep valleys onto a relatively gentle slope or plain Alluvial fans may extend for many miles, and confluent fans may eventually cover and fill relatively large intermontane basins. (R M F)

ALLUVIUM. A general term used to designate the sand, silt and mud deposited by a stream, along its banks or upon its **floodplain,** during periods of high water The word is derived from the Latin *ad,* to, and *luo,* wash When alluvium is relatively fine-textured and contains sufficient organic matter it forms **soil.** Some of the oldest and richest agricultural regions are the great **delta** areas, such as the Nile, Euphrates, etc (E S C S)

ALMAGEST. This is the name assigned by the Arabs to the great treatise on astronomy written by **Ptolemy** during the second century A D The very name Almagest, which is a hybrid combination of the Greek superlative (μεγιστη) with the Arabic article (al), indicates the importance of this work to the early astronomers

The Almagest is a collection of treatises on a variety of astronomical subjects In it is to be found the complete exposition of the Ptolemaic system for the structure of the universe Perhaps the best known section of the almagest is that dealing with the stars and the **constellations.** This section was taken from the works of Hipparchus and incorporated in the Almagest by Ptolemy with some improvements and additions In this catalogue we first find the brightnesses of the stars divided into six **magnitudes,** a system which has persisted down to modern times The positions of the stars given in the Almagest have proved of some little value in determining the constants of **precession** and also the **proper motions** of the stars (W K G)

ALMANAC. For the work of every person engaged in astronomy, whether as an astronomer in an observatory, a navigator on a ship at sea, or in the air, or a surveyor in the field, tables of certain astronomical data are absolutely indispensable Many, in fact most, of these tables change from year to year Among such material may be listed the positions of the **sun, moon,** and **planets** for every day in the year, accurate positions of **stars** to be used for determination of local **time,** tables for computing **precession,** nutation, **aberration,** etc Such material is published in almanacs which are computed and published several years in advance so that ships going off on long voyages can have the data at hand when they leave port

In addition to the ephemerides and data listed above, almanacs also contain descriptions of such phenomena as **eclipses** of the sun and moon, **occultations** of stars by the moon, eclipses and configurations of the **satellites** of **Jupiter,** etc

At the present time the computation of the material for the ephemerides of the different governments is a cooperative plan The nautical almanac offices of the United States, Great Britain, France, Germany, and Spain each do a share of the work An examination of the preface for the American Ephemeris and Nautical Almanac for any year will show how the work for that particular year was distributed (W K G)

ALMANDITE. Garnet.

ALMOND. *Prunus Amygdalus* Rosaceae A medium-sized tree with pale pink or white flowers, probably native in western Asia and northern Africa The fruit, a drupe (See **Fruit**), has the seed or kernel enclosed within a reticulated endocarp (See **Fruit**)

There are two kinds of almonds, bitter and sweet Bitter almonds, used for flavoring, contain a high percentage of **hydrocyanic acid.** The sweet almond yields almond oil, and is used as a dessert and for confections Almonds are grown incidentally in Mediterranean Europe, and in this country extensively in California (R M W)

ALOE. Liliaceae A large genus of plants characteristic of drier parts of Africa, especially the southern part Because of their ornamental appearance, with stiff habit and spiny-margined leaves, many of them are grown in cultivation The rather small yellow or red flowers are born in large masses Many species yield from the crushed leaves a purgative juice, which is called aloes, and which has been used extensively by eastern people (R M W)

ALOPECIA. Baldness—abnormal or natural loss of hair It may be partial or complete, transient or permanent It may be the natural accompaniment of old age or an indication of a **toxic** process in certain diseases It can affect all body hair (R S M)

ALPACA. Mammalia, Artiodactyla A South American domestic animal of the **camel** family, probably derived from the wild species known as the **guanaco,** *Lama huanaco* It is the source of a long wool of fine quality and its flesh is excellent Alpacas are kept at high altitudes in Bolivia and Peru (A W L)

ALPHA PARTICLES, OR ALPHA RAYS. Radioactive Changes.

ALPHERATZ. Alpheratz (α **Andromedae**) is a star which was formerly allotted to the **constellation** of **Pegasus** by the Arabs It is situated at the northeast corner of the great square of Pegasus In **astrology,** Alpheratz portends honor and riches to all born under its influence The star is a **spectroscopic binary** with a period of approximately one hundred days (W K G)

ALSTONITE. Bromlite.

ALTAIR. Altair (α **Aquilae**) forms with β and γ of the same **constellation** the well known line of stars which is a conspicuous feature of the early autumn sky and is sometimes referred to as the shaft of Aquila This star was ill omened in **astrology,** portending danger from reptiles (W K G)

ALTAZIMUTH. The altazimuth is the earliest type of mounting for astronomical telescopes It is an instrument so mounted that it may be rotated about a horizontal and a vertical axis (i e, rotated in **altitude** and **azimuth**) Perhaps the most familiar altazimuth instrument is the ordinary surveyor's transit or theodolite

The great advantage of this type of instrument is the ease with which it may be set up If the instrument has been properly constructed by the maker, the horizontal and vertical axes will be strictly perpendicular to each other, and all that is necessary to adjust the instrument for use is to level the horizontal axis of the instrument for all azimuths

The altazimuth instrument is used in the field for laying down azimuth lines and for determination of **latitude** and **longitude** by measuring altitudes of celestial objects A few large fixed altazimuth instruments are in use in observatories for accurate determination of **declinations** of stars but for this purpose the **meridian circle** is most commonly used

For ordinary astronomical observing the altazimuth instrument is not so convenient as the **equatorial** because of the fact that the diurnal motion of the celestial sphere is parallel to the equator rather than the horizon, with the result that the instrument has to be moved about both axes to follow the celestial objects (W K G)

ALTERNATING CURRENTS. Currents in which the electricity moves periodically back and forth The usual types of generator are so constructed that the electromotive forces induced in the armature conductors are periodically reversed, and unless the machine is provided with a commutator or other type of **rectifier,** this alternating voltage will be impressed upon the external circuit, giving rise to an alternating current (See **Electric Currents** and **Electric Circuits**)

The electromotive force may be represented by an equation of the type

$$E = E_0 \cos 2\pi nt, \qquad (1)$$

in which E_0 is the maximum value of the e m f ($t = 0$) and n is the frequency (Some writers use the sine instead of the cosine in Eq (1)) The resulting current follows a similar law, though it is in general out of phase with the e m f

When a harmonic voltage such as that represented by Eq (1) is impressed upon a circuit, the current is in general not derivable from the e m f by a simple application of **Ohm's law,** but depends upon several factors In the general case, account must be taken not only of the resistance R (ohms) of the circuit, but also of its *inductance* L (henrys), and its **capacitance** C (farads) (The circuit may include a series condenser, or may have enough **distributed capacitance** to have similar effect) The current at any instant t in a series circuit is then given by the equation

$$I = \frac{E_0}{\sqrt{R^2 + \left(2\pi nL - \frac{1}{2\pi nC}\right)^2}} \cos(2\pi nt - \varphi) \qquad (2)$$

Here φ is the "phase angle," the angular amount by which the phase of the e m f exceeds that of the current. Its value is given by

$$\tan \varphi = \frac{4\pi^2 n^2 LC - 1}{2\pi nRC} \qquad (3)$$

φ reduces to zero if $L = 0$ and C is infinite (a non-inductive, no-condenser circuit), or if the circuit and the frequency are so adjusted that $C = 1/4\pi^2 n^2 L$; in which latter case the circuit is in **resonance** with the e m f (as is a tuned radio circuit) Under either of these conditions also, the current is related to the e m f by Ohm's law, that is, $I = E/R$ Large inductances tend to make φ positive (current lags behind voltage), small capacitances tend to make it negative

The radical in Eq (2), which takes the place of R in Ohm's law and which equals R in the case of a resonant or a non-inductive, no-condenser circuit, is called the impedance of the circuit, while the parenthesis containing L and C represents the reactance

Since the power at any instant in a circuit of resistance R is E^2/R, the average power over a complete period is proportional to the average value of E^2 This may be denoted by E_v^2, in which E_v is the effective or virtual e m f, equal to $E_0/\sqrt{2} = 0.707\, E_0$ and to 1.11 times the average e m f Similar relations hold for effective, average, and maximum current The average power is not in general the product of the effective voltage and the effective current, $\frac{1}{2}E_0 I_0$, (the apparent power), as it would be in a non-reactive circuit, but is equal to

$$P = \tfrac{1}{2} E_0 I_0 \cos \varphi, \qquad (4)$$

in which cos φ is called the "power factor" The actual power is given by Eq (4) in **watts,** as usual, while the apparent power is rated in "volt amperes" (effective volts × effective amperes) See also **Polyphase Currents** and **Transients.** (L D W)

ALTERNATING CURRENT CIRCUITS. The **alternating current** circuit is that type which carries electrical current which rapidly reverses in direction of flow The major portion of **electrical circuits** are now alternating current, although at first direct current was a formidable contender Alternating current generation has received great impetus because of the simple way in which it can be changed in voltage This is of great advantage in transmitting electrical energy over long distances, since the cost of transmission lines decreases when the current carried is at high voltages The advantages of the induction **motor** are also a point in favor of alternating current, but alternating current is not without defect, since **inductance** and **capacitance,** factors unknown to direct current circuits, are present The essence of alternating current can be simply pictured by a curve showing the relationship between **voltage** and time Such a pictorial representation is seen

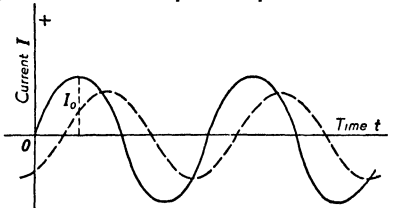


Figure 1. Current Time curves for circuits without reactance (full line), and with reactance (dotted)

in Figure 1. The points on the curve above the time axis represent voltage pressure in one direction along the conductor, and below the line, voltage pressure in the opposite direction. An ideal alternating current gen-

erator would produce an output which would be represented by the *a* part of Figure 2, but **harmonics** of this fundamental wave are usually present, and they modify

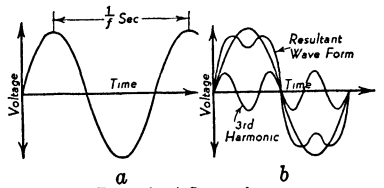


Figure 2 A C wave forms

the wave form Figure 2, *b*, shows the resultant wave form as produced by a third harmonic Similar wave forms would be observed in the current The effective value of an alternating current (that is, the average value which would be used in the same way as the value of a direct current in amperes), is that current which would give the same heating effect as a direct current of the same magnitude Unless otherwise specified, the numerical value of an alternating current refers, not to the magnitude of its peak, but to the effective value, sometimes called root-mean-square current In the case of the ideal sine wave, the root-mean-square equals the maximum current divided by $\sqrt{2}$

The frequency of an alternating current circuit is the number of complete alternations per second Sixty cycles per second is becoming the standard frequency (f) in the United States The sine wave of Figure 2 could be formed by the projection upon a time axis of the end of a **vector** rotating at $2\pi n$ radians per second In a purely resistive circuit, the current and voltage are in phase, that is, the rotating current **vector** coincides with the voltage vector, and the peaks of current occur simultaneously with the peaks of voltage The current lags the voltage in time sequence if the circuit contains inductance, and leads it if the circuit contains capacitance This lag or lead will also be introduced if the current vector is displaced from the voltage vector by a certain

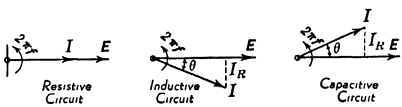


Figure 3 Voltage Current relations in A C circuits

angle θ, as shown in Figure 3 The component of current that is actually in phase with the voltage gives the direct **power,** while the component perpendicular to the voltage gives "wattless," or reactive, power It will be noted that the smaller the angle θ, the less the reactive, and the more the "active," power, also, that inductance and capacitance displace the current vector in opposite directions from the voltage vector Electrical power is always the voltage times the current that is in phase with it As seen in Figure 3, this current is $I \cos \theta$, and thus power equals $EI \cos \theta$ The $\cos \theta$ is an important characteristic of alternating current circuits, and is called the power factor Series and parallel arrangements of alternating current circuits are somewhat more difficult to solve than in direct current circuits, because they may contain inductance and capacitance, which necessitates the use of impedance as well as resistance in obtaining the electrical characteristics of the circuit The basic equations and quantities for the solution of alternating current series and parallels are given herewith.

$E = IZ,$
Z = impedance = $\sqrt{R^2 + X^2}$ (ohms)
X = reactance = $X_L - X_C$

X_L = inductance = $2\pi nL$ (L in henries)
X_c = capacitance = $\frac{1}{2\pi nC}$ (C in farads)

In series circuits

$R = R_1 + R_2 + R_3$
$X = X_1 + X_2 + X_3$

In parallel circuits conductance and susceptance are used.

G = conductance = R/Z_2
B = susceptance = X/Z^2
Y = admittance = $1/Z = \sqrt{G^2 + B^2}$
$G = G_1 + G_2 + G_3 \ldots$
$B = B_1 + B_2 + B_3 \ldots$

Ordinarily, the alternating current generator (or **alternator**) is wound with three armature circuits spaced 120 electrical degrees apart This has become common practice because of the advantages of polyphase generation, transmission, and utilization, compared to single phase The superiority of three phase power is founded on the following facts

1 Three phase transmission is more economical than single phase
2 The equipment is smaller and less complicated than single phase
3 The power fluctuates between narrower limits in a three phase circuit The power is $\sqrt{3}$ or 1 732 times greater than in the single phase circuit carrying the same line voltage and current (F T M)

ALTERNATING CURRENT MOTOR. Motors.

ALTERNATION OF GENERATIONS. In the life history of many **Thallophytes** and of all plants in the divisions above the Thallophytes, there are two distinct phases in the life cycle which regularly alternate In the **algae,** the alternating individuals are frequently indistinguishable until fruiting occurs, when it becomes apparent that one plant produces asexual **zoospores** which grow directly to form new plants, while the other plant (of the alternate generation) produces **gametes,** or sexual **cells** These gametes fuse in pairs before growing to form new plants Since two cells, and also their nuclei, fuse, it is obvious that there is a doubling of the nuclear substance The plant having this double nuclear nature is called diploid, while the other generation is called haploid In a mature diploid plant, there occurs at the time of spore formation a special type of division, **meiosis,** or reduction division, in which the double nuclear condition is reduced While many algae have the two generations of similar appearance, others, notably the brown algae known as kelps, show a striking dissimilarity The asexual plants are the familiar large brown seaweeds so frequently cast up on our coasts, while the sexual plants are minute and rarely seen In kelps, and many other plants, these sexual plants are of two sorts, one, the male, producing minute biciliate sperms, the other, the female, forming oogonia with which the sperms unite The alternate generations in the higher plants are separately described under each division (**Bryophytes, Pteridophytes,** and **Spermatophytes**) Among animals, alternation of generations is well marked in the **hydrozoan coelenterates,** where the **polyp** of many species is an asexual form capable only of securing nourishment, defending the colony, and producing new individuals by budding or some similar asexual process The **medusa** is a sexual form produced in this manner It gives rise to **germ cells** and through its sexual reproduction new individuals are formed which constitute another asexual generation (R M W, A W L)

ALTERNATOR. An **electromotive force** is generated in a conductor when it is moved so as to cut the lines of force between the poles of a magnet The elementary principle of a simple two pole, single phase alternator is shown in Figure 1 When the magnet revolves it will carry with it lines of force which will cut

the conductor, which is a wire loop embedded in the stationary portion called the armature, and will generate an alternating current

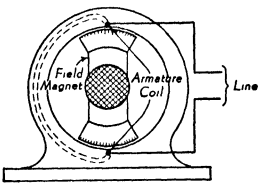


Figure 1 Elementary alternator

This elementary principle must be expanded in several directions, if a practical generator of alternating current is to be had First, the rotating part, or rotor, must have magnetic strength in excess of that which could be obtained from a simple permanent magnet In other words, the poles must be formed by electromagnets whose energy, in the form of direct current, must be carried to the rotor through slip ring connections The rotor is called the field, and the current it uses is called the field current Occasionally as few as two poles are used, but since this requires a very high rotative speed, four or more poles are much more frequently employed The stationary part, called the stator, or armature, usually has three sets of overlapping coils, connected in three separate circuits These three circuits, or phases, are usually connected in one or the other ways shown in Figure 2 The Y connection is preferred be-

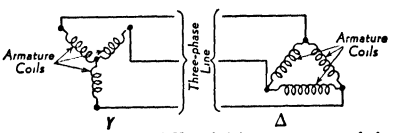


Figure 2 Comparison of Y and delta connections of three phase alternator windings

cause of the usefulness of the neutral point, and the fact that the line voltage is $\sqrt{3}$ times the phase voltage, whereas it is only equal to the phase voltage in Δ connection The neutral point is connected to the fourth wire of a four wire, three phase system, and left unconnected, or grounded, in the three wire system Many advantages are realized by making the rotating part the **field,** and the stationary part the **armature.** The alternating current may be generated at very high voltages because it is not necessary to commutate it The armature conductors can be very rigidly braced in position, and may be much better disposed than if they were required to be in the rotor

Engine and hydraulic turbine driven alternators are in the slow speed class, and are characterized by large diameter and short length The steam turbine driven alternator is a high speed machine having a length much larger than its diameter Standard speeds of turbine driven alternators range from 1200 to 3600 revolutions per minute, with 1800 revolutions per minute very common practice

Basically, the alternator is a device for converting mechanical into electrical energy While it is able to do this with a high degree of efficiency, it does suffer the following losses

1 Friction and windage from bearings and fan action of the rotor
2 Core loss, which is the result of **eddy currents** and **hysteresis** in the iron **core.**
3 Resistance heating loss in the armature and field conductors
4 Resistance loss of the field **rheostat.**

Practically all generator losses appear as heat in and about the windings, and to maintain these at a safe working temperature, a cooling medium must be employed Air has been the medium generally used. The rotor may or may not be able to produce its own fan action, depending on the size, speed, and construction of the rotor Ventilating air frequently has to be brought through a duct and discharged through the alternator To supply the direct current for the field, a source of direct current at 110 or 220 volts is necessary. This is delivered from a small direct current generator called the exciter The exciter may be driven from an extension of the alternator shaft, or it may be driven by some independent means, such as motor or engine

When alternators are operated in **parallel,** the division of load between them is not accomplished by changing the generated voltage, as in direct current generators, but by changing the rotative speed through the adjustment of the engine or turbine **governor** Before being paralleled, two alternators must have the same phase sequence and frequency Their voltages must be equal, and in phase, that is, with the peaks of wave forms coincident in time and direction (F T M)

ALTITUDE. Altitude is a synonymous term for height used in a geographical sense The altitude of a celestial object is the coordinate in the **horizontal** system of **spherical coordinates** measured in the plane of the vertical circle through the object from the **horizon** to the object Altitude is probably the most frequently measured of all celestial co-ordinates and is universally used for the determination of terrestrial **latitude** and **longitude,** and frequently for determination of terrestrial **azimuth,** and celestial **declination**

On land the **altazimuth** instrument is frequently used for measuring altitude, and an altitude observed with this instrument must be corrected for **astronomical refraction** and for **geocentric parallax.** At sea, where the use of an altazimuth instrument adjusted to the horizon is impossible, the observation of altitude is made with the **sextant,** and, in addition to the above corrections, a correction for dip of the **horizon** must be applied

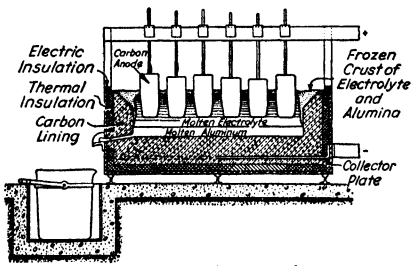
In case the altitude of an object presenting a finite disk (such as the sun, moon, or one of the larger planets), is desired, the altitude of either the upper or lower edge (limb) of the object is measured and the observation reduced to the center of the object by subtracting or adding the semidiameter (W K G)

ALUMINUM. Symbol. Al Atomic number· 13 Atomic weight 26 97 Density 2 70 Hardness. 3 Melting point 660° C Boiling point 1800° C No isotope, but of single atomic form 27

Aluminum is a silver-white metal, with a bluish tinge, capable of taking a high polish, ductile and malleable, a thin protective, transparent film of oxide is formed upon exposure to air, upon heating to 580° C in **oxygen,** burns with intense heat and light, soluble in **hydrochloric** acid, in **sulfuric acid** (of strength above 10%), and in concentrated or very dilute **nitric acid,** but made passive by other concentrations, insoluble in organic acids at room temperature, soluble in **sodium** hydroxide solution, forming sodium aluminate solution and **hydrogen** gas, reacts with dry **chlorine** upon heating to form aluminum chloride anhydrous Isolated by Wohler in 1827

Aluminum occurs abundantly in all ordinary rocks, except **limestone** and **sandstone,** is third in abundance of the elements in the earth's crust (8 1% of the solid crust), exceeded only by **oxygen** and **silicon,** with which two elements aluminum is generally found combined in nature, present in igneous rocks and clays as aluminosilicates, in the mineral **cryolite** in Greenland as sodium aluminum fluoride (Na_3AlF_6), in the minerals **corundum** and **emery,** the gems ruby and sapphire, as aluminum oxide (Al_2O_3), in the mineral bauxite in Southern France, the Guianas of South America, Arkansas, Georgia and Alabama of the United States as hydrated oxide ($Al_2O(OH)_4$); in the mineral **alunite** or alum stone in Utah as aluminum potassium sulfate ($Al_2(SO_4)_3 \cdot K_2SO_4 \cdot 4Al(OH)_3$).

Bauxite, the commercial source of aluminum metal, is treated to obtain pure aluminum oxide, and the oxide is electrolyzed from solution in fused cryolite. This method



Hall process for aluminum manufacture.

of producing aluminum metal was discovered independently by Hall in the United States and by Héroult in France in 1886, and has been the sole method since that time. In present day production and consumption of metals, aluminum stands fifth, and has shown a quantity increase in recent years greater than any other metal. Aluminum is largely used in articles of commerce and technology (1) where there is demanded lightness and strength, e.g., airplane, automobile, rail car, either pure or in alloy with silicon and another metal such as magnesium, (2) as electrical **conductor**, in competition with copper, (3) due to ease of workability and resistance to wear and corrosion, as cooking utensils, large and small containers, chemical apparatus, (4) for the production of local, very high temperature, or reduction of difficultly reducible oxides, e.g., aluminum plus **iron** oxide to form aluminum oxide glass, plus iron, and for iron oxide there may be substituted many other oxides, (5) for paint, when finely powdered.

Aluminum compounds are generally made starting with bauxite, which is reactive with acids and with bases. With acids,.e.g., sulfuric acid, any iron contained in the bauxite is dissolved along with the aluminum and silicon is left in the residue, whereas with bases, e.g., sodium hydroxide, any silicon is dissolved and iron left in the residue.

Acetate: aluminum acetate ($Al(C_2H_3O_2)_3$), white crystals, soluble, by reaction of aluminum hydroxide and **acetic acid** and then crystallizing. Used (1) as a mordant in dyeing and printing textiles, (2) in the manufacture of lakes, (3) for fireproofing fabrics, (4) for waterproofing cloth.

Alums: aluminum potassium sulfate, "alum" ($K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$), white crystals, soluble, by crystallizing a solution of aluminum sulfate and **potassium** sulfate; other alums may be prepared, (1) by substituting for potassium sulfate, **sodium**, or **ammonium** sulfate, (2) by substituting for aluminum sulfate, **chromium** or **ferric** sulfate. The alums, therefore, are mixed salts of the type shown above, and do not necessarily contain aluminum; anhydrous aluminum potassium sulfate, "burnt alum" ($K_2SO_4 \cdot Al_2(SO_4)_3$), is made by heating alum until water is removed.

Aluminates: sodium aluminate ($NaAlO_2$), white solid, soluble, (1) by reaction of aluminum hydroxide and sodium hydroxide solution, (2) by fusion of aluminum oxide and sodium carbonate; the solution of sodium aluminate is reactive with carbon dioxide to form aluminum hydroxide. Used as a mordant. See silicates below and **calcium aluminates**.

Alundum: see oxide (below).

Carbide: aluminum carbide (Al_4C_3), yellowish-green solid, by reaction of aluminum oxide and **carbon** in the **electric furnace**, reacts with water to yield **methane** gas and aluminum hydroxide.

Chlorides: aluminum chloride ($AlCl_3 \cdot 6H_2O$), white crystals, soluble, by reaction of aluminum hydroxide and **hydrochloric acid**, and then crystallizing; anhydrous aluminum chloride ($AlCl_3$), white powder, fumes in air, formed by reaction of dry aluminum oxide plus carbon heated with chlorine in the electric furnace, used as a reagent in **petroleum** refining and other organic reactions.

Fluoride: aluminum fluoride (AlF_3), white solid, soluble, by reaction of aluminum hydroxide plus **hydrofluoric acid** and then crystallizing ($2AlF_3 \cdot 7H_2O$), used in glass and porcelain ware.

Hydroxide: aluminum hydroxide ($Al(OH)_3$), white gelatinous precipitate, by reaction of soluble aluminum salt solution and an alkali hydroxide, carbonate or sulfide (sodium aluminate is formed with excess sodium hydroxide but no reaction with excess ammonium hydroxide), upon heating aluminum hydroxide the residue formed is aluminum oxide. Used as intermediate substance in transforming bauxite into pure aluminum oxide.

Nitrate: aluminum nitrate ($Al(NO_3)_3$), white crystals, soluble, by reaction of aluminum hydroxide and **nitric acid**, and then crystallizing.

Oleate: aluminum oleate ($Al(C_{18}H_{33}O_2)_3$), yellowish-white powder, by reaction of aluminum hydroxide, suspended in hot water, shaken with **oleic acid**, and then drying, the product is used (1) as a thickener for lubricating oils, (2) as a drier for paints and varnishes, (3) in waterproofing textiles, paper, leather.

Oxide: aluminum oxide, alumina (Al_2O_3), white solid, insoluble, melting point 2020° C., formed by heating aluminum hydroxide to decomposition; when bauxite is fused in the electric furnace and then cooled there results a very hard glass ("alundum"), used as an abrasive and heat refractory material. Aluminum oxide is the only oxide which reacts both in water medium and at fusion temperature, to form salts with both acids and alkalis.

Palmitate: aluminum palmitate ($Al(C_{15}H_{31}O_2)_3$), yellowish-white powder, by reaction of aluminum hydroxide, suspended in hot water, shaken with palmitic acid, and then drying, the product is used (1) as a thickener for lubricating oils, (2) as a drier for paints and varnishes, (3) in waterproofing textiles, paper, leather, (4) as a gloss for paper.

Silicates: many complex aluminosilicates or silicoaluminates are found in nature. Of these, clay in more or less pure form, pure clay, kaolinite, kaolin, china clay ($H_2Si_2Al_2O_8$ or $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) is of great importance. Clay is formed by the weathering of igneous rocks, and is used in the manufacture of bricks, pottery, porcelain and Portland cement. See **calcium aluminosilicates**; **Ceramics**; **Cement, Portland**.

Stearate: aluminum stearate ($Al(C_{18}H_{35}O_2)_3$), yellowish-white powder, by reaction of aluminum hydroxide suspended in hot water, shaken with **stearic acid**, and then drying the product, used (1) as a thickener for lubricating oils, (2) as a drier for paints and varnishes, (3) in waterproofing textiles, paper, leather, (4) as a gloss for paper.

Sulfate: aluminum sulfate ($Al_2(SO_4)_3$), white solid, soluble, by reaction of aluminum hydroxide and **sulfuric acid**, and then crystallizing, used (1) as a clarifying agent in water purification, (2) in baking powders, (3) as a mordant in dyeing, (4) in sizing paper, (5) as a precipitating agent in sewage disposal; aluminum potassium sulfate, see alums and alunite.

Sulfide: aluminum sulfide (Al_2S_3), white to grayish black solid, reactive with water to form aluminum hydroxide and **hydrogen sulfide**, formed by heating aluminum powder and sulfur to a high temperature.

Aluminum in solution of its salts is detected by the reaction (1) with ammonium salt of aurin tricarboxylic acid ("aluminon"), which yields a red precipitate persisting in ammonium hydroxide solution, (2) with alizarin red S, which yields a bright red precipitate persisting in acetic acid solution. (R.K.S.)

ALUMS. These are double salts having the general formula $M_2SO_4X_2(SO_4)_3 24H_2O$. M is any univalent **cat-**

ion and X any trivalent **cation**, e.g., sodium alum, ammonium alum, chrome alum. (See **Aluminum**). (R.K.S.)

ALUNITE or **ALUMSTONE.** The mineral alunite is a basic hydrous **sulfate** of **aluminum** and **potassium**; a variety called natroalunite is rich in **soda**. Alunite crystallizes in the **hexagonal** system and forms rhombohedrons with small angles, hence resembling cubes. It may be in fibrous or tabular forms, or massive. Hardness, 3.5–4.; specific gravity, 2.58–2.75; luster, vitreous to pearly; streak white; transparent to opaque; brittle; color, white to grayish or reddish.

Alunite is commonly associated with acid **lavas** due to the sulfuric vapors often present; it may occur around **fumaroles** or associated with **sulfide** ore bodies. It has been used as a source of potash. It is found in Czechoslovakia, Italy, France, and Mexico. In the United States alunite is found in Colorado, Nevada, and Utah. (E.S.C.S.)

ALVEOLUS. 1. A minute sac-like chamber in a hollow organ, such as the air sacs of the lungs and the components of various glands. Its sac-like form distinguishes it from other chambers in which the walls are relatively thicker. 2. The cavity in the jaw in which the root of a tooth is fixed. (A.W.L.)

AMALGAM. An amalgam is an **alloy** of **mercury** with another metal. Usually amalgams are prepared by man, but there is a rare mineral, called amalgam, which is probably a mutual solid solution of silver and mercury, as the percentages of each vary to some extent. It crystallizes in the **isometric** system; hardness, 3.–3.5; specific gravity, 13.75–14.1; luster, metallic; color, silver white; streak the same, opaque.

Occurs in Bavaria, Czechoslovakia, France, Spain, Norway, Chile, and British Columbia. (E.S.C.S.)

AMANITA. **Agarics.**

AMARANTHS. A group of plants, including many coarse and obnoxious pigweeds. *Amarantus caudatus*, the familiar Love-lies-bleeding, and *A. hypochondriacus*, the Princess feather, are more attractive, widely planted garden annuals. (R.M.W.)

AMAZONITE. **Feldspar.**

AMAZONSTONE. **Feldspar.**

AMBER. Amber is a **fossil resin** which has been known since early times because of its property of acquiring an **electric charge** when rubbed. In modern times it has been used largely in the making of beads, cigarette holders, and trinkets. Its amorphous non-brittle nature permits it to be carved easily and to acquire a very smooth and attractive surface. Amber is soluble in various organic solvents, such as ethyl alcohol and ethyl ether.

It occurs in irregular masses showing a **conchoidal** fracture. Hardness 2.25; specific gravity, 1.09; luster, resinous; color, yellow to reddish or brownish; it may be cloudy. Some varieties will exhibit **fluorescence**. Amber is transparent to translucent, melts between 250° and 300° C.

Amber has been obtained for over 2000 years from the **lignite** bearing Tertiary **sandstones** on the coast of the Baltic Sea from Danzig to Memel, also Denmark, Sweden and the other Baltic countries. Sicily furnishes a brownish red amber that is fluorescent.

The association of amber with **lignite** or other fossil woods as well as the beautifully preserved insects that are occasionally in it is ample proof of its organic origin. (E.S.C.S., R.M.W.)

AMBERGRIS. A fragrant waxy substance formed in the intestine of the sperm whale and sometimes found floating in the sea. It is used in the manufacture of **perfumes**. (A.W.L.)

AMBLYGONITE. A rather rare compound of **fluorine**, **lithium**, **aluminum** and **phosphorus**. It crystallizes in the **triclinic** system, hardness 6, specific gravity 3.01–3.09, luster vitreous to greasy or pearly, color white to greenish, bluish, yellowish or greyish, streak white, translucent to sub-transparent.

Amblygonite occurs in **pegmatite** dikes and veins associated with other lithium minerals, is used as a source of lithium salts. Its name is derived from two Greek words meaning blunt and angle in reference to its cleavage angle of 75° 30′.

It is found in Saxony, France and Australia; and in the United States at Hebron, Paris, Greenwood, Rumford and Auburn, Maine; Branchville, Connecticut; Black Hills, South Dakota; and Pala, California. (E.S.C.S.)

AMBLYOPIA. Impairment of vision without organic disease of the **eye** proper. It may be due to **alcohols**—especially **methyl alcohol**, or various chemicals such as **arsenic** or **quinine**, etc. It can also be produced by toxins from various diseases as in **nephritis** or **uremic** poisoning. It may also indicate certain diseases of the optic nerve or of the brain. (R.S.M.)

AMBLYPODS. **Paleocene.**

AMBULACRAL FEET. **Tube feet.**

AMBULACRAL GROOVE. The groove along the lower or oral surface of the arm of a starfish, in which the tube feet are located. (A.W.L.)

AMBUSH BUG. Insecta, Hemiptera. Predacious **bugs** named from their habit of lying in wait for their prey in flowers where their colors conceal them. The most common species is *Phymata erosa*. (A.W.L.)

AMEIVA. Reptilia, Sauria. A **lizard** of Central and South America. The name is that of the genus, applied as a common name to the score of included species. (A.W.L.)

AMENORRHEA. Absence of normal menstrual flow. This occurs during pregnancy, and may occur during certain diseases and glandular disturbances. Castration, or removal of the **ovaries** or their radiation by **x-ray** or **radium**, and, of course, removal of the **uterus**, will also produce amenorrhea. (R.S.M.)

AMENT, OR CATKIN. An inflorescence composed of many flowers, aggregated into long, often tassel-like masses. The perianth (See **Flower**) is completely lacking, or may be present in a scale-like form. The flowers of willows (pussy-willows), poplars, alders, beeches, oaks and birches are familiar examples. Most of them are wind-pollinated flowers. (R.M.W.)

Flowers of willow, *Salix*. 1, pistillate catkin; 2, a single pistillate flower; 3, staminate catkin; 4, a single staminate flower.

AMERICAN MONKEY. Mammalia, Primates. Any **monkey** of the family Cebidae, restricted to the New World. They differ from the apes and monkeys of the Old World in the broader nose and have sometimes been included with the marmosets in a group Platyrhini, based on this character. (A.W.L.)

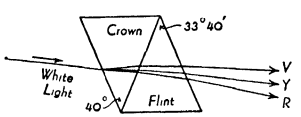
AMETHYST. Amethyst is purple or violet colored **quartz**, believed to be due to the admixture of a small amount of a **manganese** compound Its physical characters are the same as quartz An old superstition is that if worn as a gem it would cure intemperance Oriental amethysts are purple **corundum**

Amethysts are found at many localities, the Ural Mountains, India, Ceylon, Madagascar, Uruguay, Brazil, the Thunder Bay district of Lake Superior in Ontario, and Nova Scotia In the United States amethysts are found in Michigan, Virginia, North Carolina, Montana and Maine

The name amethyst is generally supposed to have been derived from the Greek word meaning not drunken Pliny suggested that the term was applied because the amethyst approaches but is not quite the equivalent of a wine color (E S C S)

AMICI PRISM. A direct-vision **prism**, that is, a prism combination by which a beam of light is dispersed into a spectrum without mean deviation Such prisms are sometimes used in direct-vision **spectroscopes.**

The principle will be clear from the following example Assume an inverted prism of crown glass with an angle



The deviation due to the crown glass prism is neutralized by that of the flint glass prism, for the middle of this spectrum (yellow) only

of 40°, used with an erect prism of flint glass Yellow sodium light (5893Å) is deviated by the crown glass prism through + 22° 32′ (upward) For the flint glass prism to produce an equal negative (downward) deviation it must have an angle of 33° 40′ (Each prism is supposedly set for minimum deviation) Together they produce no deviation for this wave length But if light of 7682A (red) is used, the deviation of the crown glass is + 22° 16′, while that of the flint is — 22° 10′, giving a net deviation of + 6′ And for the wave length 4047A (violet), the deviations are, respectively, + 23° 12′ and — 23° 44′, giving — 22′ There is thus, between the ends of the visible spectrum, a separation of 28′ Additional pairs of prisms may be used to increase the dispersion (L D W)

AMIDES Amines and Amides.

AMIDOL A developer used in photography It is 2–4 diamino **phenol**

AMIDOPYRINE. The chemical name for "pyramidon," often used as an **antipyretic** and to relieve pain—particularly of teeth, **joint** inflammations, headaches and in colds In certain individuals who are sensitive to the **drug**, it diminishes the number of white **blood** cells (R S M)

AMINES AND AMIDES. Amines are derivatives of **ammonia** in which there is replacement of one or more **hydrogens** of ammonia (NH_3) by an alkyl group, e g, methyl (—CH_3), ethyl (—C_2H_5) or an aryl group, e g, phenyl (—C_6H_5), naphthyl (—$C_{10}H_7$) Aniline ($C_6H_5NH_2$) is a familiar and important amine, used in the dyestuff industry See **Aniline,** and **Dyes and Dyeing** Mixed amines contain at least one alkyl and one aryl group, e g, methylaniline, methylphenylamine ($C_6H_5N\langle^{H}_{CH_3}$) When one, two, and three hydrogens are thus replaced, the resulting amines are known as primary, secondary, tertiary, respectively Methylaniline is, therefore, a secondary and dimethyl aniline a tertiary amine Quaternary ammonium compounds, e g, tetramethylammonium iodide, result from the reaction of a tertiary amine, e g, trimethylamine and an alkyl haloid, e g, methyl **iodide** The corresponding hydroxide, tetramethylammonium hydroxide is a strong base, of the order of strength of sodium hydroxide Amines have a characteristic odor, and many of the alkyl amines are soluble in water

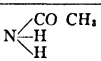
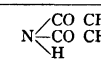
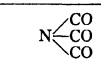
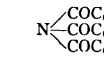
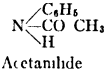
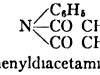
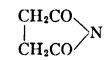
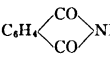
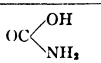
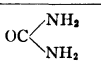
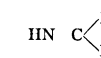
Amides are derivatives of ammonia in which there is replacement of one or more hydrogens of ammonia by an acyl group, e g, acetyl (—$COCH_3$), yielding acetamide (CH_3CONH_2), benzoyl (—COC_6H_5) yielding benzamide ($C_6H_5CONH_2$) When one, two and three hydrogens are thus replaced, the resulting amides are known as primary, secondary, tertiary, respectively Tribenzamide is, therefore, a tertiary amide

STRUCTURAL GROUPING OF AMINES AND AMIDES

Ammonia	Primary Amine	Secondary Amine	Tertiary Amine	Quaternary ammonium compound
NH_3	CH_3NH_2 Methylamine	$(CH_3)_2NH$ Dimethylamine	$(CH_3)_3N$ Trimethylamine	$(H_3C)_4NI$ Tetramethyl ammonium iodide
	$C_6H_5NH_2$ Aniline (phenylamine)	$(C_6H_5)_2NH$ Diphenylamine	$(C_6H_5)_3N$ Triphenylamine	
		$(C_6H_5)(CH_3)NH$ Methylphenylamine (Methylaniline)	$(C_6H_5)(CH_3)_2N$ Dimethylphenylamine (Dimethylaniline)	

(Continued on next page)

STRUCTURAL GROUPING OF AMINES AND AMIDES—*Continued*

	Primary Amide	Secondary Amide	Tertiary Amide	Quaternary ammonium compound
	 Acetamide	 Diacetamide	 Triacetamide	
	Benzamide	Dibenzamide	 Tribenzamide	
	 Acetanilide (phenylacetamide)	 Phenyldiacetamide		
	Diphenylacetamide	 Succinimide (butamide)		
		 Phthalimide		
Amides of carbonic acid				
 Carbamic acid (Ethyl esters called Urethanes)	 Urea	Semicarbazide	Guanidine (iminourea)	 Aminoguanidine
	Biuret			

The ionization constants of some nitrogen bases (also silver hydroxide), which constants indicate the relative strength of these bases, are as follows, arranged in decreasing basic strength

Base	Ionization Constant of Base
Piperidine	2×10^{-3}
Diethylamine	1×10^{-3}
Dipropylamine (normal)	1×10^{-3}
Dimethylamine	7×10^{-4}
Brucine	7×10^{-4}
Triethylamine	6×10^{-4}
Ethylamine	6×10^{-4}
Tripropylamine (normal)	6×10^{-4}
Tetramethylenediamine	5×10^{-4}
Methylamine	5×10^{-4}
Propylamine (normal)	5×10^{-4}
Methyldiethylamine	4×10^{-4}
Silver hydroxide	1×10^{-4}
Ethylenediamine	9×10^{-5}
Trimethylamine	7×10^{-5}
Diethylbenzylamine	4×10^{-5}
Benzylamine	2×10^{-5}
Ammonium hydroxide	2×10^{-5}
Dimethylbenzylamine	1×10^{-5}
Hydrazine	3×10^{-6}
Quinine	2×10^{-7}

Base	Ionization Constant of Base
Pyridine	2×10^{-9}
Para-toluidine	2×10^{-9}
Phenylhydrazine	2×10^{-9}
Quinoline	1×10^{-9}
Meta-toluidine	6×10^{-10}
Aniline	5×10^{-10}
Ortho-toluidine	3×10^{-10}
Ortho-phenylenediamine	3×10^{-10}
Beta-naphthylamine	2×10^{-10}
Alpha-naphthylamine	1×10^{-10}
Semicarbazide	3×10^{-11}
Methyl red	3×10^{-12}
Thiazole	3×10^{-13}
Anthranilic acid	1×10^{-12}
Theobromine	5×10^{-14}
Caffeine	4×10^{-14}
Acetanilide	4×10^{-14}
Urea	2×10^{-14}
Acetamide	3×10^{-15}
Propylcyanide (normal)	2×10^{-15}
Thiourea	1×10^{-15}

The ionization constants of some nitrogen acids (also carbonic and acetic acids) are given for comparison, which constants indicate the relative strength of these

acids, arranged in decreasing basic (increasing acidic) strength:

Acid	Ionization Constant of Acid	Acid	Ionization Constant of Acid
Hydrocyanic acid	7×10^{-10}	Acetic acid	2×10^{-5}
Cyanuric acid	2×10^{-7}	Hydrazoic acid	2×10^{-5}
Carbonic acid	3×10^{-7}	Barbituric acid	1×10^{-4}
Uric acid	2×10^{-6}	Hippuric acid	2×10^{-4}
Nicotinic acid	1×10^{-5}	Nitrous acid	4×10^{-4}
		Picric acid	2×10^{-1}

SELECTED REPRESENTATIVE AMINES

Primary Amines

	Amine	Formula	Melting Point °C	Boiling Point °C
1	Methylamine	CH_3NH_2	−93	−7
2	Ethylamine	$C_2H_5NH_2$	−81	17
3	Propylamine (normal)	$C_3H_7NH_2$	−83	50
4.	Propylamine (iso)	$C_3H_7NH_2$	−101	33
5	Butylamine (normal)	$C_4H_9NH_2$	−50	78
6	Butylamine (iso)	$C_4H_9NH_2$	−85	68
7	Amylamine (normal)	$C_5H_{11}NH_2$	−55	103
8	Amylamine (iso)	$C_5H_{11}NH_2$		95
9	Vinylamine	$CH_2{=}CHNH_2$		56
10	Allylamine	$CH_2{=}CHCH_2NH_2$		53
11	Aniline (phenylamine)	$C_6H_5NH_2$	−6	184
12	Benzylamine	$C_6H_5CH_2NH_2$		184
13	Para-phenylaniline (4-biphenylamine)	$C_6H_5{-}C_6H_4{-}NH_2$	51	302
14	Ortho-toluidine (2-methylaniline)	(2)$CH_3C_6H_4NH_2$(1)	−16	200
15	Meta-toluidine (3-methylaniline)	(3)$CH_3C_6H_4NH_2$(1).	−31	203
16.	Para-toluidine (4-methylaniline)	(4)$CH_3C_6H_4NH_2$(1)	44	200
17	Naphthylamine, alpha	$C_{10}H_7NH_2$(1)	50	301
18	Naphthylamine, beta	$C_{10}H_7NH_2$(2)	111	306
19	2,4,6-trimethylaniline (mesidine)	(2,4,6)$(CH_3)_3C_6H_2NH_2$(1)		229
20	Alpha-phenylethylamine	$C_6H_5CHNH_2CH_3$		187 (740 mm)
21	Beta-phenylethylamine	$C_6H_5CH_2CH_2NH_2$		198
22	Dimethylenediamine (ethylenediamine)	$\left.\begin{matrix}CH_2NH_2\\ \vert \\ CH_2NH_2\end{matrix}\right\}$	8	116
23	Trimethylenediamine	$(CH_2)_3\left\langle\begin{matrix}NH_2\\ NH_2\end{matrix}\right\}$		135 (740 mm.)
24	Tetramethylenediamine	$(CH_2)_4\left\langle\begin{matrix}NH_2\\ NH_2\end{matrix}\right.$		
25	Pentamenthylenediamine (cadaverine)	$(CH_2)_5\left\langle\begin{matrix}NH_2\\ NH_2\end{matrix}\right\}$	9	179
26.	Hexamethylenediamine	$(CH_2)_6\left\langle\begin{matrix}NH_2\\ NH_2\end{matrix}\right\}$	42	204
27	1,2-diaminopropane	$CH_3CHNH_2CH_2NH_2$		119
28	4,4′-diaminobiphenyl (benzidine, para-para-prime-diaminobiphenyl) (crystallized from boiling water)	(4′)$H_2NC_6H_4C_6H_4NH_2$(4)	218	200 (740 mm)
29.	Ortho-tolidine	$\left.\begin{matrix}(4')H_2N\rangle C_6H_3C_6H_3\langle NH_2(4)\\ (3')H_3C\langle\qquad\qquad\langle CH_3(3)\end{matrix}\right\}$	129	
30	Ortho-phenylenediamine	$C_6H_4(NH_2)_2$(1,2)	103	257
31	Meta-phenylenediamine	$C_6H_4(NH_2)_2$(1,3)	63	285
32	Para-phenylenediamine	$C_6H_4(NH_2)_2$(1,4)	140	267
33.	1,2,3-triaminobenzene	$C_6H_3(NH_2)_3$(1,2,3)	103	336
34	1,2,4-triaminobenzene	$C_6H_3(NH_2)_3$(1,2,4)	<100	340 appr.
35	Hexamethylenetetramine (urotropine)	$(CH_2)_6N_4$		
36	Ethanolamine ((beta-aminoethyl alcohol)	$NH_2CH_2CH_2OH$	171	

Secondary Amines

37	Dimethylamine	$(CH_3)_2NH$	−96	7
38	Diethylamine	$(C_2H_5)_2NH$	−39	55
39	Methylethylamine	$\begin{matrix}CH_3\\ C_2H_5\end{matrix}\rangle NH$		34
40	Dipropylamine (norm)	$(C_3H_7)_2NH$	−40	110
41.	Dipropylamine (iso)	$(C_3H_7)_2NH$		83 (743 mm.)
42	Dibutylamine (norm)	$(C_4H_9)_2NH$		159
43	Dibutylamine (iso)	$(C_4H_9)_2NH$		139
44	Diphenylamine	$(C_6H_5)_2NH$	53	302
45	Ortho-aminodiphenylamine	(2)$NH_2C_6H_4NHC_6H_5$	79	
46.	Para-aminodiphenylamine	(4)$NH_2C_6H_4NHC_6H_5$	66	
47.	Methylphenylamine (N-methylaniline)	$C_6H_5NHCH_3$	−57	195
48.	Ethylphenylamine ((N-ethylaniline)	$C_6H_5NHC_2H_5$	−64	204
49.	Propylphenylamine (norm) (N-normal-propylaniline)	$C_6H_5NHC_3H_7$		222

25000

(Continued on next page)

SELECTED REPRESENTATIVE AMINES—*Continued*

Secondary Amines

	Amine	Formula	Melting Point °C	Boiling Point °C
50	Propylphenylamine (iso) (N-iso-propylaniline)	$C_6H_5NHC_3H_7$		
51	Butylaniline (norm.) (N-normal-butylaniline)	$C_6H_5NHC_4H_9$		235 (720 mm)
52	Butylaniline (iso) (N-iso-butylaniline)	$C_6H_5NHC_4H_9$		231
53	Allylaniline (N-allylaniline)	$C_6H_5NHC_3H_5$		218 (735 mm)
54	Phenylbenzylamine (N-benzylaniline)	$C_6H_5 \atop C_6H_5CH_2 \rangle NH$	37	306
55	Benzalaniline (benzylideneaniline)	$C_6H_5CH{=}NC_6H_5$	56	300 appr
56	Dibenzylamine	$(C_6H_5CH_2)_2NH$	−26	270 (250 mm)
57	Diethanolamine (Iminoethyl alcohol)	$NH(CH_2CH_2OH)_2$	28	270 (748 mm)

Tertiary Amines

58	Trimethylamine	$(CH_3)_3N$	−124	3
59	Triethylamine	$(C_2H_5)_3N$	−115	89
60	Methyldiethylamine	$CH_3N(C_2H_5)_2$		66
61	Dimethylethylamine	$(CH_3)_2NC_2H_5$		37
62	Tripropylamine (norm.)	$(C_3H_7)_3N$	−93	156
63	Tripropylamine (iso)	$(C_3H_7)_3N$		
64	Tributylamine (norm.)	$(C_4H_9)_3N$		216
65	Tributylamine (iso)	$(C_4H_9)_3N$		190
66	Dimethylaniline	$C_6H_5N(CH_3)_2$	3	193
67	Diethylaniline	$C_6H_5N(C_2H_5)_2$	−34	216
68	Methylethylaniline	$C_6H_5N \left\langle \begin{matrix} CH_3 \\ C_2H_5 \end{matrix} \right\rangle$		201
69	Dipropylaniline (norm.)	$C_6H_5N(C_3H_7)_2$		241
70	Dipropylaniline (iso)	$C_6H_5N(C_3H_7)_2$		
71	Dibutylaniline (norm.)	$C_6H_5N(C_4H_9)_2$		263
72	Triphenylamine	$(C_6H_5)_3N$	126	365
73	Dibenzylaniline	$C_6H_5N(CH_2C_6H_5)_2$	70	>300
74	Diphenylbenzylamine	$(C_6H_5)_2NCH_2C_6H_5$	86	
75	Methyldiphenylamine	$(C_6H_5)_2NCH_3$		293
76	Ethyldiphenylamine	$(C_6H_5)_2NC_2H_5$		297
77	Triethanolamine	$N(CH_2CH_2OH)_3$	20	278 (150 mm)

SELECTED REPRESENTATIVE AMIDES

Primary Amides

	Amide	Formula	Melting Point °C	Boiling Point °C
1	Formamide	$H\ CONH_2$	2	193
2	Acetamide	CH_3CONH_2	82	222
3	Propionamide	$C_2H_5CONH_2$	79	213
4	Acrylamide	$CH_2{=}CH\ CONH_2$	84	
5	Methylacetamide (N)	$CH_3CONHCH_3$	28	206
6	Ethylacetamide (N)	$CH_3CONHC_2H_5$		205
7	Benzamide	$C_6H_5CONH_2$	130	290
8	Benzylacetamide (N) (acetylbenzylamine)	$CH_3CONHCH_2C_6H_5$	60	>300
9	Dimethylbenzamide (N,N)	$C_6H_5CON(CH_3)_2$	41	272
10	Ethylbenzamide (N)	$C_6H_5CONC_2H_5$	70	299
11	Oxamide	$\left.\begin{matrix} CONH_2 \\ \cdot \\ CONH_2 \end{matrix}\right\}$	418 dec	
12	Malonamide	$H_2C \left\langle \begin{matrix} CONH_2 \\ CONH_2 \end{matrix} \right\rangle$	170	
13	Succinamide	$\left.\begin{matrix} H_2CCONH_2 \\ \\ H_2CCONH_2 \end{matrix}\right\}$	242	
14	Acetanilide (phenylacetamide) (N)	$CH_3CONHC_6H_5$	113	305
15	Methylacetanilide (N) (acetylmethylphenylamine)	$CH_3CON \left\langle \begin{matrix} C_6H_5 \\ CH_3 \end{matrix} \right\rangle$	103	253 (710 mm)
16	Benzanilide (N-phenylbenzamide)	$C_6H_5CONHC_6H_5$	163	118
17	Diphenylacetamide (N) (acetyldiphenylamine)	$CH_3CON(C_6H_5)_2$	103	subl
18	Acetotoluide, ortho (N-tolylacetamide)	$CH_3CONHC_6H_4CH_3(2)$	110	296
19	Acetotoluide, meta	$CH_3CONHC_6H_4CH_3(3)$	65	303
20	Acetotoluide, para	$CH_3CONHC_6H_4CH_3(4)$	153	306

SELECTED REPRESENTATIVE AMIDES—*Continued*

Secondary Amides

Amide	Formula	Melting Point °C	Boiling Point °C
21 Diacetamide	$(CH_3CO)_2NH$	78	223
22 Dibenzamide	$(C_6H_5CO)_2NH$	148	

Tertiary Amides

23 Tribenzamide	$(C_6H_5CO)_3N$	207	subl

Imides

Imides	Formula	Melting Point °C	Boiling Point °C
24 Succinimide (butamide)	$CH_2(CO)_2NH$	125	287
25 Ortho-Phthalimide	$C_6H_4(CO)_2NH$	238	subl

REPRESENTATIVE COMPOUNDS RELATED TO AMINES AND AMIDES

Carbamates

Carbamate	Formula	Melting Point °C	Boiling Point °C
1 Carbamic acid (not isolated)			
2 Methyl carbamate	$OC(OCH_3)(NH_2)$	54	177
3 Ethyl carbamate (urethane)	$OC(OC_2H_5)(NH_2)$	49	184
4 Propylcarbamate (norm)	$OC(OC_3H_7)(NH_2)$	60	200
5 Phenylcarbamate	$OC(OC_6H_5)(NH_2)$	142	
6 Benzylcarbamate	$OC(OCH_2C_6H_5)(NH_2)$	86	dec
7 Ethyl-N-methyl carbamate (N-methylurethane)	$OC(OC_2H_5)(NHCH_3)$		170
8 Ethyl-N-ethyl carbamate (N-ethylurethane)	$OC(OC_2H_5)(NHC_2H_5)$		175
9 Ethyl-N-normal-propyl carbamate (N-normal-propylurethane)	$OC(OC_2H_5)(NHC_3H_7)$		192
10 Ethyl-N-phenyl carbamate (N-phenylurethane)	$OC(OC_2H_5)(NHC_6H_5)$	52	237
11 Ethyl-N,N-diphenyl carbamate (N,N-diphenylurethane)	$OC(OC_2H_5)(N(C_6H_5)_2)$	72	>360
12. Thiourethane	$OC(SC_2H_5)(NH_2)$	108	subl

Ureas

Urea	Formula	Melting Point °C	Boiling Point °C
1 Urea	$OC(NH_2)(NH_2)$	133	dec.
2 Methylurea	$OC(NHCH_3)(NH_2)$	101	dec
3 Dimethylurea (sym)	$OC(NHCH_3)(NHCH_3)$	106	269

(*Continued on next page*)

REPRESENTATIVE COMPOUNDS RELATED TO AMINES AND AMIDES—*Continued*

UREAS

	Urea	Formula	Melting Point °C	Boiling Point °C
4	Dimethylurea (unsym)	$OC\langle^{N(CH_3)_2}_{NH_2}\}$	183	
5	Ethylurea	$OC\langle^{NHC_2H_5}_{NH_2}\}$	92	
6	Diethylurea (sym)	$OC\langle^{NHC_2H_5}_{NHC_2H_5}\}$	112	263
7	Diethylurea (unsym)	$OC\langle^{N(C_2H_5)_2}_{NH_2}\}$	74	
8	Normal-propylurea	$OC\langle^{NHC_3H_7}_{NH_2}\}$	107	
9	Dipropylurea (sym , norm)	$OC\langle^{NHC_3H_7}_{NHC_3H_7}\}$	105	255
10	Dipropylurea (unsym , norm)	$OC\langle^{N(C_3H_7)_2}_{NH_2}\}$	76	
11.	Tetramethylurea .	$OC\langle^{N(CH_3)_2}_{N(CH_3)_2}\}$	. . .	177
12	Tetraethylurea	$OC\langle^{N(C_2H_5)_2}_{N(C_2H_5)_2}\}$		210 app.
13	Allyl urea	$OC\langle^{NHC_3H_5}_{NH_2}\}$	85	
14	N-Acetylurea	$OC\langle^{NHCOCH_3}_{NH_2}\}$	218	
15	Phenylurea	$OC\langle^{NHC_6H_5}_{NH_2}\}$	147	160 dec
16	Benzylurea .	$OC\langle^{NHCH_2C_6H_5}_{NH_2}\}$	147	
17	N-Benzoylurea	$OC\langle^{NHCOC_6H_5}_{NH_2}\}$	214	
18	Diphenylurea (sym) (carbanilide)	$OC\langle^{NHC_6H_5}_{NHC_6H_5}\}$	238	261
19	Diphenylurea (unsym)	$OC\langle^{N(C_6H_5)_2}_{NH_2}\}$	189	
20	Ethylphenylurea (N,N′)	$OC\langle^{NHC_6H_5}_{NHC_6H_5}\}$	99	
21	Tetraphenylurea	$OC\langle^{N(C_6H_5)_2}_{N(C_6H_5)_2}\}$	183	
22	Ethyleneurea	$\begin{matrix}CH_2—NH\\ \vert \quad\quad \rangle CO\\ CH_2—NH\end{matrix}$	131	
23	Ethylideneurea .	$CH_3CH\langle^{NH}_{NH}\rangle CO$	154	160 dec.
24	Glycollylurea (hydantoin)	$\begin{matrix}CH_2—NH\\ \vert \quad\quad \rangle CO\\ CO—NH\end{matrix}$	220	
25	Oxalylurea (parabanic acid)	$\begin{matrix}CO—NH\\ \vert \quad\quad \rangle CO\\ CO—NH\end{matrix}$	243 dec	
26	Malonylurea (barbituric acid)	$H_2C\langle^{CO—NH}_{CO—NH}\rangle CO$	245	260 dec.
27	Acetyonylurea (dimethylhydantoin)	$\begin{matrix}(CH_3)_2C—NH\\ \vert \quad\quad\quad \rangle CO\\ CO—NH\end{matrix}$	175	subl.
28	Glyoxyldiureide (allantoin) . .	$\begin{matrix}NH_2CONH—CH—NH\\ \vert \quad\quad\quad\quad \rangle CO\\ CO—NH\end{matrix}$	235	
29	Mesoxalylurea (alloxan)	$CO\langle^{CO—NH}_{CO—NH}\rangle CO$	256 dec	
30	Biuret	$NH_2—CO—NH—CO—NH_2$	192 dec	
31	Acetylbiuret	$CH_3CONHCONHCONH_2$	107	
32	Thiourea	$SC\langle^{NH_2}_{NH_2}\}$	181	
33	Methylthiourea	$SC\langle^{NHCH_3}_{NH_2}\}$	118	
34	Ethylthiourea	$SC\langle^{NHC_2H_5}_{NH_2}\}$	113	
35	Diethylthiourea (sym) . .	$SC\langle^{NHC_2H_5}_{NHC_2H_5}\}$ . .	77	
36	Phenylthiourea	$SC\langle^{NHC_6H_5}_{NH_2}\}$	154	
37	Diphenylthiourea (sym) .	$SC\langle^{NHC_6H_5}_{NHC_6H_5}\}$ . .	154	dec.
38	Benzylthiourea . .	$SC\langle^{NHCH_2C_6H_5}_{NH_2}\}$	163	
39	N-Benzoylthiourea	$SC\langle^{NHCOC_6H_5}_{NH_2}\}$ . . .	169	

REPRESENTATIVE COMPOUNDS RELATED TO AMINES AND AMIDES—*Continued*

SEMICARBAZIDES

SEMICARBAZIDE	FORMULA	MELTING POINT °C	BOILING POINT °C
1 Semicarbazide	$OC\langle^{NHNH_2}_{NH_2}\rangle$.	96	
2. Phenylsemicarbazide (1)	$OC\langle^{NHNHC_6H_5}_{NH_2}\rangle$	172	
3. Phenylsemicarbazide (4)	$OC\langle^{NHNH_2}_{NHC_6H_5}\rangle$	122	

SEMICARBAZONES

By reaction of hydrogens of number 1 nitrogen with oxygen of carbonyl group (>CO)

SEMICARBAZONE	FORMULA	MELTING POINT °C	BOILING POINT °C.
1 Acetaldehydesemicarbazone	$CH_3CH\ NNHCONH_2$	162	
2 Acetonesemicarbazone	$(CH_3)_2C\ NNHCONH_2$	190 dec	

GUANIDINES

GUANIDINE	FORMULA	MELTING POINT °C	BOILING POINT °C
1 Guanidine .	$HN:C\langle^{NH_2}_{NH_2}$		
2 1,3-diphenylguanidine	$HN\ C\langle^{NHC_6H_5}_{NHC_6H_5}\rangle$.	147	
3 1,1,3,3-tetraphenylguanidine	$HN\cdot C\langle^{N(C_6H_5)_2}_{N(C_6H_5)_2}\rangle$	130	
4 1,2,3-triphenylguanidine	$C_6H_5N\ .\ C\langle^{NHC_6H_5}_{NHC_6H_5}\rangle$.	144	
5 1,1,3-triphenylguanidine	$HN\ .\ C\langle^{NHC_6H_5}_{N(C_6H_5)_2}\rangle$	131	
6 Guanylurea	$HN:C\langle^{NH_2}_{NHCONH_2}\rangle$	105	160 dec.
7 Aminoguanidine .	$HN\ C\langle^{NHNH_2}_{NH_2}\rangle$	dec	

Primary amines react (1) with **nitrous acid**, yielding (a) with alkyl amine, nitrogen gas plus alcohol, (b) with aryl amine warm, nitrogen gas plus phenol The amino-group of primary amines is displaced by the hydroxyl group to form **alcohol** or **phenol**, (c) with aryl amine cold, **diazonium-compounds**, (2) with **acetyl chloride** or **benzoyl chloride**, yielding substituted amide, thus, ethylamine plus acetyl chloride to form N-ethylacetamide ($C_2H_5NHOCCH_3$), (3) with benzene-sulfonyl chloride ($C_6H_5SO_2Cl$), yielding substituted benzene sulfonamides, thus, ethylamine to form N-ethylbenzenesulfonamide ($C_6H_5SO_2NHC_2H_5$), soluble in sodium hydroxide, (4) with **chloroform** ($CHCl_3$) and a base, yielding **isocyanides** (Very poisonous!), (5) with nitric acid concentrated, yielding nitramines, thus, ethylamine to form ethylnitramine ($C_2H_5NHNO_2$) Primary amines may be formed (1) by reduction of **nitro-compounds** (aniline from nitrobenzene), **nitroso-compounds**, **hydroxylamines**, **cyanides**, **oximes** or **hydrazones**, (2) by the alkaline (NaOH) hydrolysis of **isocyanates** (sodium carbonate also formed) or isocyanides (sodium formate also formed), (3) by reaction with **bromine** followed by treatment with sodium hydroxide (Hofmann Reaction) (sodium carbonate and bromide also formed), (4) by reaction of sodium phthalimide plus alkyl halide, followed by heating with fuming hydrochloric acid (Gabriel reaction) (phthalic acid also formed), (5) with vapor of **alcohols** plus **ammonia** in the presence of a **catalyzer**, e g , **thorium** oxide at 360°C, (6) from aminoacids, by living organisms, e g , decomposition of fish, in the case of methylamine

Secondary amines react (1) with nitrous acid, yielding nitrosoamines, yellow oily liquids, volatile in steam, soluble in ether The secondary amine may be recovered by heating the nitrosoamine with **hydrochloric acid**, concentrated, or **hydrazines** may be formed by reduction of the nitrosamines, e g , methylaniline forms methylphenylnitrosamine $\left(\begin{matrix}CH_3\\C_6H_5\end{matrix}\right)N\ NO\right)$, reduction yielding unsymmetrical methylphenylhydrazine

$$\left(\begin{matrix}CH_3\\C_6H_5\end{matrix}\right)NHNH_2\right)$$

(2) with **acetyl** or **benzoyl chloride**, yielding substituted amide, thus, diethylamine plus acetyl chloride to form N-N-diethylacetamide ($(C_2H_5)_2NOCCH_3$) (3) with benzene sulfonyl chloride, yielding substituted benzene sulfonamides, thus, diethylamine to form N-N-diethylbenzenesulfonamide ($C_6H_5SO_2N(C_2H_5)_2$), insoluble in sodium hydroxide, (4) with **phenol** warmed with **sulfuric acid** concentrated, then diluted with water and made alkaline with sodium hydroxide, yielding a blue to violet coloration

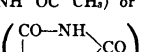
Secondary amines may be formed (1) by alkylation

of primary amines, using, for example, methyl chloride, dimethyl sulfate, (See **Esters**), **methyl alcohol**, heated, **formaldehyde** in acid medium heated, and may be recovered from mixtures with primary or tertiary amines by means of the nitrosamine reaction above, (2) from **aminoacids** by living organisms, e g, decomposition of fish, in the case of dimethylamine

Tertiary amines do not react with nitrous acid, acetyl chloride, benzoyl chloride, benzenesulfonyl chloride, but react with alkyl haloids to form quaternary ammonium haloids, which are converted by silver hydroxide to quaternary ammonium hydroxides Quaternary ammonium hydroxides upon heating yield (1) tertiary amine plus alcohol, (or, for higher members, olefin hydrocarbon plus water) Tertiary amines may also be formed (2) by alkylation of secondary amines, for example, by dimethyl sulfate, methyl alcohol heated, formaldehyde in acid medium heated, (3) from aminoacids by living organisms, e g, decomposition of fish in the case of trimethylamine

Primary amides react (1) with **hypobromite** in sodium hydroxide, to form amines, of one carbon less than in the amides (sodium carbonate and bromide also formed) (Ureas yield nitrogen gas plus carbon dioxide with sodium hypobromite), (2) with **nitrous acid**, to form nitrogen gas plus the corresponding **carboxylic acid** (Ureas yield carbon dioxide), (3) with **phosphorous** pentoxide, to form cyanides by loss of water, (4) with **sodium** hydroxide, to form ammonia gas plus the corresponding carboxylic acid Primary amides are formed (1) by reaction of **acid chlorides, acid anhydrides** or **esters** with ammonium hydroxide, (for urea, carbonyl chloride is used) (2) by heating the ammonium salt of the desired acid, e g, ammonium acetate to obtain acetamide, (3) by reaction of **cyanides** with acids, e g, hydrochloric acid concentrated cold When amines instead of ammonium hydroxide are used with acid chlorides, acid anhydrides or esters, alkylated amides are obtained, e g, N-methyl-acetamide (CH_3CO NH CH_3) Succinimide, it is to be noted, contains the ring of pyrrole, and may be converted into pyrrole by treatment with zinc and acetic acid, or with hydrogen in the presence of finely divided platinum heated

Urea may be substituted, as to the hydrogens, (1) by alkyl or aryl, mono, di, tetra, most commonly di, symmetrical (1, 3), (2) by carbonyl groups (=CO) either (a) as open chain ureides, e g, acetylurea (NH_2CO NH OC CH_3) or (b) as cyclic ureides, e g,

oxalylurea  Purine and uric acid compounds contain two of these cyclic ureides, namely oxalylurea and malonylurea, interlocked Biuret is formed by heating urea at 160°C, and its formation is commonly used as a test for urea When **sodium** hydroxide plus **copper** sulfate is added to biuret a violet-red color is produced Urea was the first artificially prepared product of vital processes, by Wohler, in 1828, by heating ammonium cyanate Urea is produced in the animal body from **proteins** of food Mammals excrete urea in the urine, while many other animals excrete nitrogen in the form of uric acid. Werner, in 1923, suggested the formula HN $C\langle^{NH_2}_{O}$ for urea.

Semicarbazide forms salts with **acids**, e g, semicarbazide hydrochloride ($NH_2CONHNH_2$ HCl), melting point 173°C dec, reacts with carbonyl group (=CO) of aldehydes and ketones to form semicarbazones, usually of sharp melting point, and useful in identification of **aldehydes** and **ketones** Semicarbazide is formed by reaction of hydrazine hydrate and sodium cyanate

Guanidine forms salts with acids, e g, guanidine nitrate $HNC(NH_2)_2HNO_3$ By heating at 120°C for several hours a mixture of **ammonium** thiocyanate and dicyandiamide, guanidine thiocyanate solution is obtained by extracting with water Treating guanidine with a mixture of nitric and sulfuric acids forms nitroguanidine $\left(HN:C\langle^{NH\ NO_2}_{NH_2}\right)$ which is reduced by zinc and acetic acid to aminoguanidine $\left(HN\cdot C\langle^{NH\ NH_2}_{NH_2}\right)$ By treating aminoguanidine (1) with dilute acid or alkali, there is obtained, first, semicarbazide, finally hydrazine, (2) with nitrous acid, diazoguanidine

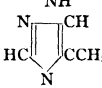
$$\left(HN:C\langle^{NHN\cdot NOH}_{NH_2}\right),$$

which is decomposed by alkali into hydrazoic acid (HN_3) plus cyanamide (H_2N CN) plus water (R K S)

AMINOACIDS, POLYPEPTIDES, AND PROTEINS. Aminoacids are formed by the reaction of water and proteins Aminoacids correspond to hydroxyacids, the amino-group (—NH_2) occupying the position of the hydroxyl-group (—OH) of the latter The simplest aminoacid is aminoacetic acid, glycocoll, glycine (CH_2NH_2 COOH) corresponding to hydroxyacetic acid, glycollic acid (CH_2OH COOH) Aminoacetic acid reacts (1) with **bases**, to form sodium aminoacetate (CH_2NH_2 COONa), (2) with **acids**, to form aminoacetic acid hydrochloride (HCl CH_2NH_2COOH), (3) with **formaldehyde**, to form CH_2 NCH_2 COOH, which can be **titrated** as an acid by a standard base, (4) with **alcohols** anhydrous plus **hydrogen chloride**, followed by treatment with **sodium** hydroxide solution cold, extraction with **ether**, and evaporation of ether, to form, for example the **ester** O-methylaminoacetate (CH_2NH_2-$COOCH_3$), boiling point 130° C, decomp Such esters are useful in the separation of aminoacids, (5) with **benzoyl chloride**, to form N-benzoylaminoacetic acid, hippuric acid (C_6H_5CO $NHCH_2$ COOH), (6) with **acetyl chloride** in large excess at 0° to 20° C plus phosphorus pentachloride, to form HCl H_2N H_2C COCl Such compounds are useful in the synthesis of polypeptides, (7) with **nitrous acid**, to form glycollic acid plus nitrogen, (8) with phenyl isocyanate (C_6H_5 NCO), to form phenyl ureidoacetic acid ($C_6H_5NHCONH$ CH_2 COOH), slightly soluble Such compounds from phenyl isocyanate and from alpha-naphthylisocyanate are useful in the separation of aminoacids, (9) with **copper** carbonate by boiling in aminoacetic acid solution, to form dark blue copper aminoacetate (CH_2NH_2 $COO)_2Cu$ H_2O) N-methylaminoacetic acid, sarcosine $\left(^{CH_3}_{H}\rangle N\ CH_2COOH\right)$ is formed when creatine (methylguanidylacetic acid, HN : C$\langle^{NH_2}_{N(CH_3)CH_2\ COOH}$) of meat juice is warmed with barium hydroxide solution

Aminoacids may be prepared (1) by reaction of halogen-substituted acids (or their esters) with ammonia, e g, chloroacetic acid ($ClCH_2$ COOH) to form aminoacetic acid (H_2NCH_2 COOH), (2) by reaction of **aldehydes** or **ketones** with **hydrogen cyanide** to form aldehyde or ketone cyanhydrin, e g, acetaldehyde cyanhydrin (CH_3 CHOH CN), which by reaction with ammonia forms aminocyanide (CH_3CHNH_2 CN), and then by hydrolysis this forms the corresponding aminoacid (CH_3CHNH_2 COOH), (3) by reaction of proteins with hydrochloric acid, the aminoacid residues constituting the protein are obtained The aminoacids thus obtained from proteins are alpha-substituted aminoacids. Some of the most important alpha-aminoacids in this connection are·

SELECTED REPRESENTATIVE ALPHA-AMINO ACIDS

	Alpha-Amino Acid	Formula
1	Aminoacetic acid (glycocoll, glycine)	CH_2NH_2COOH
2	N-methylaminoacetic acid (sarcosine)	CH_3NHCH_2COOH
3.	Alpha-aminopropionic acid (alanine)	$CH_3CH_2NH_2COOH$
4.	Alpha-amino-beta-hydroxy-propionic acid (serine)	$CH_2OHCHNH_2COOH$
5	Alpha-aminoisocaproic acid (leucine)	$(CH_3)_2CHCH_2CHNH_2COOH$
6	Alpha-amino-beta-methylvaleric acid (isolucine)	$C_2H_5 \diagdown CH_3 \diagup CHCHNH_2COOH$
7	Alpha-aminosuccinic acid (aspartic acid)	$COOHCH_2CHNH_2COOH$
8	Alpha-aminoglutaric acid (glutamic acid)	$COOHCH_2CH_2CHNH_2COOH$
9	Alpha-amino-delta-guanidine-valeric acid (arginine)	$HN \cdot C \diagdown^{NH_2}_{NHCH_2CH_2CH_2CHNH_2COOH}$
10	Alpha-epsilon-diaminocaproic acid (lysine)	$CH_2NH_2CH_2CH_2CH_2CHNH_2COOH$
11	Bi-alpha-amino-beta-thiopropionic acid (cystine)	$CH_2S—SCH_2$ $\vert \quad \vert$ $CHNH_2 \quad CHNH_2$ $\vert \quad \vert$ $COOH \quad COOH$
12	Alpha-amino-beta-phenylpropionic acid (phenylalanine)	CH_2CHNH_2COOH
13	Alpha-amino-beta-parahydroxyphenylpropionic acid (tyrosine)	CH_2CHNH_2COOH
14	Alpha-pyrrolidine carboxylic acid (pyroline)	
15	Alpha-amino-beta-imideazolepropionic acid (histidine)	
16	Alpha-amino-beta-indolepropionic acid (tryptophane)	

Phenylalanine, tyrosine, tryptophane are benzenoid compounds and consequently react readily with **nitric acid** to form yellow nitro-compounds They are responsible for the yellow xanthroproteic reaction of proteins with concentrated nitric acid

Tyrosine is a phenolic compound and consequently reacts with nitric acid to form upon boiling with nitrous acid plus **nitric acid** plus **mercurous** salt plus mercuric salt (Millon's solution) a brick-red color

Tryptophane, when treated with glyoxylic (glyoxalic) acid (CHO COOH), and stratified by concentrated **sulfuric acid** forms a violet-color at the junction of the liquids Glyoxylic acid is made by reduction of **oxalic acid** solution by **sodium** amalgam

Cystine, the only aminoacid of those listed above which contains sulfur, reacts with **sodium** hydroxide warm to form sodium sulfide, which with **lead** nitrate solution forms a black precipitate of lead sulfide

When amino- or hydroxyacids lose ammonia or water, respectively, characteristic reactions occur, as follows:

Amino- or Hydroxyacid	Formula	Product
Alpha-amino	CH_2NH_2COOH	Lactim· $CH_2—NH—CO$ $\vert \quad \quad \vert$ $CO—NH—CH_2$
Beta-amino	$CH_2NH_2CH_2COOH$	Unsaturated acid $CH_2 \ CHCOOH$
Gamma-amino	$CH_2NH_2 \ CH_2CH_2COOH$	Gamma-lactam $CH_2CH_2CH_2CO$ $\vert \quad \quad \vert$ $\quad —NH—$
Alpha-hydroxy	$CH_3CHOHCOOH$	Lactide $H_3CCH—CO—O$ $\vert \quad \quad \vert$ $O—CO—HCCH_3$
Beta-hydroxy	$CH_3 \ CHOH \ CH_2COOH$	Unsaturated acid· $CH_3CH : CH \cdot COOH$
Gamma-hydroxy	$CH_3 \ CHOH \ CH_2 \ CH_2 \ COOH$	Gamma-lactone $CH_3CHCH_2CH_2CO$ $\vert \quad \quad \vert$ $\quad —O—$

Aminoacids may be combined with one another, up to 19 aminoacid units, to form polypeptides, thus alpha-aminopropionic acid, alanine (CH_3CHNH_2COOH), by reaction with aminoacetic acid, glycine (CH_2NH_2COOH) forms alanylglycine ($CH_3CHNH_2—CO—NH—CH_2COOH$) in which the peptide group (—CO—NH—) serves to unite the two nuclei In the reverse direction, alanylglycine can be caused to react with water to form alanine plus glycine, the disruption occurring at the peptide grouping.

Aminoacids are of great importance on account of being constituents, through the peptide group, of naturally occurring proteins of plants and animals The percentage of **nitrogen** element found in proteins varies between the limits 15 0 and 17 6, of **sulfur** between 0 5 and 2 2, and of **phosphorus** between 0 4 and 0 9 Proteins are important **food** materials and are characterized by the above nitrogen content, being in this way distinguished from the other grand classes of food materials, namely, fats, carbohydrates Proteins are among the most important constituents of the living **cell**, and intimately connected with life processes Each type of organism and each kind of cell within the organism possess its own characteristic proteins Proteins are essential constituents of animal diet, and cereal grains, legumes, eggs, milk, cheese and meat are outstanding food sources of proteins Wool, hair, silk, and skin are also proteins Some proteins, such as keratin of hair and horn, are not broken down by the **enzymes** of the alimentary canal, and are thus not utilizable as foods Certain proteins have important industrial uses These are wool, silk, skins and hides for leather, hair, gelatin, casein for plastics, glue and casein for adhesives

COMPOSITION OF CHIEF PROTEIN FOODS

	Protein, %	Fat, %	Carbohydrate, %
Wheat	8–17	1 5–4	65–79
Corn	7 5–13	3–7 5	65–76
Oats	12–14	5–8	67
Rice	8	2	77
Peas, dried	25	1	62
Beans, dried	23	2	60
Potatoes	1 4–2 8	0 2–0 4	15–29
Bananas	1 5	0 5	22
Apples	0 4	0 5	14
Peanuts	26	40	22
Milk	3 5	4	5
Butter	1	85	
Cheese, cream	26	37	3
Cheese, cottage	21	1	4
Beef, raw	19	19	
Eggs	15	11	

Proteins are complexes, which contain alpha-aminoacids united by peptide linkage (—CO NH—) Unlike dissolved sugars, proteins do not diffuse through animal membranes, and, except for **aleurone** grains in the seeds of plants, are not found crystallized, and are only obtained crystalline with great difficulty Proteins possess the acid-base characteristics of aminoacids, and the properties of protein solutions depend to a large degree upon the **hydrogen-ion** concentration At the **isoelectric point**, which is characteristic of each protein, it is found that optimum conditions exist for coagulation of proteins by heating Proteins are coagulated not only by heating, as in the familiar case of egg albumin, which coagulation is not reversible, but also by addition of **sodium, potassium** or **ammonium** salts, which, at a definite concentration of salt in solution, precipitate proteins. Thus precipitated, the protein retains its original properties, and, by filtration and dissolving out of the salt, may be obtained in its original condition The precipitation is thus reversible The addition of certain substances, such as **alcohol, acetone, tannic acid**, or salts of heavy metals, (for instance, mercuric chloride) causes irreversible precipitation

The coagulation of proteins by heat is also affected by the presence of salts, small quantities of salts usually raise the coagulation temperature, and large quantities lower it

A system of classification of proteins has been adopted by the American Society of Biochemists

I SIMPLE PROTEINS naturally occurring proteins formed from aminoacids only

1 Albumins Coagulable by heat, soluble in water and dilute salt solutions Examples, serum albumin, egg albumin and lactalbumin

2 Globulins Coagulable by heat, soluble in dilute salt solutions and dilute solutions of acids and alkalis Generally insoluble in water, but a few ("pseudo-globuline") are soluble in water Examples, serum globulin of the blood, and myosin, the chief protein of meat Among the commonest protein reserves of the higher plants, except cereals

3 Glutelins Found in cereals Coagulable by heat, insoluble in neutral solvents, but soluble in dilute acids and alkalis. Examples, glutenin of wheat, and oryzenin of rice

4 Prolamines Found in cereals Distinguished from glutenins by being soluble in 75% alcohol Examples, gliadin of wheat and rye, zein of corn and wheat, and hordein of barley

5 Albuminoids Found in the skeletal and connective tissues of animals Insoluble in most reagents Examples, keratin of hair and hoofs, fibrosin of silk, elastin of yellow connective tissue, collagen of tendons and white connective tissue, producing gelatin solution upon boiling with water

6 Protamines Basic proteins, formed mainly from basic aminoacids, such as arginine and lysine Examples, in the heads of ripe spermatozoa, and in ova

7 Histones Similar to protamines, but lower percentages of basic aminoacids Examples, in unripe **spermatozoa**, in red blood corpuscles, and in lymphoid body tissues

II CONJUGATED PROTEINS proteins joined to a non-protein group Rarely found in plants

8 Chromoproteins The non-protein group is colored Examples, **haemoglobins** of the blood of vertebrates, haemocyanin of the blood of invertebrates Haemoglobin, when hydrolyzed, yields the protein globin and the non-protein haematin, a **pyrrole** derivative

9 Glucoproteins The non-protein group is a **carbohydrate** group Examples, mucin (protein plus glucosamine) of mucous and saliva, and mucoids of tendons

10 Nucleoproteins The non-protein group is nucleic acid, which contains **phosphorus, purine** bases, **pyrimidine** bases and a sugar group Examples, in plant and animal cells, especially in the nuclei of the cells, in blood, chyle and lymph

11 Phosphoproteins The non-protein group is the **phosphoric** acid group Distinguished from nucleoproteins by not containing purine bases or pyrimidine bases Examples, casein of milk, and vitellin of egg yolk

III DERIVED PROTEINS decomposition products of any of the above Produced by boiling in water, or by hydrolysis with dilute acids, alkalis, or enzymes Includes artificially prepared polypeptides

12 Meta proteins Insoluble in water or dilute salt solutions Soluble in dilute acids or alkalis. Coagulated by heat when in suspension.

13 Proteoses Soluble in water Not coagulated by heat Precipitated by saturation with **ammonium** sulfate

14 Peptones. Similar to proteoses, but not precipitated by saturation with ammonium sulfate.

15 Peptides Simple peptones, generally of known composition.

Proteins, in general, give positive reactions in many of the tests described under aminoacids, for example, (1) xanthoproteic acid reaction with nitric acid concentrated, the yellow color being changed orange by alkalis, (2) Millon's reaction, (3) glyoxylic acid reaction, (4) biuret reaction, by the reaction of protein in sodium hydroxide solution plus copper sulfate a violet red color is produced, (5) sulfur reaction of cystine Proteins are precipitated in acid solution by phosphotungstic acid, tannic acid, picric acid, and hydroferrocyanic acid, and, in neutral or slightly alkaline solution, by salts of certain metals, such as cupric, mercuric, lead, gold, and ferric Proteins are usually present in plant and animal materials in the colloidal state

The following data on the composition of some proteins is selected from the work of Mitchell and Hamilton (1929)

Protein	Tryptophane %	Glutamic Acid %	Arginine %	Cystine %	Phenylalanine %	Tyrosine %	
Gliadin	1	44	3	2	2	3	Proline 13%
Zein		31	2	1	8	6	
Milk albumin	3	13	3	4	1	2	
Casein		22			4	7	
Egg albumin	1	13	6	1	5	4	Leucine plus isoleucine 25%
Gelatin		6	9		1		Glycine 25%, hydroxyproline 14%

(R K S)

AMINOAZO-COMPOUNDS Azo-, Diazo-, and Related Compounds.

AMINOGUANIDINES. Amines and Amides.

AMITOSIS. Cell division.

AMMETER. An instrument for measuring electric currents in amperes Direct current ammeters are usually of the moving-coil type, being similar in principle to the d'Arsonval **galvanometer** A coil carrying the current to be measured turns between the poles of a permanent magnet against the torque of a hair-spring and causes a pointer to move over its dial Alternating-current ammeters commonly have two coreless coils in series, one turning in the field set up by the other which is fixed (electrodynamometer type) The reversal of current thus has no effect upon the direction of the torque Some simple ammeters are of the hot-wire type, in which the longitudinal expansion of the wire carrying the current controls the movement of the pointer For currents heavier than the coil or the hot wire can safely stand, a shunt may be provided in d-c ammeters, which allows only a predetermined fraction of the current to pass through the instrument, while a small transformer serves a similar purpose with a-c ammeters Very sensitive ammeters, graduated in milliamperes, are called milliammeters (L D W)

AMMINES. Dry **ammonia** gas reacts with dehydrated salts of some of the metals to form solid ammines Ammines, upon warming, evolve ammonia, sometimes with final decomposition of the salt itself, in a manner analogous to the decomposition of certain hydrates. The ammines of **chromic** (Cr^{+3}), **cobaltic** (Co^{+3}), **platinic** (Pt^{+4}) and other metals have been studied in detail Two series of ammines are shown below, the first one in which the neutral ammonia group is replaced step by step by the negative nitro group (NO_2^{-1}), and the second one in which the neutral ammonia group is replaced step by step by the neutral H_2O group

Number of Neutral Groups, e g, (NH_3), on Metal, e g, Co, varied from 6 to 0

Square bracket contains the ion
Equivalent electrical conductivity
inserted below each compound.

$[Co(NH_3)_6]Cl_3$
410

$[Co(NH_3)_5(NO_2)]Cl_2$
240

$[Co(NH_3)_4(NO_2)_2]Cl$
95

$[Co(NH_3)_3(NO_2)_3]$
1 5

$K[Co(NH_3)_2(NO_2)_4]$
95

$K_2[Co(NH_3)(NO_2)_5]$

$K_3[Co(NO_2)_6]$
420

Number of Neutral Groups Constant, but Groups Varied X = unit anion
$[Cr(NH_3)_6]X_3$
$[Cr(NH_3)_5(H_2O)]X_3$
$[Cr(NH_3)_4(H_2O)_2]X_3$
$[Cr(NH_3)_3(H_2O)_3]X_3$
$[Cr(NH_3)_2(H_2O)_4]X_3$

The neutral group of the complex may be replaced step by step by the following negative groups. Cl^-, Br^-, I^-, F^-, OH^-, NO_2^-, NO_3^-, CN^-, CNS^-, SO_4^{--}, CO_3^{--}, $C_2O_4^{--}$, or by the following neutral groups H_2O, NO, NO_2, SO_2, S, N_2H_4, H_2NOH, CO, C_2H_5OH, C_6H_6 All neutral groups are of substances capable of independent existence

In the ammines, trivalent metals, such as **cobaltic** and **chromic** above, possess a coordination number of 6, this number being the sum of the unit replacements on the metal in the complex ion Since a regular octahedron has six corners equidistant from the center, it is assumed that the metal occupies the center and each of the six replacing groups occupies a corner of a regular octahedron Support for this assumption is offered by the X-ray examination of these ammines When there is only one of the six groups replaced by a second group, as in $[Co(NH_3)_5(NO_2)]Cl_2$ and in $[Cr(NH_3)_5$

$(H_2O)]X_3$, the octahedral placement of groups supplies only one form, but when two of the six groups are replaced by a second group, as in $[Co(NH_3)_4(NO_2)_2]Cl$, and in $[Cr(NH_3)_4(H_2O)_2]X_3$, two different octahedral corner arrangements are possible depending upon whether the two replacing groups are adjacent (cis-form) or opposite (trans-form) Two substances differing in physical properties and corresponding to these two forms are known Further, when three divalent groups, e g , $3C_2O_4^{--}$ are present in the complex, two arrangements—not identical but mirror-images of each other—are possible Two optically active substances are known in such cases corresponding to these two stereisomeric forms

Six is the ordinary coordination number for metallic ammines and similar complexes Additional examples are $K_2[Pt(NH_3)_2(CN)_4]$, $[Ni(NH_3)_6]Cl_2$, $K_4[Fe(CN)_6]$, $K_3[Fe(CN)_6]$, $K_2[Fe(CN)_5(NO)]$, $K_2[SiF_6]$, $[Ca(NH_3)_6]Cl_2$ But, for the elements boron, carbon, and nitrogen four is the coordination number, e g , $[BH_4]Cl$, $[CH_4]$, $[NH_4]Cl$, and in these substances the groups are assumed to occupy the corners of a regular tetrahedron, in $K_4[Mo(CN)_8]$ and $[Ba(NH_3)_8]Cl_2$ the coordination number is eight, and the groups are assumed to occupy the corners of a cube (R K S)

AMMONIA. Ammonia (NH_3) is a colorless gas, of characteristic choking odor, density 0 7710 gram per liter, 0° C , 760 mm , or 0 60 when air equals 1 00, melting point —78° C , boiling point —33° C , critical temperature 132° C , critical pressure 112 atmospheres, most soluble of the common gases (about 30% NH_3, 70% water, at room temperature and pressure)

Ammonia is used in solution (1) as an important **alkali** and (2) in producing ammonium compounds, as liquid (3) in refrigeration, and (4) as a **solvent** for certain substances, as (5) gas in local production of **hydrogen** by thermal decomposition for use in high temperature combustion, and (6) in the manufacture of **nitric acid** by incomplete combustion with air over heated platinum

Ammonia is formed (1) in the destructive distillation of **coal** in the production of coke and coal gas, and is recovered from the gas by dissolving in water, and then distilling, (2) by reaction of **nitrogen** and hydrogen gases under pressure at elevated temperature in the presence of a **catalyzer.** Since the gases must be pure for this reaction to take place the resulting ammonia is of high purity, and may be directly liquefied, dissolved in water, or used as gas When passed over heated **magnesium**, ammonia gas yields hydrogen gas and magnesium nitride (yellow solid, evolving ammonia with water), and when passed over heated cupric oxide, yields nitrogen gas, water, and finely divided **copper** metal The reactions commonly assigned to ammonia as a base are given under **Ammonium.** (R K S)

AMMONITE. Invertebrate Paleontology.

AMMONIUM Radical NH_4 The chemical radical ammonium (NH_4) is composed of **nitrogen** and **hydrogen** and it commonly behaves as a unit Thus, it forms a series of ammonium salts which resembles the corresponding **potassium** salts The radical should be distinguished carefully from ammonia (NH_3), which is a gas of separate existence (See **Ammonia**), whereas ammonium is encountered in compounds, such as ammonium chloride (NH_4Cl) When a concentrated water solution of ammonium chloride is electrolyzed, using a **mercury** cathode at 0° C , mercury ammonium amalgam, resembling sodium amalgam, is formed. When warmed above 0° C , there are formed mercury, ammonia, and hydrogen

Acetate: ammonium acetate ($NH_4C_2H_3O_2$), white solid, soluble, formed by reaction of ammonia or ammonium hydroxide and **acetic acid**, reacts upon heating to yield acetamide

Alum· ammonium alums are those alums, such as **aluminum** ammonium sulfate ($Al_2(SO_4)_3 \cdot (NH_4)_2SO_4$ $24H_2O$), **ferric** ammonium sulfate ($Fe_2(SO_4)_3$ $(NH_4)_2$ SO_4 $24H_2O$), **chromium** ammonium sulfate ($Cr_2(SO_4)_3$ $(NH_4)_2SO_4$ $24H_2O$) where ammonium sulfate is crystallized with the heavier metal sulfate

Benzoate ammonium benzoate ($NH_4C_7H_5O_2$), white solid, soluble, formed by reaction of ammonium hydroxide and **benzoic acid** Used (1) as a food preservative, (2) in medicine

Borate ammonium borate, ammonium tetraborate ($(NH_4)_2B_4O_7$ $4H_2O$), white solid, soluble, formed by reaction of ammonium hydroxide and **boric acid** Used (1) in fireproofing fabrics, (2) in medicine

Bromide ammonium bromide (NH_4Br), white solid, soluble, sublimes at 542° C , formed by reaction of ammonium hydroxide and **hydrobromic acid** Used in photography

Carbonates ammonium carbonate, sal volatile ($(NH_4)_2CO_3$), white solid, soluble, formed by reaction of ammonium hydroxide and **carbon dioxide** by crystallization from dilute alcohol, loses ammonia, carbon dioxide, and water at ordinary temperatures, rapidly at 58° C , ammonium hydrogen carbonate, ammonium bicarbonate, ammonium acid carbonate (NH_4HCO_3), white solid, soluble, formed by reaction of ammonium hydroxide and excess carbon dioxide This salt is the important reactant in the ammonia soda process for converting **sodium** chloride in solution into sodium hydrogen carbonate solid

Chloride ammonium chloride, sal ammoniac, muriate of ammonia (NH_4Cl), white solid, soluble, sublimes at 520° C , formed (1) as a white smoke by reaction of ammonia gas and **hydrogen chloride** gas, (2) by reaction of ammonium hydroxide and hydrochloric acid, and then evaporating Used (1) as an important nitrogenous fertilizer, (2) in dry cell electric batteries, (3) in soldering flux, (4) in the textile and tanning industries

Chloroplatinate ammonium chloroplatinate ($(NH_4)_2$ $PtCl_6$), yellow solid, insoluble, formed by reaction of soluble ammonium salt solutions and **chloroplatinic acid** Used in the quantitative determination of ammonium

Cobaltinitrite diammonium sodium cobaltinitrite ($(NH_4)_2NaCo(NO_2)_6$ H_2O) golden yellow precipitate, formed by reaction of sodium cobaltinitrite solution in acetic acid with soluble ammonium salt solution Used in the detection of ammonium

Cyanate ammonium cyanate (NH_4CNO), white solid, soluble, formed by fractional crystallization of **potassium** cyanate and ammonium sulfate, (ammonium cyanate is soluble in alcohol), when heated changes into urea (the classical experiment by Wohler in 1828)

Dichromate ammonium dichromate ($(NH_4)_2Cr_2O_7$), red solid, soluble, upon heating evolves nitrogen gas and leaves a green insoluble residue of **chromic** oxide

Fluoride ammonium fluoride (NH_4F), white solid, soluble, formed by reaction of ammonium hydroxide and **hydrofluoric acid**, and then evaporating Used (1) as an antiseptic in brewing, (2) in etching glass, ammonium hydrogen fluoride, ammonium bifluoride, ammonium acid fluoride (NH_4F_2), white solid, soluble

Hydroxide ammonium hydroxide (NH_4OH), colorless solution, by solution of (1) ammonia gas in water, commercially of strength 26° Baumé (Specific gravity at 66° F , water at 60° F , 0 8974), 29 40% NH_3, (2) anhydrous liquid ammonia (in cylinders) Used (1) as a mild, moderately cheap alkali, e g , laundering, (2) as a source of ammonium for many salts, (3) as an important chemical reagent

Iodide ammonium iodide (NH_4I), white solid, soluble, formed by reaction of ammonium hydroxide and **hydriodic acid**, and then evaporating Used (1) in photography, (2) in medicine

Linoleate ammonium linoleate ($NH_4C_{18}H_{31}O_2$). Used (1) as an emulsifying agent, (2) as a detergent

Nitrate ammonium nitrate, nitrate of ammonia (NH_4

NO_3), white solid, soluble, melting point 170° C, formed (1) by fractional crystallization of ammonium sulfate or chloride and **sodium** nitrate, (2) by reaction of ammonium hydroxide and **nitric acid**, and then evaporating Used (1) in the preparation of nitrous oxide gas (by heating), (2) in explosives, pyrotechnics, (3) in freezing mixtures of salts

Nitrite ammonium nitrite (NH_4NO_2), when ammonium sulfate or chloride and sodium or potassium nitrite are heated, the mixture behaves like ammonium nitrite in yielding nitrogen gas

Oxalate ammonium oxalate ($(NH_4)_2C_2O_4$), white solid, soluble, formed by reaction of ammonium hydroxide and **oxalic acid**, and then evaporating Used as a source of oxalate, ammonium binoxalate ($NH_4HC_2O_4 \cdot H_2O$), white solid, soluble

Perchlorate ammonium perchlorate (NH_4ClO_4), white solid, soluble, formed by reaction of ammonium hydroxide and **perchloric acid**, and then evaporating Used (1) in explosives and pyrotechnics

Periodate ammonium periodate, (NH_4IO_4), white solid, moderately soluble

Persulfate ammonium persulfate ($(NH_4)_2S_2O_8$), white solid, soluble, formed by **electrolysis** of ammonium sulfate under proper conditions Used (1) as a bleaching and oxidizing agent, (2) in electroplating (3) in photography

Phosphate diammonium hydrogen phosphate ($(NH_4)_2HPO_4$), white solid, soluble, formed by reaction of excess ammonium hydroxide and **phosphoric acid**, and then evaporating at room temperature Used (1) in fireproofing, (2) as a fertilizer supplying nitrogen and phosphorus, (3) in medicine, ammonium dihydrogen phosphate ($NH_4H_2PO_4$), white solid, soluble, formed by heating diammonium phosphate to 155° C

Phosphomolybdate ammonium phosphomolybdate, ($(NH_4)_3PO_4 \cdot 12MoO_3$ or similar composition), yellow precipitate, soluble in alkalis, formed by excess ammonium molybdate and nitric acid with soluble phosphate solution Used as an important test for phosphate (similar product and reaction when arsenate replaces phosphate)

Salicylate ammonium salicylate ($NH_4C_7H_5O_3$), white solid, soluble, formed by reaction of ammonium hydroxide and **salicylic acid**, and then evaporating Used in medicine

Sulfate ammonium sulfate, sulfate of ammonia ($(NH_4)_2SO_4$), white solid, soluble, formed by reaction of ammonium hydroxide and **sulfuric acid**, and then evaporating Used (1) as an important nitrogenous **fertilizer**, largely obtained by recovery of ammonia from by-product coke oven operations, (2) as a soldering liquid, (3) in fireproofing fabrics, (4) in electric dry cell batteries, (5) as a source of ammonia, ammonium hydrogen sulfate, ammonium bisulfate, (NH_4HSO_4), white solid, soluble, melting point 147° C

Sulfide ammonium sulfide ($(NH_4)_2S$), colorless to yellowish solution, formed by saturation with **hydrogen sulfide** of one-half of a solution of ammonium hydroxide, and then mixing with the other half of the ammonium hydroxide Dissolves sulfur to form ammonium polysulfide, yellow solution Used as a reagent in analytical chemistry, ammonium hydrogen sulfide, ammonium bisulfide, ammonium acid sulfide (NH_4HS), colorless to yellowish solution, formed by saturation with hydrogen sulfide of a solution of ammonium hydroxide

Tartrate ammonium tartrate ($(NH_4)_2C_4H_4O_6$), white solid, moderately soluble, formed by reaction of ammonium hydroxide and **tartaric acid**, and then evaporation Used in the textile industry, ammonium hydrogen tartrate, ammonium bitartrate, ammonium acid tartrate ($NH_4HC_4H_4O_6$), white solid, slightly soluble, formation sometimes used in detection of ammonium or tartrate

Thiocyanate ammonium thiocyanate, ammonium sulfocyanide, ammonium rhodanate (NH_4CNS), white solid, soluble, absorbs much heat on dissolving with consequent marked lowering of temperature, melting point 150° C, formed by boiling ammonium cyanate solution with sulfur, and then evaporating Used (1) as a reagent for ferric, (2) in making cooling solutions, (3) to make thiourea

Ammonium compounds liberate ammonia gas when warmed with sodium hydroxide solution (R K S)

AMNION. An accessory embryonic membrane common to reptiles, birds and mammals and a superficially similar structure found in some insects

To the three vertebrate classes, all fundamentally terrestrial, the amnion gives the name Amniota In this group the amnion is usually formed by the growth of folds of the somatopleure, consisting of ectoderm and somatic mesoderm, about the **embryo** The union of the folds produces two membranes, the outer **serosa** and the inner amnion, the latter encloses the embryo and is filled with amniotic fluid which protects it against dessication and equalizes mechanical stresses The amnion is lined with ectoderm and covered with mesoderm, both continuous with the same tissues of the embryo itself

In the insect egg the amnion develops from folds of ectoderm which extend between the embryo and the shell of the egg and fuse to form an outer serosa and an inner amnion These structures are not uniform in their appearance and are not persistent throughout embryonic development in all species in which they form, hence their functions are in doubt (A W L)

AMNIOTA The classes **Reptilia, Aves**, and **Mammalia** of the vertebrates, in which an **amnion** appears during embryonic development (A W I)

AMOEBA. An order of one-celled animals in which the body consists of a naked mass of **protoplasm** and the organs of locomotion are temporary blunt protuberances of cytoplasm (See **Cell**) known as pseudopodia (See **Pseudopodium**) (A W L)

AMOEBIC DYSENTERY. An infection of the large intestine, contagious in character, caused by a parasitic type of **amoeba.** (See **Amoeba.**) The disease is characterized by great wasting of the body tissues and discharge of blood and mucous from the rectum Sometimes in the later stages of the disease, **abscesses** of the **liver, brain** or **spleen** may develop The amoeba definitely known to cause this disease is the *Entamoeba Histolytica*

Amoebic dysentery usually occurs in **endemic** form in sub-tropical and tropical climates Occasional outbreaks may appear however in colder climates It is spread as a rule by **carriers**—a vegetative or encysted form is found in their intestines Upon food being contaminated by them and ingested by others these amoeba leave their inactive form and produce the acute disease Relapses are common, even with treatment Treatment is most efficacious when given early It consists of one or another of the amoebecides such as emetine, etc (R S M)

AMOEBULAE Spores of amoeboid form which are produced by some one-celled animals (A W L)

AMOSITE. Amosite is a long fiber gray or greenish asbestiform mineral related to **anthophyllite,** found in South Africa (E S C S)

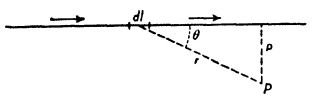
AMPERE. The ampere is the practical unit of electric current It is primarily an electromagnetic unit, the absolute ampere being defined as one-tenth of the **abampere** For reasons of expediency in standardization measurements, however, another basis has been adopted in the definition of the international ampere, which is one international **coulomb** per second, i e, that current which would deposit silver at the rate of 0 001118 gram per second from a silver nitrate solution

in a **coulombmeter** under prescribed conditions This electrolytic unit of current is slightly less than the absolute ampere (by about 5 parts in 100,000), but the difference is commonly overlooked in practical measurements Since the ampere is rather large for many laboratory purposes (a 50-watt, 110-volt lamp requires less than half an ampere), the milliampere (1/1000 ampere) and even the microampere (1/1,000,000 ampere) are often found convenient (L D W)

AMPERE-HOUR. An ampere-hour is a quantity of electricity, equal to 3600 **coulombs:** Viz, the electricity flowing in one hour past any point of a circuit carrying one ampere It is not a measure of quantity of electrical energy, since voltage does not enter into the product of amperes times hours The use of the ampere-hour is confined largely to storage battery practice (See **accumulator**) Storage batteries are rated in ampere-hours to show the quantity of electricity that can be used without discharging the battery beyond safe limits The quantity may be measured by an ampere-hour meter (F T M)

AMPÈRE'S LAW. This is a classic law of electromagnetism, useful in discussions of electrodynamics It has been stated in two apparently distinct forms, which are, however, interconvertible

One form, sometimes known as Laplace's law, states that the electric current i (**abamperes**), flowing along



Current in element *dl* produces magnetic field at point *P*

any line through an element of length dl, gives rise, at a point P distant r (cm) from the element, to a magnetic field of intensity $dH = ipdl/r^3$ (**oersteds**), in which p is the perpendicular distance from P to the line of the element dl, or $dH = i \sin \theta dl/r^3$, in which θ is the angle between the line of the element and the line joining dl to P The ultimate basis of the law is, of course, experimental It may, for example be deduced indirectly from the **Biot-Savart** law for the field about an infinitely long, straight wire Ampère's law furnishes a basis for the solution of all problems relating to the magnetic fields produced by electric currents

What is sometimes called the circuital form of Ampère's law may be tangibly expressed by saying that if a unit magnetic pole is carried completely around a conductor or system of conductors in which electricity is flowing, in such a way as to oppose the field set up by the currents, the work done, in **ergs**, is 4π times the algebraic sum of the currents, in abamperes This is easily illustrated by a special case The Biot-Savart law above referred to gives, as the magnetic intensity at a point distant r (cm) from an infinitely long, straight wire carrying a current i (abamperes), the value $H = 2i/r$ (oersteds), directed, of course, along the circumference of the circle having r as its radius The force acting upon a unit pole placed at this point is therefore $2i/r$ (**dynes**) If now the pole is moved around the circle, against the field, the work done is

$$\frac{2i}{r} \times 2\pi r = 4\pi i \text{ (ergs).}$$

Maxwell pointed out that Ampère's law holds only for constant currents, and that when currents vary, the resulting changes of electric displacement in the surrounding space, giving rise to the radiation of energy in the form of electromagnetic waves, involves modifications embodied in the so-called Maxwell-Ampere law as expressed by the first of **Maxwell's equations.** (L.D W.)

AMPHIBIA. The frogs, toads, newts, salamanders and related forms A class of the phylum **Chordata.** Since these animals live only in moist places their distribution is restricted and they are among the less familiar vertebrates

The amphibians are distinguished by: 1. Moist **skin.** 2 The absence of scales and claws 3 Most species undergo a metamorphosis during development from an aquatic, gill-breathing larva to a semi-terrestrial, air-breathing adult stage

While some of the salamanders are permanently aquatic and some of the tree frogs permanently terrestrial, most members of the class live near the water or in moist places and undergo the metamorphosis mentioned above

The following orders of amphibians are recognized:

Order **Gymnophiona** (Apoda) Legless, worm-like animals ,confined to the tropics of the Old and New Worlds

Order **Urodela** (Caudata) Elongate animals with long tails and weak, short legs The **salamanders, newts, efts, hellbender,** and **mud puppy.**

Order **Anura** (Salientia) Tailless species whose hind legs are the larger pair, more or less strongly developed for jumping Most species have a larval stage known as the tadpole with a compact body and a long compressed tail but no legs until the onset of metamorphosis The **frogs** and **toads.** (A W L)

AMPHIBOLE. This is the name given to a closely related group of minerals all showing in common a prismatic cleavage of 54° to 56° as well as similar optical characteristics and chemical composition

The amphiboles may be said to represent chemically a series of **metasilicates** corresponding to the general formula $RSiO_3$ where R may be **calcium, magnesium, iron, aluminum, titanium, sodium** or **potassium** The crystals of the amphiboles may be in one of the three systems, **orthorhombic, monoclinic** or **triclinic.**

There is a clear parallelism between the amphiboles and the **pyroxenes** The chief difference between the minerals of these two groups lies in the cleavage angles of 56° and 124° for amphibole and 87° and 93° for pyroxene Amphibole crystals are usually long and slender and tend to be simple while pyroxene crystals tend to be complex, short and stout prisms

Amphibole is common in both lavas and deep-seated rocks, though less so in the basic lavas than pyroxene Many of the amphiboles may be developed as metamorphic minerals The following members of the amphibole group are described under their own headings: **actinolite, anthophyllite, cummingtonite, glaucophane, grünerite, hornblende, riebeckite** and **tremolite** Amphibole was so named by Hauy from the Greek word, meaning doubtful, because of the many varieties of this mineral (E S C S)

AMPHIBOLITE. The amphibolites form a large group of rather important rocks of **metamorphic** character As the name implies they are made up very largely of minerals of the amphibole group There may be also a variety of other minerals present, such as **quartz, feldspar, biotite, muscovite, garnet,** or **chlorite** in greater or less amounts

Depending upon the particular amphibole present these rocks may be light to dark green or black, the amphibole usually being in long slender prisms or laths, often quite coarse, sometimes in acicular or fibrous forms

Because the mineral constituents are arranged parallel to the schistosity, amphibolites may have a strongly developed cleavage

The occurrence of amphibolites accompanying gneisses, schists, and other metamorphic rocks of probable sedimentary origin strongly suggests a similar derivation. Yet some amphibolites cut other metamorphic rocks in the manner of dikes or sills. It is very likely that

they have been derived from both original igneous and sedimentary rocks Large masses of amphibolite suggest **gabbroic** stocks Well known areas in which amphibolites are found are New England, New York State, Canada, Scotland, and the Alps (E S C S)

AMPHILINIDEA. An order of **tapeworms** parasitic in fishes (A W L)

AMPHINEURA. The chitons and allied forms, a class of the phylum **Mollusca** The more familiar members are flattened marine animals of oval outline They have a shell composed of a series of separate plates, sometimes concealed within the body The foot makes up most of the ventral surface and the limited **mantle** extends down about it to form a shallow groove Nerve cells are in many cases distributed through the nerve cords so that the nervous system contains no ganglia (See **Ganglion**)

The class contains two orders

Order **Aplacophora** (Solenogastres) Wormlike animals, somewhat cylindrical and elongate Shell lacking

Order **Polyplacophora.** The chitons Flattened and oval, with shell plates They are widely distributed, chiefly in the shallow waters Sometimes used as food (A W L)

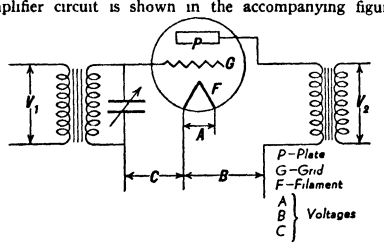
AMPHIOXUS. Commonly used to designate any of the primitive **chordates** called lancelets but more accurately a genus of these animals **Cephalochordata** (A W L)

AMPHIPODA. An order of **crustaceans** including marine and fresh-water species The beach-fleas are among the few which have a common name (A W L)

AMPHISBAENA. Reptilia, Lacertilia The typical genus of a family of **lizards** which are snake-like because of the absence of legs (A W L)

AMPHOTERIC HYDROXIDES. These are hydroxides which can act as either **bases** or **acids**, e g, **aluminum** hydroxide, **iron** hydroxide, etc (R K S)

AMPLIFIER The amplifier is an essential part of a radio communicating system since the energy received by the **antenna** is so small that, without amplification, it could not be transformed into a usable signal The wireless transmission of sound was made possible by the invention of the **thermionic** tube by Dr Lee de Forest, since the amplification so essential to building up the energy received by the antenna to that sufficient to operate a loud speaker is made possible by the use of the **vacuum tube** A vacuum tube amplifier is also part of public address systems, making possible the magnification of ordinary voice levels to where every word may be heard by a large audience A simple amplifier circuit is shown in the accompanying figure



Simple three-element tube as an amplifier

In this a certain variable voltage, V_1, is to be increased, or amplified, with corresponding variations The position of the vacuum tube in the circuit is clearly shown To use the vacuum tube there must be three sources of voltage. The *A* is filament heating, and is sometimes a c, sometimes d c., *B* is plate voltage, and the *C* is grid bias Both *B* and *C* must be unidirectional Several vacuum tubes may be used in series for any desired degree of amplification There are different ways, however, of connecting the tubes in multi-stage amplification, namely, resistance coupling, in which condensers are used to insulate the grids from the B battery, grid leaks are provided to prevent the grids from accumulating high negative potential, and the resistance is inserted in the plate circuit, **impedance** coupling, in which the resistance is replaced by an impedance to decrease the necessary *B* voltage, and the transformer coupling, in which the isolation of the stages so far as the direct current voltages is concerned, is obtained by inductively coupling them with **transformers**, as shown in the figure The transformers themselves contribute to the amplification

Amplification may be accomplished in the **radio frequency** portion of the set, or the **audio frequency** portion Modern receiver practice is such that the input from the antenna is amplified by one to three stages of radio frequency amplification, followed by a detector and one or more stages of audio frequency amplification Radio frequency stages make great use of the screen grid tube instead of the ordinary three element or triod tube, as these are designed to eliminate oscillations which produce the squealing so common in early types of **receivers** The last stage of audio frequency amplification must also deliver power to the loud speaker, and for this reason is often called the power stage In direct current operated amplifiers, the *A*, *B*, and *C* voltages are all taken from batteries which are called, respectively, *A*, *B*, and *C* batteries In an alternating current operated set, the *A* voltage is a low voltage alternating current, obtained as the output of a step-down transformer, while *B* and *C* voltages are unidirectional, obtained from a voltage divider which receives current made unidirectional by a rectifier tube and filters (F T M)

AMPUL or **AMPOULE.** A small sealed glass container for **drugs** that are to be given by hypodermic As they are completely sealed, the contents are kept in their original sterile condition (R S M)

AMPULLA. Any flasklike dilatation, such as the small saccular outgrowth of the water vascular system of starfishes, at the inner end of the tube foot, or the dilated portion of the semicircular canals of the vertebrate **ear** (A W L)

AMPULLIFORM GLANDS. Silk glands of **spiders** which produce the radial lines of the web (A W L)

AMPUTATION. This term is applied to the severance of a limb or other portion of the body Traumatic or accidental amputation is the loss of a part of the body by accident Congenital amputation is the removal of a part of the **fetus** by a constricting band before birth (R M S)

AMYGDALE. Amygdaloid.

AMYGDALIN. Glucosides.

AMYGDALOID. A vesicular rock, commonly a **lava**, whose cavities have become filled with a secondary deposit of mineral material such as **quartz**, **calcite**, **zeolites**, etc The term is derived from the Greek word meaning almond in reference to the frequent almond-like appearance of the filled vesicles which are called amygdales or amygdules (E S C S)

AMYGDULE. Amygdaloid.

ANABOLISM. Metabolism.

ANACONDA. Reptilia, Serpentes A giant **snake**, *Eunectes murinus*, of northern South America, related

to the pythons and boas It attains a length of thirty or more feet and is said occasionally to attack human beings The species occurs in tropical forests and spends much of its life in the water (A W L)

ANAEROBE. Any micro-organism that does not require free **oxygen** or air for growth Among such organisms are the **tetanus**-bacillus, certain forms of **Streptococci**, the organisms of gas gangrene, etc A facultative anaerobe is a micro-organism which usually lives in air or oxygen, but which can, if necessary, live without it (R S M)

ANAEROBIC BACTERIA. Anaerobe.

ANAESTHESIA (ANESTHESIA). Loss of sensation or feeling in a part or a whole of the body This occurs with interruption of sensory impulses of any portion of a nerve or the nerve pathways in the **spinal cord, brain**, or the centers in the brain It can occur as the result of injury or severance, infection, circulatory disturbances, in or about nervous tissue Any **drug** that depresses or inhibits nerve impulses, or **tumor** formation near or in nervous tissue may produce anaesthesia Anaesthesia may or may not be accompanied by motor **paralysis**, depending on whether or not the motor pathways are involved

Block anaesthesia is the blocking of nerve impulses to a part of the body by injection of a drug into or near the nerve supplying that portion of the body

Local anaesthesia refers to anaesthesia confined to a certain portion of the body This is produced by the injection of a drug (novocaine or similar substances) in and about that area This may also be done in very small areas by freezing, as with an ethyl chloride spray

Spinal anaesthesia is produced by the injection of novocaine or related drugs into the spinal fluid in the lower back region By this method anaesthesia of the trunk and lower limbs may be obtained while the patient retains full consciousness The level of anaethesia (lower and upper abdomen and lower chest) may be regulated by the amount of drug, amount of injected fluid and position of the patient There are certain cases in which spinal anaesthesia is indicated, although it is not used as frequently as inhalation anaesthesia

Intravenous anaesthesia is a process in which certain drugs may be injected into the blood stream to produce anaesthesia for short periods Such drugs as barbituric acid derivatives, for example sodium amytal, "evipan," etc Basal anaesthesia is a very light anaesthesia that is produced by drugs given by mouth, by rectum or by injection which requires added inhalation anaesthesia but in much lighter concentration than if the preliminary medication had not been given Avertin, and other narcotic and sedative drugs are used for this purpose The process known as twilight sleep falls in this category A further advantage in their use is the fact that patients need not see the operating room, as the basal anaesthetic is given to the patient in bed in his room

General anaesthesia refers to anaesthesia of the entire body accompanied by loss of consciousness and involving paralysis of all vital functions of the body except the respiration and circulatory centers

The anaesthetic agents most commonly used are as follows (For their chemical and physical properties, see the individual terms)

1 **Chloroform.** At present chloroform is not commonly used in this country for anaesthesia After prolonged or repeated use of chloroform changes in the liver and kidneys may occur It is contra-indicated for children, for long operations, in patients who have diabetes, kidney, or liver disease and in general, when safer anaesthetics are available Its anaesthetic qualities were first pointed out in 1847 by Flournes and by James Simpson

2 **Diethyl ether.** In non-expert hands diethyl ether is the safest of all anaesthesias There are certain disagreeable after effects following its use in any great quantity such as nausea, vomiting and headache It may be given by the open drop method or through a closed machine mixed with oxygen or with nitrous oxide, ethylene, or cyclopropane It also can be given by rectum, the diethyl ether being mixed with a bland oil Diethyl ether (which is commonly referred to by the group name, that is, simply as "ether") was discovered in 1540 but it was over three hundred years before it was used as an anaesthetic in surgery Henry Hickman of England first made successful experiments with anaesthesia by inhalation in 1820, but no one was impressed with his discoveries Crawford W. Long first used ether intelligently in 1842 but did not publicize its use until after Morton and Jackson claimed priority William Morton at the suggestion of Charles Jackson, a chemist, experimented with ether as an anaesthetic agent and in 1846 demonstrated it before the staff and students of the Harvard Medical School in the Massachusetts General Hospital All modern methods date from this public demonstration Of all anaesthetic agents ether is the most commonly used, usually in conjunction with other gaseous agents It should not be given in the presence of lung diseases

3 **Nitrous oxide.** (Laughing gas) When inhaled it produces temporary asphyxia and loss of consciousness It is given mixed with oxygen and is usually given only for minor procedures For longer and deeper anaesthesia, ether is given with the gas When administered by an expert it is a safe anaesthesia It should not be given to infants or when circulatory disease is present

4 **Ethylene** When mixed with oxygen, ethylene is highly explosive in the presence of fire For deep anaesthesia it is given with ether It is a very safe and satisfactory anaesthesia, and one that is commonly used

5 **Cyclopropane** (See **Hydrocarbons**) For deep anaesthesia cyclopropane is given mixed with ether It is explosive when mixed with oxygen in the presence of fire It is a very safe and commonly used anaesthesia when given by one expert in its use

6 **Ethyl chloride.** This is an inflammable liquid which vaporizes when sprayed on a mask It is used for brief, light anaesthesia for minor procedures and as a preliminary agent to put a patient to sleep before giving him ether Its use alone is not as safe as other anaesthetic agents It is also used for local anaesthesia, being sprayed directly on the skin

7 **Avertin** (Tribromethylalcohol) Avertin is a fluid preparation which, when given by rectum produces a light anaesthesia For surgical procedures of any degree, anaesthesia must be supplemented by inhalation agents It is used for the purpose of reducing the amount of inhalation anaesthesia It also removes the element of fear before an operation since it is given while the patient is in his room in bed (R S M)

ANALCIME Analcite

ANALCITE. Analcite, sometimes called analcime, is a common **zeolite** mineral, a hydrous **soda-aluminum silicate.** It crystallizes in the **isometric** system, hardness, 5–5 5, specific gravity, 2 2, vitreous luster, colorless to white, but may be grayish, greenish, yellowish or reddish It resembles **garnet** but is softer, and is distinguished from **leucite** only by chemical tests

There are many excellent European localities In the United States at Bergen Hill and West Paterson, N J, Keweenaw County, Mich, and Jefferson County, Colorado Nova Scotia furnishes beautiful specimens

Analcite is a relatively common mineral and occurs with other zeolites in cavities and fissures in basic **igneous** rocks, occasionally in **granites** or **gneisses.** It seems to occur as a replacement and perhaps in some cases as a primary mineral crystallizing from a **magma** rich in soda and water vapor under pressure The name

analcite is derived from the Greek word meaning weak, in reference to the weak electric charge developed when heated or subjected to friction (E S C S)

ANAL FEELERS. Posterior sensory appendages such as the anal cirri of annelid worms and the cerci of insects (A W L.)

ANALOGY. Homology.

ANALYTIC FUNCTIONS OF A COMPLEX VARIABLE. A complex variable w is said to be a function of a complex variable z when to each value of z in a certain region there corresponds a value of w The function may be single-valued or multiple-valued

At a given point of a region let Δz be an increment of the variable z and let Δw be the corresponding increment of a function $w = f(z)$, and form the ratio $\Delta w/\Delta z$ If this increment ratio $\Delta w/\Delta z$ approaches a unique limit when $\Delta z \to 0$, which is independent of the way in which $\Delta z \to 0$, then the function $f(z)$ is said to be differentiable at the point, and the limit is denoted by $f'(z)$ or dw/dz and is called the derivative of w

An analytic function of a complex variable, $w = f(z)$, is a function which is differentiable everywhere in a certain region with the possible exception of a finite number of points, called singular points

In order that a variable $w = u + iv$ may be an analytic function of the complex variable $z = x + iy$, it is necessary and sufficient that the following conditions,

$$\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}, \quad \frac{\partial u}{\partial y} = -\frac{\partial v}{\partial x},$$

called the Cauchy-Riemann differential equations, are satisfied

If the function $w = u + iv$ is an analytic function of the variable $z = x + iy$, then both the real and imaginary parts u and v will satisfy **Laplace's equation.**

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0, \quad \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} = 0.$$

Two such functions u and v are called conjugate functions (L L S)

ANALYTIC GEOMETRY. Analytic geometry is essentially the study of geometric problems by use of algebraic (analytic) methods

Elementary **geometry** had its beginnings with the ancient Greeks and most of its propositions were discovered by them The first systematic treatment of this subject which we have was written by Euclid about 300 B C , our present geometry textbooks are merely modifications of this great work of Euclid This development of geometry was attained by use of purely geometric methods and with almost no use of algebraic methods Indeed, **algebra** was practically unknown to the ancient Greeks

Elementary algebra originated among the ancient Hindus and was later developed further by the Arabs of the earlier middle ages The stage of development indicated by our present elementary textbooks of algebra was not reached historically until after the close of the middle ages Thus, elementary geometry and algebra developed historically as two separate branches of mathematics

The development of elementary geometry made little progress beyond the stage of the ancient Greeks until the seventeenth century, when algebra was first applied systematically to the treatment of geometric questions In 1637 the French mathematician and philosopher René Descartes published his great work *"La Géométre,"* in which he showed how algebraic methods could be applied to the study of geometry He thus became the recognized founder of analytical geometry Almost simultaneously, another Frenchman, Pierre Fermat, also discovered the idea of applying algebra to geometry systematically, but his work was not published and recognized until much later

While analytical geometry deals with a much more extensive subject-matter than does elementary geometry, its especial value lies in its new method, by which geometric properties of figures are treated systematically by means of algebraic methods

The methods of solution of problems and proofs of theorems in elementary geometry involve a great many special and ingenious devices, and no general and uniform procedure is apparent Analytical geometry, however, furnishes simple, general precedures for the solution of problems, which greatly simplifies the study of geometry These new methods also enable us to solve in a simple manner many problems of geometry not considered by the ancient Greeks or problems very difficult of solution by the methods of elementary geometry Thus, analytical geometry gives a new powerful tool for the study of old and new problems of geometry

The essence of the new method of analytical geometry lies in its representation of points by sets of numbers and its representation of geometric figures by algebraic equations

Some idea of the subject-matter usually treated in Analytic Geometry may be gained by consulting the following topics

Rectangular Coordinates, Polar Coordinates, Locus of an Equation, Equation of a Locus, Curves in a Plane, Graph of a Function, Slope of a Line, Straight Line in a Plane, Circle, Conic Sections, Ellipse, Parabola, Hyperbola, Higher Plane Curves, Parametric Equations, Trigonometric Curves, Exponential Curve, Empirical Equations, Transformation of Coordinates, Plane, Straight Line in Space, Surfaces, Sphere, Quadric Surfaces, Curves in Space (L L S)

ANALYTICAL CHEMISTRY. Analytical chemistry is that branch of the science of chemistry which deals with the detection or identification of a substance or a part of the same, either element or radical, by qualitative tests and the estimation of the same by quantitative tests The difficulties encountered are in part caused by the chemical inertness of a given unknown substance itself, and in part to the other substances that may accompany a given unknown material It is comparatively easy to analyze **air** for **oxygen,** qualitatively by heating **copper** or **iron** metal in air and observing the formation of copper or iron oxide on the surface of the metal, and quantitatively by subjecting an isolated measured volume of air to an oxygen-absorbent, such as a **cuprous** salt solution in **hydrochloric acid** or **ammonium** hydroxide, or **sodium** pyrogallate solution, and measuring the non-oxygen residue

The reaction with or resistance to action of various selected reagents serves to indicate whether an unknown substance is or is not a known substance Analytical chemistry, therefore, demands the knowledge of a vast range of reactions of individual substances, the ability to apply this knowledge in systematic sequence, and the experience to make correct observations and deductions

Quantitative analysis may be said to be applied qualitative analysis, since the methods used in the quantitative estimation of a substance depend largely upon the accompanying substances Furthermore, a good qualitative analysis should furnish evidence of the quantitative order of magnitude of each substance present

Methods of treating an unknown substance, in order to establish its identity, are known as dry or wet Dry methods involve the heat treatment at various temperatures either alone or with various reagents Assay methods for some metals, e g , **silver, gold,** and many organic methods are of this type Wet methods involve first the problem of getting the substance into solution by some reasonable treatment, or its proved resistance to this treatment Such simple and apparently inconsequential matters as the size of the particles of a sub-

stance tested or the time allowed for treatment may determine the correctness or incorrectness of a given test The technique demands ability to attend to details

In the detection, identification and estimation of substances methods must be invented to cope with gases, liquids, solids, with active and inactive, and with similar and dissimilar substances The greater the differences in chemical behavior, the easier it is in general to accomplish the analytical purpose The principles of procedure involve

Solubility of substances in water

Reactivity of substances
(a) With acids
(b) With bases
(c) With certain salts
(d) With certain other chemicals

(1) In water as a medium,
(2) By the application of high temperature or electricity

General, group, and specific (individual) tests.

Much information can be gained by such simple preliminary examinations as those concerned with (a) color, ordinary and if solid of the fine powder, (b) odor, (c) general and detailed appearance of the specimen, (d) hardness, if solid, (e) density, (f) approximate solubility, in water, (g) behavior on heating *without* free access of air (as in a test tube), (h) melting, boiling, sublimation, transition, decomposition point, if any

The accepted system of qualitative analysis in which 23 metals are separated and identified in *solution* of their nitrates well illustrates the principles under discussion Arranging these in the order of group separation, the reaction serving to separate the group is stated

In the case of Group II, a sub-group treatment with yellow ammonium sulfide (ammonium sulfide containing dissolved sulfur) is used to dissolve **arsenic, antimony** and tin sulfides Followed by filtration

Analytical Group Number	Metals of the Group	Precipitate	Reaction Used to Separate the Group
I.	Lead Mercurous Silver	$PbCl_2$, white HgCl, white AgCl, white	Addition of hydrochloric acid to the cold solution resulting in the precipitation of these chlorides followed by filtration The separation of lead is not complete
II, A.	Mercuric Lead Bismuth Cupric Cadmium	HgS, black PbS, black Bi_2S_3, black CuS, black CdS, yellow	Addition of hydrosulfuric acid to the properly acidified (0 25 normal hydrochloric acid) filtrate from Group I resulting in the precipitation of these sulfides Followed by filtration
II, B	Arsenic Antimony Tin	As_2S_3, As_2S_5, yellow Sb_2S_3, Sb_2S_5, orange SnS, brown, SnS_2, yellow	
III.	Iron Chromium Aluminum	$Fe(OH)_3$, red-brown $Cr(OH)_3$, green $Al(OH)_3$, white	Addition of ammonium hydroxide to the properly prepared filtrate from Group II, resulting in the precipitation of these hydroxides Preparation involves removal of hydrogen sulfide by boiling, and the oxidation of ferrous to ferric Followed by filtration
IV	Cobalt Nickel Manganese Zinc	CoS, black NiS, black MnS, pink ZnS, white	Addition of ammonium sulfide to the filtrate from Group III, resulting in the precipitation of these sulfides Followed by filtration
V	Barium Strontium Calcium	$BaCO_3$, white $SrCO_3$, white $CaCO_3$, white	Addition of ammonium carbonate to the properly prepared filtrate, from Group IV, resulting in the precipitation of these carbonates Preparation involves removal of ammonium salts by evaporation and dry heating Followed by filtration
VI	Magnesium Sodium Potassium Ammonium		Individual tests for these in properly prepared portions of the filtrate from Group V, except ammonium must be tested for in the original material

The groups are separately treated for the final identification of the presence or absence of each member by the use of reactions whose effectiveness in separation and identification have been found satisfactory in each case

The **anions** or the acid radicals of inorganic salts have been classified by Bunsen in 1878 in the following way

Group I Silver nitrate produces a precipitate insoluble in nitric acid while barium chloride produces no precipitate: chloride, bromide, iodide, cyanide, hypochlorite, ferrocyanide, ferricyanide, thiocyanide

Group II Silver nitrate produces a precipitate which is soluble in nitric acid while barium chloride produces no precipitate sulfides, tellurides, selenides, nitrites, acetates, cyanates

Group III· Silver nitrate produces a white precipitate soluble in nitric acid and barium chloride also produces a precipitate soluble in nitric acid sulfites, selenites, tellurites, phosphites, carbonates, oxalates, iodates, borates, molybdates, tartarates, citrates, metaphosphates and pyrophosphates

Group IV: Silver nitrate produces a colored precipitate soluble in nitric acid and barium chloride also produces a precipitate soluble in nitric acid orthophosphates, arsenates, arsenites, vanadates, thiosulphates, chromates and periodates

Group V Both silver nitrate and barium chloride produce no precipitate: nitrate, chlorate, perchlorate, persulphate and manganates

Group VI: Silver nitrate produces no precipitate while barium chloride produces a precipitate insoluble in nitric acid sulfates, fluorides, fluosilicates
Group VII Non-volatile acids which form precipitates with both silver nitrate and barium chloride Both precipitates are insoluble in nitric acid silicate, tungstinate and anions of some rare elements
After identifying the group into which the anion falls recourse must be made to confirmatory tests which can be found under the corresponding acid (R K S)

ANAMNIA. Vertebrates which do not develop an **amnion** during embryonic life The group includes the cyclostomes (See **Cyclostomata**), **fishes,** and **amphibians** (A W L)

ANAMORPHISM. A term proposed by Van Hise in 1904 to designate the deep-seated constructive processes of **metamorphism** by which new complex (metamorphic) minerals are formed from the pre-existing simpler minerals, as contrasted with the surface alteration of rocks due to **weathering** and **cementation,** termed katamorphism (R M F)

ANASARCA. General dropsy—the presence of **edema** in the cellular tissues of the body This commonly occurs in certain stages of heart and kidney disease, etc (R S M)

ANATASE. **Octahedrite.**

ANATEXIS. A term proposed by Sederholm in 1907 for the supposed end-processes of deep-seated **metamorphism** resulting in the partial or complete remelting of a specific type of rock in situ (R M F)

ANATOMY. In zoology, the structure of the body, also the science embracing our knowledge of structure The term is usually applied to gross structure while the minute structure is treated under **histology,** but the two fields are sometimes distinguished as gross anatomy and microscopic anatomy Another aspect of anatomy is **morphology** While this term applies properly to all structure it is usually employed in connection with external anatomical features of importance in **taxonomy**
The simplest animals (**Protozoa**) are made up of a single **cell,** hence their structure is essentially that of the cell Parts which are developed for the performance of special functions are known as organelles With the grouping of cells to form more complex bodies a division of labor becomes possible and cells are specialized to perform different functions for the benefit of the individual In the **sponges** this association is loose and the cells preserve a greater range of independent action than in other complex animals The body is organized about a central cavity and is perforated by canals through which currents of water pass, carrying food and oxygen to the cells of the interior
Above the sponges the cells of the body are more closely co-ordinated and are found in aggregates of varying complexity The simplest aggregate is an association of similar cells for the performance of a special function, such a structure is called a **tissue** One or more tissues may also enter into the formation of structures called **organs** which also perform special tasks, based on the associated functions of the component cells and tissues Thus the stomach digests food through the motion produced by its muscular tissue, the secretion by its glandular lining, and the co-ordination of all parts by its nervous structures.
The initial differentiation of the body in animals above the sponges is the formation of two or three **germ layers** from which the various tissues, organs, and systems are derived At the maximum ten systems appear the **skeletal system** provides support, the **muscular system** produces motion, the **integumentary system** is a protective covering which also takes part in interchange with the environment, the **digestive system** receives food and prepares it for absorption, the **respiratory system** provides oxygen, the **excretory system** removes wastes, the sensory (**sense**) **organs** receive stimuli from the environment and from the body itself and with the **nervous system** provide for co-ordination of the entire body, the **circulatory system** distributes materials throughout the organism, and the reproductive system (See **Reproduction**) perpetuates the species There is some overlapping of these functions in many animals
A consideration of the anatomy of any animal involves all of the details of development of these basic structures and systems The anatomy of **vertebrates,** and human anatomy in particular, has become an intricate subject because of its relation to medicine Some of the details of the general subject will be found under the various systems, under the principal groups of animals, under appendages, and under special anatomical terms too numerous to be listed here (A W L)

ANCHOR ICE. **Ground ice.**

ANCHOR RING. **Torus.**

ANCHOVY. Pisces, Teleostei Any of numerous small sardine-like fishes (**Pisces**), related to the herrings, whose richly flavored flesh is esteemed as a hors d'oeuvre Especially the common anchovy, *Engraulis encrasicholus,* of the Mediterranean and the east Atlantic (A W L)

ANDALUSITE. An **aluminum silicate** corresponding to the formula Al_2SiO_5, this mineral is usually found in **metamorphic** rocks with **sillimanite, kyanite, garnet,** and **tourmaline** It crystallizes in the **orthorhombic system,** developing coarse prisms of approximately square cross-section, but may be massive or granular It shows a distinct cleavage parallel to the prism, hardness, 7 5, specific gravity, 3 16–3 20, vitreous luster, colorless to white, gray, brown, greenish or reddish, streak, white, transparent to opaque
This mineral is named for its original locality, Andalusia, Spain A variety of andalusite, chiastolite, has carbonaceous impurities so oriented that they produce a cross or a tesselated figure at right angles to the prism Chiastolite comes from the Greek word meaning a cross Localities are the Urals, the Alps, the Tyrol, The Pyrenees, Australia and Brazil In the United States at Standish, Maine, Sterling and Lancaster, Massachusetts, Delaware County, Pennsylvania, and Madera County California
When clear it is used as a gem, and it has also been used to manufacture porcelain for spark plugs (E S C S)

ANDESINE. **Feldspar.**

ANDESITE. A term originally applied to a porphyritic **lava** from the Andes Mountains by Leopold Van Buch, in modern terminology andesite is an extrusive **igneous rock,** the surface equivalent of **diorite** In other words, it is composed chiefly of **plagioclase,** corresponding in chemical composition to **oligoclase** or **andesine** together with **biotite, hornblende,** or **pyroxene** in varying quantities
Andesites are of rather widespread occurrence, being found in the Rocky Mountains, California, Alaska, South America, and at many other foreign localities (E S C S)

ANDRADITE. **Garnet.**

ANDROGENESIS The development of an egg after the entry of the male germ cell without the participation of the egg nucleus See also **Merogony** (A W L)

ANDROMEDA. (Map, page 306) The brighter stars of this **constellation** make an almost straight line between the constellations of **Perseus** and **Pegasus** The most famous feature of the constellation is the great **nebula** This is the only **spiral** which is actually visible to the naked eye and may be distinguished as a faint

blur against a moonless sky close to the faintest star in the constellation which appears on the map (page 306) This is the largest of the spirals and is distant from the earth about 800,000 **light years**

The bright star in Andromeda closest on the map to Perseus was called Almach by the Arabs and is a **double star**, one of the most beautiful in the sky in a small telescope One component is a brilliant orange and the other a striking emerald color Careful examination in a large telescope shows the green component to be also a double star (W K G)

ANDROMEDES. Andromedes is an alternative name for the **Bielid meteor shower** which is observed the latter part of November This alternative name comes from the fact that the **radiant point** is in the **constellation of Andromeda.** (W K G)

ANEMIA. This term signifies a deficiency or reduction in the quantity or quality of the red **blood** cells This may appear as a reduction in the number of red blood cells or as a diminution in the amount of **hemoglobin** in these cells, or both

Normally the red blood cells average 4,500,000 to 5,000,000 cells per cubic centimeter and the hemoglobin varies in healthy individuals from 80% to 100%

Anemia occurs as a result of (1) hemorrhage or severe or continued loss of blood, (2) increased destruction of blood cells, or (3) formation of defective cells by the bone marrow

The symptoms of acute hemorrhage depend on the quantity of blood lost and the rapidity with which it is lost Such acute loss of blood may occur during or after childbirth, traumatic injuries to large blood vessels in accidents, in the lung when a tuberculous cavity erodes an artery, in an ulcer of the stomach or intestine, when a vessel is eroded in a similar manner, or in any diseased condition in which the continuity of a blood vessel is severed In acute intoxication with lead or **benzene** and in fulminating infections as **septicemia**, anemia may be produced rather quickly, although as a rule several days are required to produce the same degree of anemia as is seen with the more abrupt loss of blood in hemorrhage

The symptoms and signs of acute loss of blood are dramatic—the patient feels faint, becomes white and clammy, is apprehensive, nervous and thirsty The pulse increases rapidly in rate, the blood pressure falls, respiration becomes rapid and shallow, and if the hemorrhage remains unchecked by the lessened blood pressure, surgical shock, followed by coma and death, occur These symptoms of hemorrhage are due to loss in volume of the blood and lack of oxygen carrying capacity of the red blood cells

If the hemorrhage can be stopped at any stage of the above picture, and blood given in large amounts by transfusion, the patient usually recovers **Morphine** is of considerable value in its quieting effect in hemorrhage cases While waiting for a donor in hemorrhage cases lives have been saved by temporarily preserving the blood volume by infusion into the veins of normal saline (physiologically normal **sodium** chloride solution), **glucose**, or mixtures of **gum acacia** In cases of slow internal hemorrhage where the hemorrhage cannot be stopped by operative measures it is sometimes inadvisable to raise the blood volume by transfusion, as this increases the blood pressure It is wiser to allow the hemorrhage to stop by low blood pressure and morphine, provided the blood pressure does not drop below a critical level

Anemia of the chronic type accompanies many diseased states The most common causes are·

(1) Slow hemorrhage over long periods of time The most common sites of hemorrhage of this kind are hemorrhoids and gastric or duodenal ulcers

(2) Defective blood formation as is seen with exhaustion of the bone marrow which manufactures the red blood cells The chief agents responsible for such a condition are certain poisons as **benzene, arsphenamine,** over-exposure to **radium** and **x-ray** Tumor tissue crowding out or displacing the blood-forming tissue will give the same picture

(3) Blood distribution. In this group the bone marrow is normal and supplies adequate red blood cells However, these cells are destroyed in the circulatory system Certain poisons as some of the coal tar derivatives, which are advertised as pain and headache remedies, are frequently responsible Lead compounds also cause a similar anemia Many of the infectious diseases or infections, especially when the illness is prolonged, result in an anemic state, varying in degree Anemia of this type often accompanies pregnancy

In cancer anemia is common and in advanced cases, with **metastasis**, may be severe The cause of the anemia is not known but it is thought to be due to a circulating toxin from the tumor

There are several other types of anemia that occur the etiology of which is not known Pernicious **anemia** falls in this category

Nutritional anemia is often seen in childhood and results principally from inadequate intake of **iron** and **vitamins**, lack of sunshine, poor diet and unhygienic surroundings.

The symptoms of chronic or secondary anemia depend on the condition or disease causing the anemia and, also, upon the degree of anemia In general the symptoms are those of weakness, tiredness after slight or no exertion, poor color, rapid pulse, dizziness and palpitation of the heart The treatment depends on eradication of the cause, if possible to do so, by surgical or medical means If this cannot be done the treatment will only be palliative In severe cases transfusion is necessary, plus the giving of blood-building substances by mouth and hypodermically, plus fresh air and sunlight (R S M)

ANEMOMETER One of a variety of instruments for measuring the velocity of the wind The most common type resembles a windmill in principle, having either a fan-like vane wheel or, in the widely used "cup anemometer," a whirligig arrangement of four cup-like vanes, the speed of whose revolution about a vertical shaft is proportional to the wind velocity if the velocity

Design of cup anemometer

is not too great Another type utilizes the pressure due to the wind blowing against a vertical surface, as measured by the compression of a spring or by a tube connected with a pressure gauge A modification of this type consists of a metal plate suspended by its upper edge and blown into an oblique position by the pressure of the wind All such instruments must be experimentally calibrated (See **Aerodynamics**) (L D W)

ANEMOTROPISM. Orientation of the body in relation to the wind (A W L)

ANEROID BAROMETER. Barometer.

ANEURYSM. A sac formed by dilatation of the walls of an artery which communicates with the interior of the artery and is therefore filled with blood This condition is in the greatest majority of cases a manifestation of late syphilis

True aneurysm is the term used when the wall of the sac is made up of at least one of the coats of the artery

False aneurysm is the term used when the walls of the

artery have been destroyed and the sac is made up of surrounding tissues and by newly formed connective tissue

Arteriovenous aneurysm is the term used when there is a connection between an aneurysm and a large vein (R S M)

ANGEL-FISH. Pisces A species, *Squatina squatina*, intermediate between the **sharks** and **rays** Also applied to several tropical genera of bony fishes (A W L)

ANGINA PECTORIS. A symptom-complex which may be seen with disease or exhaustion of the heart muscle. It is characterized by paroxysmal attacks of severe pain in the **sternal** region over the heart, accompanied by extreme anxiety and a sense of impending death

Many factors participate in the causation of angina, some of which are not understood It has been regarded as a sort of neuralgia of the cardiac nerves, as the result of insufficient blood supply to the heart muscle thereby causing a "cramp" of the muscle, or the result of tension in the ventricles of the **heart** or more likely in the **aorta** itself

The incidence of this disorder is increasing due to the strain and habits of present-day life It is, therefore, not as common in rural districts or in laboring classes It is more common in educated and emotional subjects Changes in the heart muscle after acute illnesses such as influenza, rheumatism, tonsillitis, etc, predispose to this condition in older subjects Actual attacks are usually precipitated by some form of physical effort, sudden emotional tension, or after eating a heavy meal Often a person suffering from an attack, attributes the pain to "acute indigestion" Many sudden deaths are reported from this latter vague term when they are due to angina—one does not die from acute indigestion

The onset of an attack is acute Usually after some exertion or emotional outburst the subject is seized with sharp pain over the left breast, accompanied by a sense of constriction of the chest and, often, a feeling of impending death The pain at times may be in the upper abdomen, frequently it shoots down the left arm The pain at times may be agonizing, so much so that the patient remains motionless without crying out The skin is ashen and clammy Other attacks may be less acute

Death may occur with the first attack or may not occur for years, the patient surviving numberless acute episodes Death is just as apt to occur with a mild as with a severe attack

The prognosis of this disease is not good unless the precipitating factor can be removed

Treatment during an attack consists of absolute mental and physical rest Large doses of **morphine** by hypodermic are necessary The **nitrites** are next in value Ethyl alcohol is frequently of value and is a time-honored remedy

During recent years various surgical procedures have been carried out in specially selected cases Removal of the **thyroid gland** has relieved the pain by interruption of the nerve pathways and by further substituting a condition of controlled **myxedema**, lessening activity on the part of the patient

Other operations for the relief of angina consist of severing of pain pathways to the brain or blocking these pathways by injection with alcohol

It is highly questionable whether the pseudo-angina caused by cigarettes, tea, or coffee ever results fatally They do not usually cause real angina pectoris (R S M)

ANGIOMA. A **tumor** which is composed mainly of **blood** vessels (hemangioma) or of **lymph** vessels (lymphangioma) (R S M)

ANGIONEUROTIC EDEMA. This **allergic** disease is characterized by localized transient swelling of the skin or mucous membrane of the body The swelling may persist for a few hours or days If the swelling occurs in the throat death may occur by obstruction of the air passages One form is inherited Other forms are due to sensitivity to some **protein** as in **hives** The disease is really a form of "giant hives"

The swellings may be accompanied by prickling, itching, and burning sensations If the mucous membrane of the gastro-intestinal tract is involved in these localized swellings, severe abdominal pain with vomiting occurs and may simulate appendicitis, obstruction of the intestines, or some other abdominal accident

Treatment is unsatisfactory as regards future attacks. **Adrenalin** by hypodermic aids during the acute attack (R S M)

ANGIOSPERMS. The angiosperms are **spermatophytes** in which the ovule matures to form a seed which is completely enclosed in an ovary, in contrast with the **gymnosperms**, spermatophytes which have the seed borne exposed on the surface of a scale Angiosperms are more familiarly known as flowering plants, and the characteristic feature is the **flower**

As a rule the angiosperms are land plants growing in a fixed position A few of them have returned to the water as a habitat, but these are obviously reversions to an aqueous life and not primitive forms pointing the way along which angiosperms evolved Tremendous diversity in size is found in this group, some of the so-called duckweeds are spherical masses of cells less than a millimeter in diameter, at the other end of the scale are the giant Australian Eucalyptus trees 200–300 feet high The variety of form shown in the angiosperms is nearly endless, each of the 130,000 and more species has a distinct appearance by which it can be distinguished Some are tiny, herbaceous plants which live but a few weeks, others are giant trees living hundreds of years

Included in the angiosperms are two types of plants. One, held to be the more primitive type, has a woody **stem** which has a much more complex structure than that found in the stems of Gymnosperms The other has an herbaceous stem, a form of stem which dies to the ground at the end of the growing season Herbaceous plants may live through to the next growing season by means of perennial roots and underground stems, or they may die completely, only the seeds surviving This habit fits herbaceous plants especially to live in regions having growing seasons alternating with cold or dry periods Herbaceous plants, or herbs, are most abundant in temperate and arctic regions

The internal structure of angiosperm stems is much more specialized than that of gymnosperms The xylem contains not only tracheids but also vessels and fibers The vessels are open tubes of considerable length through which water is rapidly carried The fibers give strength to the stem In the **phloem** there are sieve tubes and companion cells, and also numerous fibers The latter are often of great value to man Linen, for example, is made from the phloem fibers of the flax plant In the woody angiosperms and in many of the herbaceous forms there is a well developed **cambium**

The leaves of angiosperms are of many shapes and sizes, but are typically thin and contain numerous veins In the axils of each leaf there is a bud which may develop into a branch or a flower

But all bear flowers at some time during their lives The flower is the basis for classifying angiosperms A flower is a special shoot or branch which is adapted to advance **pollination** and **fertilization** Flowers may arise from the **axils** of ordinary leaves or may be found in the axils of special modified leaves called bracts A flower consists essentially of two organs stamens in which the pollen grains are formed, and pistils in which the ovules are found In addition to these two essential organs, there are usually accessory structures, which collectively make up the perianth These accessory structures include the calyx, composed of separate parts called sepals, and the corolla, composed of petals. The latter

are usually bright-colored and are assumed to attract insects or other animals which effect **pollination.**

The mechanical transfer of pollen grains from the stamens to the pistil is known as pollination In many flowers the wind is the agent effecting pollination, in others, insects, and in a few, water or other agents

Having reached the pistil, the pollen grain germinates, forming a slender tube called the pollen tube, which grows down through the tissues of the pistil until it reaches the ovule The latter is enclosed in one or two layers called the integuments, in which there is a minute hole called the micropyle The pollen tube grows through this micropyle and into the embryo sac The embryo sac is typically a seven-celled structure with rather definite characteristics At the end farthest from the micropyle there are three small cells called antipodal cells which are of little importance At the opposite end, nearest the micropyle, there are three cells, one of which is the egg cell The remainder of the embryo sac is a large cell in the center of which there are two nuclei close together These two nuclei soon unite, forming the fusion nucleus

In angiosperms two male nuclei are discharged from the pollen tube into the embryo sac One of these nuclei unites with the egg nucleus, forming the **zygote,** from which the **embryo** develops The other nucleus unites with the fusion nucleus in the center of the embryo sac, forming the endosperm nucleus There are therefore two separate nuclear fusions in the embryo sac This is characteristic in all angiosperms and is called double fertilization

From the fertilized egg or zygote the embryo is formed Usually this embryo is an elaborate body consisting of one or two seed leaves or cotyledons, a primitive root or hypocotyl and a primitive bud or epicotyl Often the embryo is surrounded by a mass of nutritive material known as endosperm which develops from the endosperm nucleus Surrounding this there are one or two seed coats, derived from the integuments This whole structure is the **seed,** which is contained in the ripened ovary or **fruit**

The angiosperms are separated into two large groups, the **dicotyledons** and the **monocotyledons** The origin of the angiosperms is as yet unknown They are known to have existed in the **Jurassic** period, but were not at all abundant until the **Cretaceous** period (See **Paleobotany**) The earliest **fossil** members of this group are well differentiated plants which give little indication as to their possible ancestry Within the group, **evolution** seems to be from the woody type to the herbaceous, and from plants with flowers having an indefinite number of parts arranged in spiral manner and not fused As evolution progressed the number of flower parts became reduced and definite and finally fused In many cases great irregularity replaced the more primitive regularity The angiosperms are the dominant land flora of the present day (R M W)

ANGLE OF ATTACK. The angle of attack is the acute angle included between the direction assumed by the wind relative to an **airfoil** and some basic reference chord of the airfoil There are two of these reference chords The one employed for general and structural use is the geometric chord, the other, the zero-lift chord When the airfoil has a flat lower surface, an element of this surface, parallel to the air stream, is taken as the geometric chord In double-cambered airfoils, the geometric chord is taken as the straight line connecting the centers of the leading and trailing edges

The zero-lift chord is that imaginary line run through the airfoil, from the trailing edge, which would parallel the windstream when the attitude of the airfoil to the wind is that for no lift The angle of attack to the zero-lift chord is useful chiefly in **aerodynamic** studies, as it varies with the lift by simple straight line relationship, whereas the angle of attack to the geometric chord varies with lift by a straight line with intercept relation (F T M)

ANGLE OF REPOSE. The angle of repose is the maximum angle with the horizontal at which loose material such as grain, sand, coal, or stone will retain its position without tending to slide The moisture content and the distribution of the fine and coarse particles have a marked effect on the value of this angle The angle of repose is an important factor in the design of **retaining walls,** earth **dams,** and embankments and is particularly valuable in the design of storage bins and **bunkers** since the allowable surcharge as well as the active horizontal pressure depends upon its value Tables giving the approximate value of the angles of repose for various materials will be found in most Civil Engineering handbooks (C W C)

ANGLER-FISH. Pisces, Teleostei Bottom-feeding fishes (**Pisces**) of the family Lophiidae named from the tufted tentacle on the head which is said to attract prey. A common species is *Lophius piscatorius* (A W L)

ANGLES. An angle is a fundamental mathematical concept, being one of the simple geometrical elements

A plane angle is generated by the rotation in a plane of a half-line about a fixed point, called the vertex of the angle, from a position called the initial side of the angle to a final position called the terminal side of the angle An angle generated by rotation in a counter-clockwise sense is called positive, by clockwise rotation negative Such an angle, in which a sense of rotation is distinguished, is called a directed angle, as shown by the two examples given (Figures 1 and 2)

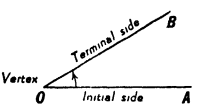


Figure 1

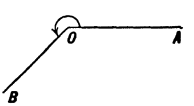


Figure 2

Co-terminal angles are angles which have the same initial and terminal sides They differ in measure by a multiple of 4 right angles The numerically smallest of a set of co-terminal angles is called the principal value of the set

Complementary angles are angles whose sum is a right angle, supplementary angles are angles whose sum is 2 right angles.

Quadrantal angles are angles which are multiples of a right angle, if such an angle is placed with its vertex at the origin of a set of **rectangular co-ordinate** axes and its initial side along the positive X-axis (in so-called standard position), its terminal side will fall along one of the axes

Besides plane angles, there are **dihedral angles** and **spherical angles** (L L S)

ANGLESITE. The mineral anglesite is naturally occurring **lead** sulfate, crystallizes in the **orthorhombic** system and may be found mixed with **galena,** from which it is usually formed by **oxidation.** Hardness, 3, specific gravity, 6 12 to 6 39, luster, adamantine to vitreous or resinous, transparent to opaque, streak, white; colorless to white or green but may be rarely yellow or blue.

It is used as a source of lead There are many foreign localities, and in the United States it has been found in large crystals in the Wheatley Mine, Phoenixville, Pa ; also in Missouri, Utah, Arizona and Idaho

It is named from Anglesey, England (E S C S)

ANGLE-WING. Insecta, Lepidoptera **Butterflies** of the genus **Polygonia** Their wings are sharply angular but no more so than those of some other species. (A W.L.)

ÅNGSTRÖM. The angstrom, or angstrom unit, named for the pioneer spectroscopist Ångstrom, is the unit of length customarily used in expressing **wave lengths** of **light.** It is equal to 0 00000001 cm or 10^{-10} meter, and is therefore sometimes called the "tenth-meter" The wave length of sodium (yellow) light is about 5890 angstroms (A) The micron, or 0 001 millimeter, used for approximate designations of wave length in the visible and infrared, is 10,000 A Both the angstrom and the micron are convenient also in expressing other very small lengths, such as the thickness of liquid films, etc. (L D W)

ANGUCLAST. Phenoclast.

ANGULAR ACCELERATION. Angular Velocity and Angular Acceleration.

ANGULAR MOMENTUM. The product of moment of inertia and angular velocity The analogy between concepts relating to translational motion and to rotation is emphasized by reference to both linear and angular velocity, acceleration, and momentum For rotational motion, **angular velocity** takes the place of linear velocity and **moment of inertia** takes the place of mass Hence the angular momentum of a body with respect to a given axis of rotation is defined as the product of its moment of inertia with respect to that axis by its angular velocity about that axis It must be regarded as a **vector** quantity, whose magnitude is that of the product just stated and whose direction is that of the angular velocity

The principle of conservation applies to angular as well as to linear momentum That is, no change of configuration within a system, uninfluenced by external forces, can alter the total angular momentum of the system Thus, a slowly rotating swarm of particles, like a cloud of gas in space, if it contracts under its own gravitational attraction with attendant decrease in moment of inertia, must rotate the more rapidly to keep its angular momentum constant Again, if a person, whirling about on tiptoe, with arms extended, suddenly brings the arms down to the sides, he will as suddenly begin to whirl faster, the effect being more pronounced if he holds heavy weights in his hands Angular momentum being a vector quantity, the principle applies as well to its direction as to its magnitude The result is that any rotating body tends to maintain the same axis of rotation, a fact well illustrated by the spinning top and by the stabilizers used on some ocean vessels (L D W)

ANGULAR VELOCITY AND ANGULAR ACCELERATION. Quantities relating to rotational motion While the use of the term "angular velocity" may be extended to any motion of a point with respect to any axis, it is commonly applied to cases of rotation It is then the **vector,** whose magnitude is the time rate of change of the angle θ rotated through, i e, $d\theta/dt$, and whose direction is arbitrarily defined as that direction of the rotation axis for which the rotation is clockwise The usual symbol is ω or Ω

Angular velocities, like linear velocities, are vectorially added; for example, if a top is spinning about an axis which is simultaneously being tipped over toward the table, the resultant angular velocity is the vector sum of the angular velocities of spin and of tipping (This enters into the theory of **precession**)

Angular acceleration is the time rate of change of the angular velocity, expressed by the vector derivative $d\omega/dt$ Only in case the direction of the axis remains unchanged can the angular velocity and angular acceleration be treated as scalars The effect of torque applied to a body free to rotate about an axis is to give it angular acceleration, and the opposition offered by the body to this process gives rise to the concept of **moment of inertia.** (L D W)

ANHARMONIC RATIO. If we have given four points *A, B, C, D* on a straight line, their anharmonic ratio (or cross-ratio) is defined as the ratio $\frac{AC}{AD} / \frac{BC}{BD}$ in which the segments are to be regarded as positive or negative according to the order of the letters

The anharmonic ratio of any four points z_1, z_2, z_3, z_4 in a complex plane is defined as the ratio

$$\frac{z_1 - z_3}{z_1 - z_4} : \frac{z_2 - z_3}{z_2 - z_4},$$

in which the *z's* are complex numbers representing the points As a special case of this we have the definition of the anharmonic ratio of four given real numbers There are in general six distinct anharmonic ratios obtained by rearranging the given numbers or points in order (L L S)

ANHEDRAL. Allotriomorphic.

ANHYDRITE. The mineral anhydrous **calcium** sulfate, $CaSO_4$, occurs in granular, scaly or fibrous masses, rarely crystallized in **orthorhombic** tabular or prismatic forms Hardness 3–3 5, specific gravity 2 9–2 98, translucent to opaque, streak white, color may be white, grey, bluish or reddish Anhydrite has three cleavages at right angles to one another It is similar to **gypsum** and occurs under the same conditions often with the latter mineral Anhydrite is usually found in **sedimentary** rocks associated with **limestones,** salt, and **gypsum,** into which it changes slowly by the absorption of water

It is found in Poland, Saxony, Bavaria, Wurtemberg, Switzerland and France In the United States in Niagara County, N Y, West Paterson, N J, and Nashville, Tenn It occurs also in Nova Scotia and New Brunswick (E S C S)

ANILIDES. Amines and Amides.

ANILINE. Aniline, phenylamine, aminobenzene ($C_6H_5NH_2$) is a colorless, odorous liquid, melting point —6° C, boiling point 184° C, slightly soluble in water, miscible in all proportions with alcohol or ether, poisonous, which turns yellow to brown in the air, is a weak base forming salts with acids, e g, anilinehydrochloride ("aniline salt" $C_6H_5NH_2$ HCl), from which aniline is reformed by addition of **sodium** hydroxide solution Aniline reacts (1) with **hypochlorite** solution, to form a transient violet coloration, (2) with **nitrous acid** (a) warm, to form **nitrogen** gas plus phenol, (b) cold, to form **diazonium** salt (benzene diazonium chloride $C_6H_5N—Cl$), (3) with **acetyl chloride, acetic anhydride,** or **acetic acid** glacial, to form N-phenylacetamide $\left(\text{acetanilide, "antifebrin" } C_6H_5N\langle^{H}_{OCCH_3}\right)$, (4) with **benzoyl chloride,** to form N-phenylbenzamide $\left(\text{benzanilide, } C_6H_5N\langle^{H}_{OCC_6H_5}\right)$, (5) with benzenesulfonyl chloride, to form N-phenylbenzene sulfonamide ($C_6H_5SO_2NHC_6H_5$), soluble in sodium hydroxide, (6) with **chloroform** ($CHCl_3$) plus alcohol plus sodium hydroxide, to form phenyl isocyanide (C_6H_5NC) very poisonous, (7) with **sulfuric acid** at 180° to 200° C, to form paraaminobenzene sulfonic acid (sulfanilic acid, $H_2N\ C_6H_4\ SO_3H(1,4)$), (8) with **nitric acid,** when the amine group is protected, e g, using acetanilide, to form mainly paranitroacetanilide ($CH_3CONH\ C_6H_4\ NO_2(1,4)$), from which para-nitroaniline ($H_2N\ C_6H_4\ NO_2(1,4)$) is obtained by boiling with concentrated hydrochloric acid, (9) with **chlorine** in an anhydrous solvent, such as chloroform or acetic acid glacial, to form 2,4,6-trichloroaniline ($(1)H_2N\ C_6H_2Cl_3(2,4,6)$), (10) with **bromine** water, to form white solid 2,4,6-tribromoaniline ($(1)H_2N\ C_6H_2Br_3(2,4,6)$), (11) with **potassium** dichromate in sulfuric acid, to form aniline black dye, and, by

further oxidation, benzoquinone ($O:C_6H_4:O(1,4)$), (12) with **potassium** permanganate in sodium hydroxide, to form azobenzene ($C_6H_5N:NC_6H_5$) along with some azoxybenzene ($C_6H_5NO:NC_6H_5$), (13) with reducing agents, to form aminohexahydrobenzene (cyclohexylamine, $H_2N \cdot C_6H_{11}$), (14) with alkyl halides or alcohols heated, to form alkyl anilines, e.g., methylaniline ($C_6H_5NHCH_3$), dimethylaniline ($C_6H_5N(CH_3)_2$).

Aniline may be made by the reduction, with iron or tin in **hydrochloric acid**, of nitrobenzene. Aniline is the end-point of reduction of most mononitrogen substituted benzene nuclei, as nitrosobenzene, beta-phenylhydroxylamine, azoxybenzene, azobenzene, hydrazobenzene. Aniline is detected by the violet coloration produced by a small amount of sodium hypochlorite.

Aniline is used (1) as a solvent, (2) in the preparation of compounds as illustrated above, (3) in the manufacture of dyes and their intermediates, (4) in the manufacture of medicinal chemicals. See also **Amines and Amides.** (R.K.S.)

ANIMAL ASSOCIATIONS. While most animals are solitary, associating with others of their kind only incidentally or during the breeding season, others normally live in some relationship with members of the same or of other species.

The simplest association of members of the same species is gregariousness. Gregarious animals are not bound by the association but profit by it. Examples are the great herds of herbivorous animals such as the bison and the packs of predacious animals, such as wolves.

Colonial association may be accompanied by structural union between individuals, as in many marine polyps, or may be based on behavior, as in the social insects. The term *merges* with social organization. This type of association is accompanied by structural specialization of individuals for special tasks except in human society, where it depends on specialized training.

The association of individuals of different species may be the relatively loose type called commensalism in which both forms benefit but not in an essential way, or the indispensable symbiosis in which neither organism can persist without the other. An excellent example of symbiosis is the relation of **termites** with the **protozoa** found in their intestine; neither can live without the other.

An association in which one individual lives at the expense of the other is called **parasitism.**

Slavery is an association practiced by some of the social insects and by man; among the insects the slaves are of a different species. (A.W.L.)

Bear animalcule.

ANIMALCULE. A minute animal. Applied to the **protozoa** and to such microscopic forms as the **rotifers.** (A.W.L.)

ANIONS. Anions are negatively charged atoms or **radicals.** (See **Ions.**) (R.K.S.)

ANISE. *Pimpinella anisum.* Umbelliferae. An herb of the Umbel family (See **Carrot Family**) having a strong odor and bearing seeds from which is distilled the aromatic substance, oil of anise. It is sometimes cultivated as a medicinal plant (See also **Volatile Oils**). (R.M.W.)

ANISOGAMY. **Heterogamy.**

ANISOLE. Methyl-phenyl ether. (See **Alcohols and Ethers.**)

ANKERITE. **Dolomite.**

ANKLE. The slender part of the lower leg at its articulation with the foot. (A.W.L.)

ANKYLOSIS. Loss of motion in a **joint.** This may be caused by a disease process in or around the joint. The disease may cause stiffening of the muscles around the joint or the laying down of bone in the joint itself In other cases, fibrous tissue and adhesions may cause the loss of motion. Surgical ankylosis or arthrodesis is done as a treatment for certain diseases of joints, especially tuberculosis. (R.S.M.)

ANNABERGITE. The mineral Annabergite is a rather rare **nickel arsenate** with the formula $Ni_3As_2O_8 \cdot 8H_2O$ crystallizing in the **monoclinic** system. It is of secondary origin, resulting from the alteration of preexisting nickel minerals. It has been found in Saxony, France, and Cobalt, Province of Ontario, Canada. It was named from Annaberg in Saxony. (E.S.C.S.)

ANNEALING. The operation of annealing is the heating of metal and subsequent cooling, by means of which changes in the structure of the metal and its physical properties are brought about. Strength, elastic limit, ductility, and hardness are properties which are to a certain extent controllable by annealing. In annealing, the metal, say steel, is first heated to slightly above its critical range, held at this temperature long enough for all parts of the interior to reach a uniform temperature, and then cooled from this annealing temperature to the temperature of the atmosphere. The range of annealing temperature varies with the metal. For instance, in the case of **steel,** it varies from 1450 to 1700° F., depending on the **carbon** content of the steel. Control of the properties of the annealed product is obtained by the rate of cooling and by the number of reheats, each one, of course, to a slightly lower annealing temperature. (P.T.M.)

ANNELIDA. The segmented worms, including **earthworms** and **leeches.** This phylum is biologically interesting because it shows in a primitive form the structural plan of the more complex animals.

The annelids are characterized by: 1. Metameric segmentation. 2. A closed tubular circulatory system in most forms. 3. A coelom. 4. An excretory system with tubules opening from the **coelom** to the exterior in various segments. 5. The alimentary tract is tubular, with regions specialized for various functions. 6. The nervous system consists of a dorsal brain above the oesophagus connected by cords passing around the **oesophagus** with a ventral chain of ganglia (see **ganglion**) below the alimentary tract. 7. **Setae** are present in many species.

The annelids are classified as follows:

Class **Archiannelida.** Small marine annelids without setae; with few to many segments.

Class **Chaetopoda.** Worms with setae. No suckers. External segmentation distinct and metameric. **Earthworms** and many aquatic species.

1. 2.

1. A sexual individual of *Autolytus* with male about to detach. (From Verrill, *Invertebrate Animals of Vineyard Sound.*) 2. Tufted worm (*Amphitrite ornata*). (Drawn by Verrill.)

Class **Gephyrea.** Large marine worms, not segmented when adult.

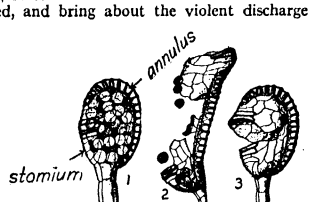
Class **Hirudinea.** Flattened worms without setae but with a sucker at each end of the body. External segmentation consisting of two to fourteen annuli to each metamere. Mostly aquatic, a few marine and a few terrestrial. Mostly blood-sucking parasites. The **leeches.** (A.W.L.)

ANNUAL. A plant which normally completes its life cycle, from seed to seed, in a single growing season. Typical annuals are corn, wheat, cucumber, and nasturtium. Annual plants are especially suited for life in regions where the growing season is short and alternates with an unfavorable cold period or dry season. (R.M.W.)

ANNUAL RING. A layer of wood added to the **stem** in one growing season.

In temperate climates stem growth occurs during the warm spring and summer months. The cells formed in spring when active growth is taking place are characteristically large, while during the summer only smaller cells are added. This alternation of cells results in the formation of definite concentric rings readily seen in cross sections of woody stems. Actually the growth increment is in the form of a sheath continuous over the entire stem except at the growing tips. External conditions may have a profound effect on the appearance of the annual ring; favorable growing seasons with ample moisture result in broad rings, while seasons of drought produce narrow rings. Removal of surrounding overshading trees may result in a pronounced increase in the thickness of the annual ring. At times events such as severe defoliation by insects or cases of drought may produce two rings in one season; such rings are ordinarily not sharply distinct as are normal ones, and are called false annual rings. Counting of annual rings gives an accurate index of the age of the tree, while attention to details such as variable thickness of successive rings serves to indicate environmental changes. By careful comparison of different logs, even though they be largely reduced to charcoal, one may determine the actual year in which the ring was formed. By this means it has proved possible to establish the probable age of many ruins in the south-western states. In tropical countries having a continuous growing season, annual rings are not formed or only slightly developed. If, however, alternating rainy and dry seasons occur, then they appear. (R.M.W.)

ANNULUS. In the **sporangium** of many **ferns**, there is a ring of cells which have their walls characteristically thickened, and bring about the violent discharge of the



Fern sporangia. 1, unopened; 2, discharging spores; 3, empty.

spores within. This ring of cells is called the annulus. In **agarics**, the ring of tissue which is found around the stalk in many genera, is also known as an annulus. (R.M.W.)

ANOA. Oxen.

ANODE. The anode is the positively charged pole in an electrolytic cell or a gas discharge tube. (See **Electrochemistry.**) (R.K.S.)

ANODE RAYS. Among the positively charged particles recognizable in a (so-called) **vacuum tube**, and mixed with the ionized molecules and atoms of the rarefied gas, are sometimes found ions which are traceable to the metallic anode or to impurities in it or upon its surface. The anode may be oxidized or have films or patches of metallic salts upon it which, in the operation of the tube, in some manner not fully understood, yield ions of the metal. If the anode is treated with alkali or alkaline-earth salts or oxides and strongly heated, very copious positive emission may result, serving as a convenient source of positive rays. In some instances occluded hydrogen seems to supply the ions. The experimental study of these rays is hampered by the uncertainty of the supply, which depends upon impurities often of unknown nature and amount; it is also complicated by the presence of the positive ions of the residual gas. The subject is intimately related to positive thermionic emission. (**Thermionic phenomena.**) (L.D.W.)

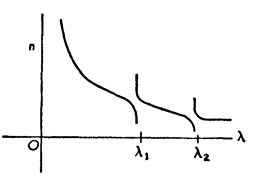
ANODYNE. Any medicine that relieves pain or discomfort. The best known anodynes are **morphine, codeine, hyoscine, atropine, ether, aspirin** and "pyramidon" (**amidopyrine**). (R.S.M.)

ANOLIS. Reptilia, Sauria. The name of a genus of **lizards** adapted also as a common name. Small, mostly brightly colored lizards of the warmer latitudes of the Americas. The little lizard sometimes sold under the name chameleon is the Carolina anolis, *Anolis carolinensis*, a common species of the southern United States and southward. (A.W.L.)

ANOMALISTIC YEAR. Year.

ANOMALODESMACEA. An order of **bivalve** molluscs, mostly burrowing marine species. (A.W.L.)

ANOMALOUS DISPERSION. Ordinarily the **refractive index** n of a medium decreases with increasing wave length λ (See **Dispersion**). It often happens, however, that in the immediate vicinity of a certain wave length λ_1 there is a break or discontinuity in the dispersion curve and the usual rule may be locally reversed (see figure). In some cases there are several such points, $\lambda_1, \lambda_2, \lambda_3, \ldots$.



Variation of refractive index with wave length, illustrating anomalous dispersion.

These discontinuities correspond to lines or bands in the **absorption spectrum** of the medium. In the Sellmeier dispersion formula,

$$n = 1 + \frac{A\lambda^2}{\lambda^2 - \lambda_1^2} + \frac{B\lambda^2}{\lambda^2 - \lambda_2^2} + \ldots,$$

the several fractional terms make provision for the respective discontinuities. The absorption wave lengths $\lambda_1\ \lambda_2, \ldots$ and the constants $A, B, \ldots$ must be determined experimentally. If there is pronounced anomalous dispersion in the visible range, the medium appears colored, as illustrated by transparent dyes. (L.D.W.)

ANONACEOUS FRUITS. *Anona* sp. Anonaceae. The genus Anona contains shrubs and small trees, many of which bear fruits much esteemed by man. These fruits are composed of many individual ovaries which are more or less sunk in the fleshy receptacle and united to it and to each other. In some species these collective fruits are five or six inches in diameter and so heavy as to drag down the branches. *Anona muricata* is the Soursop, whose somewhat acid white pulp is used in making sherbets and drinks. A native of southern Asia, *Anona squamosa*, the Sugar apple or Sweetsop has sweet fruits which are pleasantly fragrant and which are considered by many the most desirable of this group. Another species native in South America is *Anona cherimolia*, in which the fleshy carpels are completely fused. This species grows best at elevations of 4000–6000 feet, and is found in the Andean region. *Anona reticulata*, the Custard-apple, also a native of tropical America, is used locally in the West Indies and elsewhere. None of

these fruits has as yet appeared in northern markets. (R.M.W.)

ANOPHELES. Mosquito; Malaria.

ANOPLURA. The order of insects which includes the true or **sucking lice.** They are wingless parasitic insects with mouths formed for piercing and sucking. See **louse.** (A.W.L.)

ANOREXIA. Loss of appetite, or distaste for food. This condition often accompanies onset of acute illness, fever—especially prolonged fevers—and particularly in chronic wasting disease. (R.S.M.)

ANORTHITE. Feldspar.

ANORTHOCLASE. Feldspar.

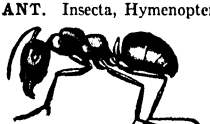
ANORTHOSITE. The name anorthosite was given by T. Sterry Hunt to rocks of **gabbroid** nature which were essentially free from pyroxene, hence almost wholly **plagioclase,** *usually* **labradorite.** The term is derived from the French word for plagioclase, anorthose. Small quantities of pyroxene may be present as well as magnetite or ilmenite. The rock is commonly white to gray, bluish, greenish, or perhaps nearly black. A variety from the Province of Quebec is purplish brown due to the inclusion of ilmenite dust within the feldspars. Although not a common rock in the ordinary sense of the word, occurrences of great areal extent are known in Canada, Norway, and Russia and in the United States in northern New York State and Minnesota. Opinions as to the origin of this rock differ. The development of anorthosite may have been due to the settling out of **labradorite** crystals from a gabbro magma as many believe, or there may have been an original anorthosite magma.

A study of anorthosite occurrences brings out two very curious circumstances, first, that there is no extrusive (lava) equivalent of anorthosite, and second, that most anorthosite masses seem to be of pre-**Cambrian** age. (E.S.C.S.)

ANOXEMIA. Deficiency in the **oxygen** content of the **blood.** This may be due to insufficient **aeration** of the blood as it passes through the lungs, insufficient **hemoglobin** content of the blood, marked **anemia,** or circulatory diseases. (R.S.M.)

ANSERIFORMES. An order of birds including the **geese, swans, ducks,** mergansers, and related species. (A.W.L.)

ANT. Insecta, Hymenoptera. Social **insects** of varied structure and habits. They may be distinguished from the related bees and wasps by the form of the slender petiole which connects **thorax** and **abdomen;** in the ants it is expanded above and looks more or less wedge-like in profile. (A.W.L.)



Ant.

ANTARES. Antares (α **Scorpii**) derives its name from two Greek words signifying that the star is "similar to" or "a rival of **Mars,**" doubtless because of its distinctly reddish hue. In fact, this reddish color has always made the star an object of interest and importance in the ancient religions, and many of the Egyptian temples are so oriented as to indicate that Antares played an important part in their ceremonials. Antares was one of the four royal stars of the Persians about 3,000 B.C., and some writers claim that it is the "lance star" referred to in the 38th chapter of the book of Job.

The diameter of Antares has been determined with the stellar **interferometer** and found to be about 390,000,000 miles or slightly greater than the distance of Mars from the sun. It is a typical M **spectral type giant** star of very low density. (W.K.G.)

ANT-BEAR. A name applied to the great **ant-eater,** *Myrmecophaga jubata,* of South America and to the **aard-vark** of South Africa. (A.W.L.)

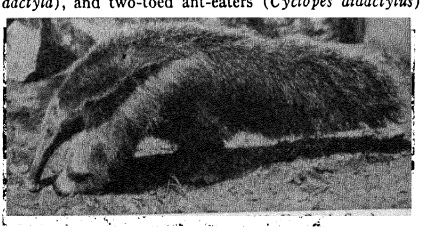
ANT-BIRD. Aves, Passeres. Several species of birds (**Aves**) found in the forests of Brazil, named from their fondness for ants. (A.W.L.)

ANT-EATER. Mammalia. Any member of the class which is highly specialized for a diet of ants or termites. The specializations are a slender elongate snout, a long sticky tongue which aids in gathering a sufficient number of the small prey, and strong claws for tearing open ant nests.

The ant-eaters include the spiny ant-eaters or **echidnas** of the Australian region, which are monotremes, the **aard-varks** of Africa (Order Tubulidentata), the scaly

Echidna. (Courtesy of N. Y. Zool. Soc.)

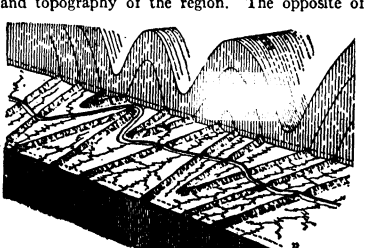
ant-eaters or **pangolins** of the Oriental region and Africa and the **ant-bear,** tamandua (*Tamandua tetradactyla*), and two-toed ant-eaters (*Cyclopes didactylus*)



Giant ant-eater. (Courtesy of N. Y. Zool.

of Central and South America (Order Edentata). The banded ant-eater (*Myrmecobius*) is an Australian **marsupial** of more squirrel-like appearance than the more highly adapted species. (A.W.L.)

ANTECEDENT STREAM. A stream whose course or valley is obviously not adapted to the existing structure and topography of the region. The opposite of a



Block diagram illustrating the structural and erosional history of the Appalachian Range. (After W. M. Davis.)

consequent stream A good example of an antecedent stream valley is one which cuts across a ridge or several ridges Excellent examples occur in the valley and ridge province of the Appalachian Mountains On the other hand, it has been recently suggested that the Appalachian antecedent stream valleys may be really **superimposed.** The accompanying diagram illustrates the origin of the present topography and stream pattern of the Appalachians It is postulated that the folds were reduced to a **peneplain** on which were flowing a few master streams Uplift of the peneplain caused the rejuvenation of the master streams which were able to maintain their courses across the upturned edges of the more resistant strata, while the new tributary stream pattern was largely determined by the less resistant formations (R M F)

ANTELOPE. Mammalia, Artiodactyla The antelopes are an extensive group between the oxen and the sheep and goats Many species occur in Africa and some in India and Tibet The prong-horn antelope of Western North America belongs to a separate group with hollow horns like the oxen, true antelopes have the horns almost solid

The antelopes include many species with special names, such as the **eland,** the **kudu,** the **addax,** the **gemsbok,** the **oryxes,** the **gazelles,** the **wildebeests,** the **hartebeests** and others (A W L)

ANTENNA. This term is used in zoology, and also in radio

In zoology an antenna is a jointed sensory appendage of the head found in several classes of **arthropods Crustaceans** have two pairs, while **insects, centipedes** and millipedes (See **Diplopoda**) have one pair

In radio, the function of an antenna, commonly called an "aerial," is to couple the transmitting or receiving set to the wave propagating medium As such, it is a radiator of **electromagnetic** energy, and usually consists of a wire or network of wires placed at some distance above the ground. The transmitting type of antenna may be either a nondirectional type used for general broadcasting, or the directional type which is so necessary for reliable transoceanic radio service There is also a difference in short and long wave transmitting antennas An antenna must receive electrical energy in the form of oscillatory output from a transmitting set The amount of energy that may be supplied to the antenna depends upon the electrical characteristics of the antenna, as is the case in the usual electrical circuit The resistance of the antenna, which determines the amount of energy taken, is the result of its radiation resistance and its loss resistance The radiation resistance depends largely upon the oscillatory frequency, and for maximum transmission efficiency a certain definite antenna length is indicated for each wave length The natural period of oscillation of an antenna is a quarter wave length, or odd multiple of it, but the antenna can be used to transmit other wave lengths by loading it with inductance coils or condensers, thus altering its natural wave length to agree with the transmitting frequency desired

The simplest type of antenna is a single vertical conductor This type is not ordinarily used because of limitations of frequencies on which it can be used, and amount of energy that can be radiated The usual types of non-directional transmitting antennas are the inverted *L, T* antenna, and umbrella antenna These antennas have a radiation substantially the same in all directions, and find their chief use in broadcasting service Radio communication between fixed points, or between ship and shore, or between airport and aircraft, use directional transmission because of the smaller amount of power required for the same signal strength, the secrecy, and the freedom from interference with other channels Long wave, directional transmitting antennas are composed of an inverted *L* antenna having a number of intermediate taps, each connected with the ground through a tuned **inductance.** Adjustment of these inductances makes possible directional transmission at right angles to the antenna By doubling the antenna and converting the half away from the desired transmitting direction into a reflector, transmission is limited to one direction only, the reflection effectively neutralizing the radiation in the other direction Short wave transmitting antennas are also suitable for directed transmission, and depend to a large extent upon an interconnection of conductors, producing an interference pattern which eliminates radiation in all directions save that wanted

Antennas for general broadcasting reception are not directive, and are tuned by means of inductive or capacitive loadings within the receiving set For sufficient electrical strength they rely upon proximity or strength of the transmitting system, or intense magnification of the signal within the receiving set However, the introduction of "all wave" radio receivers added importance to the antenna for general broadcast reception The advantage of short wave broadcasting is that the waves are able to travel great distances from relatively low powered transmitters This necessitates a very efficient antenna, and special antennas have been developed to fill this need Amongst directional receiving antennas the wave antenna, sometimes called Beverage antenna, is frequently used for transoceanic service In its simple form it consists of a long horizontal wire pointed towards the transmitting antenna, with the end towards the distant station being grounded through an impedance The other end is inductively coupled to the receiving set Where a single long wire is impractical, a loop antenna may be employed for directional reception The signal strength with a loop antenna is maximum when the loop is in the plane of the direction of the oncoming waves (F T M, A W L)

ANTENNAL GLAND. Glands associated with the antennae of certain **crustaceans,** probably excretory (A W L)

ANTENNAL SCALE. The modified outer branch (exopodite) of the second **antenna** in some **crustaceans.** (A W L)

ANTHELMINTIC. A **vermifuge** or a remedy used to rid a patient of worms (See **Drugs**) (R S M)

ANTHER. The terminal part of a stamen, containing the pollen sacs (See **Flower**) (R M W)

ANTHERIDIUM The structure which gives rise to the **spermatozoids.** In the **algae** it is a single cell, the contents of which may become a single antherozoid or divide to produce many antherozoids In the higher divisions of plants, the antheridium is a multicellular body which contains the antherozoids (R M W)

ANTHOCYANINS. Pigments present in the cell-sap of many plants, and causing most of the purple, blue and red colors found in plants Anthocyanins are soluble in water and in alcohol, and belong to that group of organic compounds known as **glucosides.** The red color of beets, the purple layer in the lower part of the leaves of certain species of Wandering Jew, and the bluish color in the skin of turnips are all due to the presence of anthocyanins The color produced by the pigments is dependent on the **hydrogen ion** concentration of the cell-sap in which they occur When the sap is acid, the color is red, when alkaline, blue Water extracts of the pigments will show the color changes very distinctly when the solution is made first acid, then alkaline, changing from bright red to a bluish color Many red and blue flowers owe their color to the presence of anthocyanin pigments in the cells of the petals The function of anthocyanins has been variously explained In flowers the bright colors were held to attract insects, in leaves and young stems they were thought to serve as

protection against the effects of excessive sunlight or again to transform some of the light into heat and so protect the plant against cold No conclusive explanation of their true function has yet been obtained (See also **Aminoacids and Proteins**) (R M W)

ANTHOPHYLLITE. The mineral anthophyllite is an **orthorhombic amphibole** essentially $(Mg,Fe)_7Si_8O_{22}$ with **aluminum** sometimes present This mineral corresponds to **enstatite** and **hypersthene** in the **pyroxene** group It has a prismatic cleavage, hardness, 5 5–6 , specific gravity, 2 8–3 2 , luster, vitreous, color, gray, yellow, brown, green or brownish green, transparent to translucent Probably always a **metamorphic** mineral, very common in **schists.** Found in Norway, Austria, Greenland, Pennsylvania, Georgia and elsewhere The name is derived from the Latin *anthophyllum,* clove, because of its usual brownish shades (L S C S)

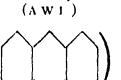
ANTHOZOA. The **sea anemones, corals, alcyonarians** and related forms A class of the phylum **Coelenterata** in which the **polyp** form gains its highest development and the **medusa** is unknown

Like the **hydrozoan** polyps, these animals have relatively thin walls, due to the thin middle layer (mesogloea), and are approximately cylindrical in form The base is a disc by which the animal is attached to some support and the opposite end forms an oral disc bearing numerous hollow tentacles surrounding the mouth The mouth leads into a long tube lined with ectoderm, known as the stomodaeum In it **ciliated** grooves serve for the passage of currents of water into and out of the enteric cavity In this cavity radiating partitions, the mesenteries, pass from the wall to the stomodaeum, which they hold in place Others extend into the cavity from the wall without reaching the stomodaeum The edges of the mesenteries bear mesenteric filaments with stinging cells They are important in digestion and respiration Reproductive bodies also develop in the mesenteries and slender acontia with many stinging cells arise from their edges Muscle bands in the mesenteries and in the body wall contract the entire animal and close the margins of the oral disc in over the tentacles

The class is divided into two orders

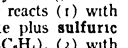
Order **Alcyonaria** Polyp with eight tentacles, pinnately branched Colonial forms, usually supported by a hard skeleton The **sea fans,** precious **coral,** and **sea feathers.**

Order **Zoantharia.** Colonial or solitary Polyp with few to many tentacles, not pinnately branched Hard deposits formed under the basal disc in some species The stony **corals** and **sea anemones.** (A W I)

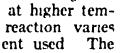
ANTHRACENE Anthracene  is a colorless solid, melting point 218° C , having blue fluorescence when pure, insoluble in water, slightly soluble in alcohol or ether, soluble in hot benzene, slightly soluble in cold benzene, transformed by sunlight into para-anthracene ($(C_{14}H_{10})_2$) Anthracene reacts (1) with oxidizing agents, e g , **sodium** dichromate plus **sulfuric acid,** to form anthraquinone ($C_6H_4(CO)_2C_6H_4$), (2) with **chlorine** in water or in dilute **acetic acid** below 250° C to form anthraquinol and anthraquinone, at higher temperatures 9,10-dichloroanthracene The reaction varies with the temperature and with the solvent used The reaction has been studied using, as **solvent,** benzene, chloroform, alcohol, carbon disulfide, ether, glacial acetic acid, and also without solvent by heating **Bromine** reacts similarly to chlorine, (3) with concentrated **sulfuric acid** to form various anthracene sulfonic acids, (4) with nitric acid, to form nitroanthracenes and anthraquinone, (5) with **picric acid** ((1)HO $C_6H_2(NO_2)_3$ (2,4,6)) to form red crystalline anthracene picrate, melting point 138° C Anthracene is obtained from coal tar in the fraction distilling between 300° C and 400° C This fraction contains 5 to 10% anthracene from which by fractional crystallization followed by crystallization from solvents, such as oleic acid and washing with such solvents as **pyridine,** relatively pure anthracene is obtained Anthracene may be detected by the formation of a blue-violet coloration on fusion with mellitic acid Anthracene derivatives, especially anthraquinone, are important in **dye** chemistry (R K S)

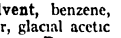
ANTHRACITE. Anthracite is the "hard **coal**" of commerce It contains usually less than 10% of volatile matter and more than 90% of **carbon,** hence burning with a smokeless flame Anthracite has a high luster and, unlike "soft" or bituminous coal will not soil the fingers when handled (E S C S)

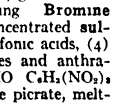
ANTHRAQUINONE. Anthraquinone (9,10)

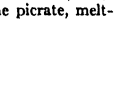


is a yellow solid, melting point 286° C , can be sublimed, forms monoxime, melting point 224° C , by heating under pressure at 180° C with hydroxylamine chloride, forms no phenylhydrazone with **phenylhydrazine,** with strong oxidizing agents reacts with difficulty to yield phthalic acid ($C_6H_4(COOH)_2(1,2)$), with reducing agents, such as **sodium** hyposulfite, **zinc** in sodium hydroxide solution, tin or **stannous** chloride in hydrochloric acid (but not sulfurous acid), anthraquinone is reduced to

anthraquinol  ,

anthrone 

dianthrol 

dianthrone 

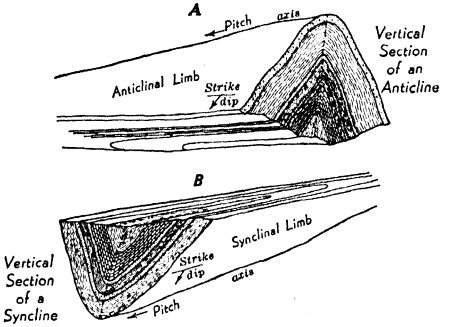
depending upon the conditions Anthraquinone is obtained by oxidation of anthracene using **sodium** dichromate plus **sulfuric acid,** and is purified by dissolving in concentrated sulfuric acid at 130° C and pouring into boiling water, whereupon anthraquinone separates as pure solid, and is recovered by filtration Further purification may be accomplished by sublimation or crystallization from nitrobenzene, aniline or tetrachloroethane Anthraquinone is used as the material from which many dyes are made, notably alizarin ($C_6H_4(CO)_2C_6H_3(OH)_2$) and related substances These are vat dyes, that is, insoluble colored substances which are readily reduced to a substance having marked affinity for the fibre to be dyed and which upon exposure to the air are readily reoxidized to the original dye Anthraquinone may be detected by the appearance of a red color on treatment with alkali, zinc powder and water For Quinones, see **Phenols and Quinones.** (R K S)

ANTHRAXOLITE. A coal-like, metamorphosed **bitumen,** often closely associated with **igneous** rocks (R M F)

ANTICLINE. A **folded** structure involving **bedded rocks** in which the strata are arched upward so that the beds bend downward on either side These downward bending beds constitute the limbs of the fold

The angle which the beds on the limbs of the fold make with the horizontal is spoken of as the dip. The term dip is also used to indicate the inclination of bedding in other structures.

Anticlinal arches may be broad and gentle or sharp with a steep dip, symmetrical or unsymmetrical, or may be complicated by minor folds on the limbs. Anticlinal folds may be of sufficient magnitude to be measured in miles, involving great thicknesses of sediments, or they may be so small as to be measured in inches.



Diagrams illustrating parts of folds. (After Willis, U. S. Geological Survey.)

The direction of prolongation of the fold is termed the axis of the fold, and if not exactly horizontal the angle of inclination of the top bed of the anticline is called the pitch. Plunge is used as a synonym for pitch by some writers. (R.M.F.)

Diagrammatic section of an anticlinorium. (After Van Hise.)

ANTICLINORIUM. A composite anticlinal structure of folded beds is called an anticlinorium; a composite synclinal structure is called a synclinorium. (R.M.F.)

ANTICYCLONE. Winds.

ANTIDOTE. A drug or **drugs** that counteract a poisonous dose of another drug. This may be accomplished by neutralization, as of an **acid** or **alkali,** or by changing the drug into an insoluble or non-toxic form. Some antidotes are drugs which give the opposite or antagonistic effect in the body to that produced by the poisoning drug. (R.S.M.)

ANTI-FRICTION BEARINGS. This term includes all bearings in which friction is minimized through the use of point or line contact between the moving parts instead of surface contact. The special characteristic of bearings of this nature is the replacement of sliding friction which is typical of the plain bearing with the rolling friction of spherical balls or cylindrical rollers. However, due to the concentrated pressures at the points or lines of contact, the load carrying ability of these bearings is less than that of plain bearings of similar dimensions. (F.T.M.)

ANTI-LOGARITHM. Logarithms.

ANTIMONY. Symbol: Sb (stibium). Atomic number: 51. Atomic weight: 121.76. Density: 6.7. Hardness: 3.0–3.3. Melting point: 630.5° C. Boiling point: 1380° C. (**Isotopes:** page 238.)

Antimony is a silver-white metal, brittle and easily pulverized; scarcely tarnished in dry air but oxidized slowly in moist air; burns at a red heat in air or **oxygen** with incandescence forming antimonous oxide; insoluble in **hydrochloric acid;** converted by **nitric acid** into antimonous oxide or antimonic oxide depending upon the concentration of acid; by **chlorine** into trichloride or pentachloride, by sodium hydroxide solution into antimonite. Discovered by Valentine in 1450.

Antimony is used in alloys, with lead for storage battery plates, with lead and tin in type metals, with tin and copper in bearing or anti-friction metals. Antimony occurs chiefly as the sulfide (**stibnite,** Sb_2S_3) which is produced mainly in China, only small amounts in Mexico and Bolivia. Stibnite is (1) melted and reduced to antimony by **iron** metal and separated from fused ferrous sulfide; (2) is roasted in air and sublimed antimonous oxide collected and reduced by heating to fusion with carbon and sodium carbonate.

Acids: antimonous acid (ortho, H_3SbO_3, pyro, $HSbO_2$), white solids forming antimonite salts; antimonic acid (ortho, H_5SbO_4, pyro, $H_4Sb_2O_7$, meta, $HSbO_3$), white solids, forming antimonate salts.

Antimonates: sodium antimonate (pyro, $Na_2H_2Sb_2O_7 \cdot H_2O$, meta, $2NaSbO_3 \cdot 7H_2O$), white solids.

Antimonide: **silver** antimonide (Ag_3Sb), black precipitate, by reaction of stibine and very dilute silver nitrate solution.

Antimonite: **sodium** antimonite (meta $NaSbO_2 \cdot 3H_2O$) white solid.

Chlorides: antimonous chloride, antimony trichloride, "butter of antimony" ($SbCl_3$) white solid, melting point 73° C., boiling point 220° C., by reaction of antimony upon heating with a deficiency of **chlorine,** reactive with water to form antimony oxychloride, antimonyl chloride (SbOCl), white solid, soluble in hydrochloric acid; oxychloride, white insoluble solid; antimonic chloride ($SbCl_5$), pale yellow liquid, boiling point 140° C., by reaction of antimony upon heating with an excess of chlorine, reactive with water to form oxychloride, white insoluble solid.

Hydride. See Stibine.

Oxides: antimonous oxide, antimony trioxide (Sb_2O_3), white solid when cold, but yellow when hot, formed (1) by burning antimony in air or **oxygen,** (2) by reaction of dilute nitric acid and antimony, melting point 656° C., sublimes at 1550° C. (in the absence of air); antimony tetroxide (Sb_2O_4), white solid, by heating antimony metal, trioxide, pentoxide, or trisulfide in air at 800°–900° C. for some time, decomposes above 900° C. to trioxide plus oxygen; antimonic oxide, antimony pentoxide (Sb_2O_5), pale yellow solid, by reaction of antimony metal or trioxide with concentrated **nitric acid,** decomposes on heating, forming tetroxide below 800° C.

Stibine, antimony hydride (SbH_3), colorless, odorless, very poisonous gas, by reaction of a solution of antimony-containing material with a metal (e.g., zinc), and **hydrochloric** or dilute **sulfuric acid** (but not with sodium hydroxide, thus differing from arsine). Stibine, (1) when heated in a glass tube yields a metallic mirror of antimony, (2) when passed into a very dilute solution of **silver** nitrate yields black precipitate of silver antimonide. Stibine burns in air with a faintly bluish-green flame forming antimonous oxide and water.

Sulfides: antimonous sulfide, antimony trisulfide (Sb_2S_3), orange-red precipitate, by reaction of antimonous salt solution and **hydrogen sulfide,** soluble in concentrated hydrochloric acid, soluble in sodium or ammonium sulfide to form thioantimonite; antimonic sulfide, antimony pentasulfide, "antimony red" (Sb_2S_5), orange precipitate, by reaction of antimonic salt solution and hydrogen sulfide, soluble in concentrated hydrochloric acid, soluble in sodium or ammonium sulfide to form thioantimonate. Used (1) in the manufacture of matches and fireworks, (2) as a pigment, (3) in vulcanizing and coloring rubber.

Numerous organic compounds containing antimony have been prepared, among these are trimethylstibine

$(Sb(CH_3)_3)$, tetramethylstibonium hydroxide $(Sb(CH_3)_4OH)$, which is a strong base, triphenylstibine $(Sb(C_6H_5)_3)$

Solutions of antimony containing substances, when boiled with hydrochloric acid and iron metal, yield a black precipitate of antimony metal

Tartrate potassium antimonyl tartrate, "tartar emetic" $(K(SbO)(C_4H_4O_6)\ \frac{1}{2}H_2O)$, white crystals, soluble, by reaction of antimony trioxide and potassium hydrogen **tartrate**, and then crystallizing Used as a mordant in dyeing textiles and leather, and in medicine (R K S)

ANTIPODAL CELLS. The three usually small cells which occur in the **embryo sac** of **angiosperms** at the end most distant from the micropyle No known function has been ascribed to them (R M W)

ANTIPYRETIC. Any **drug** or physical agent which lowers the temperature of the body Formerly antipyretic drugs were commonly used in **fevers** To-day they are little used, as fever is considered an index of the resistance of the body to **infection**, and is probably exerting a beneficial effect In certain conditions when fever is very high, it may be lowered, though generally by cold applications rather than by antipyretic drugs The most common antipyretics are "aspirin" (**acetylsalicylic acid**), **quinine, antipyrine, acetanilid** and **phenacetin.** (R S M)

ANTISEPTIC Any substance inhibiting the growth of or killing microorganisms, without undue injury to bodily tissues The chief antiseptics used in surgery are **iodine, ethyl alcohol,** "merthiolate," "metaphen," **"mercurochrome," phenol,** picric **acid, Dakins solution,** and **azochloramid.** (R S M)

ANTLER. The large and complex horns of **deer,** consisting of bony outgrowth with no covering of **keratin.** When growing they are covered with skin, the velvet, which is soon lost (A W.I)

ANT-LION Insecta, Neuroptera Immature **insects** of the family Myrmeleonidae which lie buried at the apex of conical pits in dry sand or dust Ants or other small insects which enter the pit slide down the loose slope and are seized by the upturned jaws below (A W L)

ANT-LOVING CRICKET. Insecta, Orthoptera, *Myrmecophila* Small peculiarly formed **crickets** which live in ant nests (A W L)

ANURA. The **frogs, toads,** and allied species, a division of the **Amphibia** characterized by the absence of the tail Also known as the Salientia from their jumping powers (A W L)

ANUS. The external opening of the **rectum.** (R S M)

AORTA. The main and largest blood vessel of the arterial blood system It arises from the left ventricle of the **heart,** and arching over the root of the left lung, descends along the vertebral column, passing through the chest, and pierces the diaphragm into the abdominal cavity, finally dividing into the right and left iliac **arteries** in the pelvis Many large and small blood **vessels** branch from it (R S M)

AORTITIS. Acute aortitis is inflammation of the walls and lining of the **aorta.** It is more common than realized and for the most part is a vascular manifestation of tertiary syphilis It may also occur in acute infections, especially with **rheumatic fever** and **septicemia** The commonest symptom is pain which closely resembles that seen in **angina pectoris.** This condition may lead to permanent damage of the aorta and heart. Treatment depends on the cause

Chronic aortitis may develop from the acute stage Other cases occur in relation to **arteriosclerosis** and old age It is characterized by dilatation of the **aorta.** The symptoms are pain and associated cardiac symptoms. (R S M)

AOUL. Mammalia, Artiodactyla A **gazelle** of northeastern Africa (A W L)

APAR. Mammalia, Edentata The **three-banded armadillo,** *Tolypeutes,* of South America (A W L)

APATITE. The mineral apatite is a **phosphate of calcium** with either **fluorine** or **chlorine** or sometimes both, hence the distinction between fluor-apatite and chlor-apatite Sometimes both fluorine and chlorine are present Most apatite is, however, fluor-apatite

Apatite crystallizes in the **hexagonal system** in prismatic and tabular forms Hardness, 4 5 to 5 , Specific gravity, 3 17 to 3 23 , luster, vitreous to resinous, transparent to opaque, streak, white, cleavage, imperfect basal and prismatic, color, white, green, yellow, red, brown and purple, sub-**conchoidal** fracture The variety called asparagus stone is yellow green and manganapatite which is a dark bluish green may contain as much as ten per cent **manganese** dioxide replacing the calcium Werner devised the name apatite from the Greek word meaning to deceive, as it was frequently mistaken for beryl and other species Apatite has been found widely distributed both geographically and petrologically as it occurs in many sorts of rocks, metamorphic **limestones, gneisses, schists, granites** and **syenites, pegmatite** veins and even with **iron** ores It has been prepared artificially It has been mined for the manufacture of fertilizers and to a slight extent for jewelry

Apatite occurs extensively in Europe and America, especially in New England, New Jersey, New York, North Carolina, California, and in the provinces of Ontario and Quebec in Canada (E S C S)

APE Mammalia, Primates Particularly any of the man-like apes, including the **gorilla, orang-utan, chimpanzee** and **gibbons** (Family Simiidae) but also applied to certain monkeys of another family, such as the Barbary ape All are tailless (A W L)

"APE-MAN" OF JAVA. Paleontology of Man.

APHANITE. An aphanite is any fine-grained **igneous** rock whose constituents cannot be distinguished with the naked eye The term is derived from the Greek, meaning invisible The adjective aphanitic is applied to these rocks as well as their fine-grained groundmasses. (E S C S)

APHASIA. Diminution or loss of expression by the spoken or written word, or of the understanding of spoken or written language It is due to injury or disease of the brain centers involving memory, hearing, or speech or other associated centers (R S M)

APHELION. Aphelion is the point in the **orbit** of a member of the **solar system,** except a **satellite,** when the object is most remote from the sun It is the point on the line of apsides diametrically opposite to **perihelion.** (W K G)

APHID, APHIS. Insecta, Homoptera A plant louse. Small delicate **insects** with sucking mouths They live on the sap of plants and many species are of economic importance They are characterized by an intricate life cycle which results in a high rate of reproduction

In the temperate zone aphids hatch in the spring from winter eggs, these individuals are females known as stem mothers They bear living young without mating (**viviparity, parthenogenesis**) and these in turn are females capable of the same type of reproduction Late in the season a generation known as the sexuparae bears both male and female offspring which mate to produce the eggs that pass the winter.

Winged aphids appear under conditions which demand migration from plant to plant Experiments have shown that the appearance of wings is a response to definite environmental conditions, probably complex in nature

Examples of the economic species are the melon aphid and the apple-grain aphid Spraying with contact poisons such as nicotine sulfate is effective against all species. (A W.L)

APHIS-LION. Insecta, Neuroptera The **larva** of the golden-eyes or lacewing flies (Family Chrysopidae), so called because they feed on aphids and other small insects. (A W L.)

APHRODISIAC. Any **drug** which is supposed to stimulate sexual desire or impulse, either by direct or indirect means There are no true aphrodisiacs Certain poisonous drugs, however, will produce irritation of the external sexual organs, probably through irritation of the whole urinary tract This is noted particularly with such drugs as cantharides (Spanish fly), **turpentine** or **camphor.** Other drugs such as large doses of **ethyl alcohol,** certain narcotics such as **cannabis indica** (hashish, marijuana) are so-called aphrodisiacs in that they dull the higher centers of the brain, allowing the baser instincts full sway (R S M)

APICAL GROWTH. **Growth** at the tip of an organ, as occurs in the roots and stems of all higher plants Examination of the stems of most plants will show that growth in length occurs only in the apical portion, and only for a relatively short period of time, usually a matter of a few weeks This may be determined by observing the distances between successive leaves near the growing tip the leaves are very small and close together, as one goes back along the stem the size of the leaves increases and also the distance between them, but after the leaf is mature little elongation of the stem occurs, as shown by the uniform distances between the mature leaves Older stems increase constantly in diameter, but only exceptionally in length One notable such exception, known as intercalary growth, is found in grasses and some other plants Here a group of **cells** in the region of the **node** are capable for a time of active division and of causing increase in the length of older portions of the stem Both here and in the tip of the stem increase in length is due to an actively dividing tissue known as a meristem (R M W)

APICAL ORGAN. A ciliated structure found in the larvae of **annelid** worms and **Bryozoa.** (A W L)

APLACOPHORA. An order of **Amphineura** made up of animals of worm-like form (A W L)

APLITE. This term is applied to fine-grained, sometimes sugary-textured **igneous** rocks, composed almost wholly of **quartz** and **feldspar.** Except for size of grain, aplites resemble **pegmatites** both in mineral composition and in mode of occurrence in dikes and veins, save that the rare minerals often present in pegmatites are wanting here The word aplite is derived from the Greek word meaning simple, referring to its ordinarily simple mineral composition (E S C S)

APODA. Gymnophiona.

APODEME. An internal projection of the hard outer covering **(exoskeleton)** of **arthropods.** Apodemes provide muscle attachments and in some species are extensively developed They are collectively termed the **endoskeleton.** (A W L)

APOMORPHINE. A powerful **emetic,** usually given hypodermically It is a crystalline **alkaloid,** $C_{17}H_{17}NO_2$, a derivative of **morphine** obtained by removing a molecule of water from morphine (R S M)

APONEUROSIS. A sheet of tough white glistening fascia or membrane which surrounds muscle and muscle fibers or connects a muscle to the part which it moves The tensile strength and resistance of muscle tissue is dependent upon the fascial tissue around the muscular fibers (R S M)

APOPHYLLITE. This mineral is a hydrous **silicate** of **potassium, calcium,** and **fluorine,** corresponding to the formula $(KFCa_4(Si_8O_8)_4)8H_2O$ It crystallizes in the **tetragonal system** in square prisms resembling cubes terminated by pyramids, may be tabular, sometimes massive Cleavage is perfect, parallel to the base, hardness, 4 5–5 Specific gravity, 2 3–2 4, luster, vitreous to pearly, transparent to translucent or nearly opaque, color may be white, grayish, greenish, yellowish or reddish This mineral was named by Hauy from the Greek words meaning from a leaf, referring to its exfoliation when heated with the blow pipe

Apophyllite is a secondary mineral found with the **zeolites** and has been classed with them by some writers, but it contains no **aluminum,** which element is understood to be an essential in a zeolite It occurs in cavities in basalts and less often filling openings in granites or other crystalline rocks, it also is a gangue mineral in certain ore veins

There are many localities for apophyllite Bohemia, Trentino, Italy, the Hartz Mountains, and Iceland Fine specimens have been obtained from the Ghats Mountains in India The Triassic trap rocks of New Jersey, Connecticut and Nova Scotia have also furnished many specimens (E S C S)

APOPHYSIS. In zoology, an apophysis is a protuberance or outgrowth of an organic structure, such as a process on a bone

In geology, an apophysis is a tongue or other direct offshoot of a larger vein or **dike.** (A W L, F S C S)

APOPLEXY. Sometimes called stroke Sudden paralysis and coma following a vascular accident in or about the brain or spinal cord The vascular accidents occur as the result of hemorrhage from a vessel or **thrombosis** of the blood within the vessel, thereby shutting off the flow of blood to a portion of the brain (R S M)

APOPYLE The opening by which a canal in the wall of a **sponge** communicates with the central cavity (A W L)

APPALACHIAN REVOLUTION. Permian.

APPENDAGE. A supplementary structure attached to an organ or body Externally many animals have appendages which serve for defense, for locomotion, for securing food, and as sensory organs

The simplest external appendages are mere outgrowths of the body wall, either solid or hollow, the tentacles of **coelenterates** are an excellent example In the **annelid** worms both tentacles and parapodia appear as external appendages, in the **echinoderms** the rays or arms may be radiating divisions of the body or appendages, and in the **molluscs** tentacles of complex structure occur In all cases these structures allow greater facility of movement than is possible for the body as a whole and so compensate the lack of freedom which attends increased size and complexity or sessile habits

The most elaborate appendages are the jointed appendages of the **arthropods** and **chordates.** Although they are not fundamentally related, the appendages of both phyla are similar in principle They consist of a series of segments connected by movable joints with each other and with the body, and are provided with muscles which operate them as a series of levers

The jointed appendages of arthropods are specialized in various species for swimming, walking, running, jumping and grasping, and in the form of antennae and

palpi as sensory organs. In the jumping appendage powerful muscles result in the extension of one segment of the leg, as in the familiar grasshoppers Grasping is accomplished by the folding back of one segment against another in the insects or by the development of a process on the next to the last segment which works against the terminal segment in a forceps-like relation, the latter is the chelate type of appendage Arthropod appendages were originally metameric, one pair appearing on each segment of the body In existing species they are variably limited as described under the term Arthropoda

The **vertebrate** appendage is also specialized for various purposes, including jumping, swimming, flight, and burrowing The primitive form appears to be the paired fins of the fishes (**Pisces**), and the arms and legs of man are good examples of fairly specialized appendages Two pairs, the pectoral or anterior pair and the pelvic or posterior pair are typical, only in highly specialized forms such as the snakes is this number reduced

The **vertebrate** appendage differs from the arthropod appendage in the terminal series of digits These structures have been developed in some animals so that they can be opposed to each other for grasping, as in the opposition of the human thumb to the four fingers In other forms they have been reduced in importance

Biramous appendage, hand, fin, foot, antenna, pentadactyl appendage, tail, wing, telson, and **mouth.** (A W L)

APPENDECTOMY The surgical removal of the appendix (R S M)

APPENDICITIS. Acute appendicitis is an acute inflammatory process involving the **appendix.** It is characterized by abdominal pain, tenderness and spasm of the muscles of the right side of the abdomen, presence or absence of fever, and usually by an elevated white blood count and vomiting

At the start of the nineteenth century the importance of the appendix was not recognized Inflammation in the right side of the abdomen was believed to be due to infection about the **cecum** and was called "typhlitis" or "perityphlitis"

Isolated reports in the early nineteenth century showed that the appendix could be involved in an acute process but operations and autopsies were quite rare The real significance of the disease was recognized by Reginald Fitz, of Boston, in 1886 who first used the term "appendicitis"

Appendicitis is more frequent in highly civilized races than in primitive peoples and is more frequent in urban than in rural districts Constipation or the treatment of constipation by habitual cathartics may well be a factor as both seem to follow along with the advances of civilization and a less natural life The disease is most common between the ages of 10 and 35, although it may occur at other periods

An attack of appendicitis may subside, but, on the other hand, with a virulent infection or with obstruction of the blood supply to the organ, the appendix may become gangrenous or rupture, allowing grossly infected material to infect the abdominal cavity This produces **peritonitis.** Nearly 25,000 individuals die from appendicitis in the United States yearly In simple acute appendicitis uncomplicated by abscess or peritonitis, the mortality is less than one percent But once these complications develop the mortality soars Hence the importance of early operation as soon as the diagnosis of acute appendicitis has been made Delay and the taking of cathartics during an attack is responsible for the high mortality One attack of appendicitis predisposes to subsequent attacks

The most important and constant symptom of appendicitis is pain in the abdomen, most frequently in the right lower abdomen. Often the pain at first is around the navel and later shifts to the right lower quadrant of the abdomen The pain may be constant or intermittent but is usually cramp-like It varies considerably in severity, depending on many factors such as anatomical peculiarities of the appendix, severity of infection, and degree of obstruction of the appendix. Frequently, with rupture of the appendix the pain becomes lessened for a time—a dangerous sign

The next most constant finding is tenderness localized over the region of the appendix Temperature may be absent, slight, or moderately high The white blood count varies but is often either slightly or moderately elevated It is a valuable confirmatory sign that at times may be misleading (a patient may have a normal blood count with a gangrenous appendix). Vomiting may accompany appendicitis but is frequently absent, especially in early appendicitis

In children diagnosis of appendicitis is more difficult than in adults and it is for this reason that operation is usually delayed too long The mortality from appendicitis is quite high in children

Treatment for acute appendicitis is always surgical The earlier surgery is undertaken, the lower the mortality

Chronic appendicitis is a much abused term as many so called cases are due to trouble in organs not having any relation to the appendix Such cases are not relieved of symptoms by **appendectomy** The term chronic appendicitis should be used only to describe an appendix that has been damaged by previous acute attacks of appendicitis (R S M)

APPENDICULARIAN. Chordata, Tunicata A free-swimming tailed tunicate These forms make up the class **Larvacea.** (A W L)

APPENDIX (Appendix Vermiformis) A worm-like tubular portion of the intestine which arises from the base of the **cecum** Its size and position vary greatly, the length averaging three and one-half inches, although it has been found to vary from three-fourths to nine inches Its position varies from the normal so that it has been reported in every possible situation in the **abdomen,** depending on the position of the cecum and the length of the organ and its attachments

An appendix is found only in man, the higher **apes,** and the **wombat,** and possibly in some **rodents.** In herbivorous animals the cecum attains a very large size and it is thought by some that the appendix represents the degenerated remains of the herbivorous cecum Others believe that it is a **lymph** organ functioning as other lymph glands in the body By many it is considered to be in the process of gradual obliteration in the human species It is subject to inflammatory processes because of its limited blood supply through obstruction from fecal impaction and because it is an organ that contains many lymph structures similar to lymph glands (R S M)

APPLE. Rose Family.

APPLICATIONS OF CHEMISTRY. Chemistry, Applied Chemistry.

APPLIED CHEMISTRY. Chemistry, Applied Chemistry.

APPROXIMATE INTEGRATION. When the **function** in the integrand of a **definite integral** is given analytically, the definite integral is usually evaluated by finding the corresponding **indefinite integral** by the methods of **integration technique** and substituting in this the given limits But it sometimes happens that the indefinite integral cannot be found, and in this case a method of approximate integration must be used. When the integrand function is given empirically by a set of values, the integration technique is not applicable, and in this case also a method of approximate

integration is ordinarily used Formulas for the approximate evaluation of **definite integrals** are given by the following rules

Suppose we wish to evaluate approximately the integral $\int_a^b f(x)dx$ Divide the interval (a, b) into n equal parts, each of length h, so that $h = \frac{b-a}{n}$ Let the successive values of x in this subdivision be denoted by $x_0(=a), x_1, x_2, \ldots, x_{n-1}, x_n(=b)$, and let the corresponding values of the function $y = f(x)$ be denoted by $y_0, y_1, y_2, \ldots, y_{n-1}, y_n$, so that

$$y_0 = f(a),\ y_1 = f(x_1),\ y_2 = f(x_2),\ \ldots,\ y_{n-1} = f(x_{n-1}),\ y_n = f(b).$$

The trapezoidal rule is expressed by the formula

$$\int_a^b f(x)dx \approx \tfrac{1}{2}h(y_0+2y_1+2y_2+2y_3+\ \ldots\ +2y_{n-1}+y_n).$$

where the coefficients of the y's are all 2 except the first and last In this case, n may be any positive integer, in general, the larger n is taken, the closer the approximation

For Simpson's one-third rule (or parabolic rule), the positive integer n must be taken as an even number, the rule is then expressed by the formula

$$\int_a^b f(x)dx \approx \tfrac{1}{3}h(y_0 + 4y_1 + 2y_2 + 4y_3 + 2y_4 + \ldots + 2y_{n-2} + 4y_{n-1} + y_n)$$

Here also the approximation is in general closer the larger n is taken

There are additional similar rules known for the approximate evaluation of definite integrals (I L S)

APPROXIMATIONS, NOTATION. The symbol $\approx$ is put between two expressions to indicate that the right hand expression is an approximation to the left hand expression

Thus, we may write $\frac{1}{3} \approx 0.33$, $\sqrt{2} \approx 1.414$, $\pi \approx 3.1416$

(L L S)

APRICOT Rose Family.

APTERYGIFORMES An order of birds containing only the flightless **kiwis** of New Zealand (A W L)

APTERYGOTA. The primitive wingless **insects** A subclass made up of the orders **Protura, Thysanura,** and **Collembola** in which the existing species are wingless and there is no evidence to show that wings have occurred in any ancestral form (A W L)

AQUA. Latin, water, previously used widely by chemists as a term for various solutions in water, e g , aqua ammonia, solution of **ammonia** in water, ammonium hydroxide, aqua calcis, lime water, **calcium** hydroxide solution, aqua fortis, **nitric acid;** aqua regia, mixture of concentrated nitric and **hydrochloric acids,** named "royal water" because it was the only acid that would attack the noble metal gold (R K S)

AQUAMARINE. Beryl.

AQUARIUM. A water-tight container, usually with glass sides, for the maintenance of aquatic organisms in captivity Also an establishment for the public exhibition of such displays

Small aquaria for the home are often of the globular type known as goldfish bowls, blown in one piece, or one-piece rectangular glass vessels Larger aquaria are made of glass plates set in a metal frame with a specially prepared aquarium cement The latter require greater care and usually leak when first filled or when shifted later; if well constructed the flexible cement permits adjustment to the changed stresses and the leaks stop automatically For laboratory purposes larger aquaria are made of a combination of stone slabs and glass plates

Formerly aquaria for the home were limited to the display of goldfishes but in recent years many species of tropical fishes have been made available In all cases the purity of the water used and the maintenance of an adequate supply of oxygen are important factors in the success of the aquarium The maintenance of tropical fishes is further complicated by the need for higher temperatures than can be found in most homes These aquaria cannot safely be allowed to drop below 70° F and should be maintained at 75° to 80° Heating is best accomplished by electric heaters with **thermostatic** control, for which special equipment can be secured from dealers in aquarium supplies

As a rule a good city water supply is safe for fishes If not, water from any clear stream or lake where fishes thrive is likely to be safe for aquarium species, or a chemical purifier can be secured from dealers in fishes

The oxygen supply can be maintained by changing the water frequently but it is better to establish a balanced aquarium by including some water plants such as **Elodea, Vallisneria,** or **Sagittaria** The plants free oxygen and utilize the carbon dioxide produced by the fishes Some plants float but others must be planted in a bed of sand or gravel in the bottom of the aquarium With a little practice pleasing arrangements may be secured by the use of a few rocks and the careful grouping of the plants, and the quantities of plants and fishes may be adjusted so that changes need not be made for months at a time A good rule to follow is "an inch of fish to a gallon of water" Plants need not be so carefully regulated, for they tend to crowd the aquarium and must usually be thinned from time to time, while fish increase only under the most favorable conditions

Some common aquarium troubles are the accumulation of **algae,** diseases, and incompatibility of different species of fishes Once algae are introduced it is difficult to keep them down without complete sterilization and renovation of the aquarium and any sand and rocks that it may contain Plants should be replaced with clean stock but the fishes may be returned to the aquarium For the recognition and treatment of diseases and for the proper stocking of the aquarium the fish-fancier should consult a reputable dealer or one of the excellent books on aquarium fishes now on the market

A few snails and bottom-feeding fishes included in an aquarium play a useful part as scavengers

While convenience must often determine the location of an aquarium in the home, plants will not thrive without some sunlight so a balanced aquarium must be kept near a window North light is by far the best If the sun's rays must strike the aquarium directly, it should be only for a short time during the day

Among the aquaria where large public exhibits of fishes are maintained may be mentioned the New York Aquarium, Shedd Aquarium in Chicago, Steinhart Aquarium at San Francisco, the Naples Aquarium, London Zoological Gardens, the Bermuda Aquarium, and the Honolulu Aquarium The two last are famous for the brilliant tropical fishes which they exhibit from neighboring waters (A W L)

AQUARIUS (The water bearer) (Map, page 306) This **constellation** is the eleventh sign of the **zodiac** and is of importance solely because of the fact that it is on the path of the **sun** and the **planets.** There is a theory that the constellation received its name because the sun is in this part of the sky during the rainy season in the Euphrates valley

Though the constellation is relatively large it contains no bright or particularly striking features (W K G)

AQUEDUCT. An artificial conduit built to carry water is called an aqueduct Generally speaking, aqueducts are built to convey the fresh water supply of

congested districts from suitable sources more or less distant, and are therefore peculiar to cities The first settlers in a place may depend upon local springs, streams, and wells, but with the growth of population there comes a time when these will prove inadequate, and suitable distant water supplies may have to be tapped through the medium of the aqueduct

An aqueduct may be of a pressure or grade-line type The former is the more expensive to construct and is only employed when the grade-line construction is unsuitable Pressure tunnels can convey water at pressures considerably above atmospheric, and are constructed with circular cross-sections They are most frequently found in tunnel sections cut through hills and mountains, and in siphons The principal distinguishing hydraulic characteristic of the pressure aqueduct is that it may depart from the normal open flow line both above and below the normal **hydraulic gradient.** Grade-line sections of aqueducts are usually built with open cut and fill construction following a hydraulic grade-line which will yield the requisite flow in the aqueduct at approximately atmospheric pressure, i e, the fall per mile being just sufficient to overcome the friction loss in the same distance Grade-line aqueducts have usually a horseshoe-shaped cross-section, with a slightly curved bottom, called an **invert**, and a highly arched top

Some of the most important of the ancient aqueducts were those supplying the city of Rome, among which might be mentioned the Marcian, with a length of 58 miles, the Julian, a length of 17 miles, and the Claudian, with a length of 43 miles These were high level aqueducts of the grade-line type, principally cut and fill where possible, with grade-line tunnels for piercing hills, and resting on multiple arches when spanning valleys These older aqueducts rarely had cross-sections greater than 30 square feet in area The Catskill aqueduct which conveys the water of the Ashokan Reservior to the City of New York, approximately 100 miles away, has a capacity of 500,000,000 gallons a day and is a splendid example of modern engineering on a large scale It has in places cross-sections greater than 150 square feet in area, inverted siphons, one going more than 1000 feet below sea level, as well as a score of tunnels (C W C)

AQUEDUCT OF SYLVIUS The portion of the central canal of the **nervous system** of **vertebrates** which lies in the mid-brain, connecting the third and fourth ventricles (A W L)

AQUIFER. Ground Water.

AQUILA. (The eagle) (Map, page 306) A constellation lying the **milky way** and hence containing rich star fields when viewed with a low powered **telescope.** The distinguishing feature of this constellation is the group of three stars in almost a straight line, with the bright star **Altair** between two fainter ones Several **Novae** have appeared in this constellation, the most famous one being Nova Aquilae III of 1918 (W K G)

ARABINOSE. Carbohydrates.

ARACHNIDA. A class of the phylum **Arthropoda** including the **spiders, mites, ticks, scorpions,** pseudo-scorpions, **whip scorpions,** sun spiders and **harvestmen.** Next to the insects this class is probably the best known among the invertebrates

Arachnids differ from the other members of the phylum in one or more of the following characters 1 The body is usually divided into two regions, a **cephalothorax** and abdomen 2 Only simple eyes are present 3 There are no **antennae.** 4 The **thorax** bears four pairs of legs in the adult 5 The **abdomen** is often unsegmented and bears no appendages. 6 The first pair of appendages are **chelate** grasping organs. 7 Respiration is carried on by **tracheae** or **lung-books.**

Arachnids are almost exclusively terrestrial and are predominantly predacious or parasitic, although some of the mites are plant feeders and the harvestmen include vegetable materials among their food

The development of poison glands is fairly general in the group Spiders have such glands, opening in the jaws or **chelicerae,** and scorpions have a special sting at the tip of the abdomen With the exception of the black-widow spider of the United States and a small scorpion found near Durango the poison is not known to be harmful to man There is some probability that these two species may sometimes inflict fatal wounds

The secretion of silk by spiders is another salient feature of the group Silk glands are located in the abdomen, discharging through a group of spinnerets near the posterior end of the body The silk is used to build webs of various forms for snaring prey, for the construction of cocoons to receive the eggs, as a lining for burrows, and in some cases as a vehicle to carry the animal on currents of air

The economic importance of arachnids is rather limited Spider silk has been woven but it is too delicate for extensive use and is valuable only as a source of cross-hairs for optical instruments Aside from the poisons mentioned above, the principal harm from these animals is derived from the mites and ticks The ticks do some damage to man and domestic animals by sucking blood but their greatest damage is due to the transmission of diseases Texas fever of cattle, Rocky Mountain spotted fever of man, and other diseases are so conveyed Mites living in the hair follicles, the **sebaceous glands,** and the tissues of the skin cause such diseases as scab in sheep and itch in man Plant-feeding species of economic importance include the bulb mite, the pear blister mite and various gall mites

The classification of the arachnids is briefly as follows

Order Scorpionida The **scorpions** Abdomen divided into a preabdomen and a slender postabdomen bearing a claw-like sting at the tip

Order Pedipalpi The **whip-scorpions.** Anterior pair of legs slender and antenna-like

Order **Solpugida.** The sun spiders Head and thorax separate

Order Chelonethida Pseudoscorpions Very small scorpion-like animals, no postabdomen nor sting

Order Phalangida **Harvestmen** or daddy longlegs, commonly regarded as spiders but have a segmented abdomen broadly joined to the thorax

Order Araneina **Spiders.** Abdomen unsegmented and joined to the thorax by a slender waist

Order Acarina **Mites** and **ticks.** Small to moderate species with a sac-like body showing no well-marked divisions (A W L)

ARAGONITE The mineral aragonite is **calcium** carbonate, $CaCO_3$, chemically identical with **calcite** but crystallizing in the **orthorhombic system,** with acicular crystals By repeated twinning, pseudo-hexagonal forms result Aragonite may be columnar or fibrous, occasionally in branching **stalactitic** forms called flos-ferri (flowers of iron) from their association with the ores at the Carinthian iron mines Its hardness is 3 5 to 4, Specific gravity, 2 93 to 2 95, luster, vitreous to resinous, colors, white, gray, green yellow or purple; transparent to translucent Aragonite forms at temperatures of 80° to 100° C and is relatively unstable at ordinary temperatures and pressures It alters to calcite, although very slowly There are many localities for aragonite in Europe, Bolivia, Pennsylvania, Iowa, Missouri, South Dakota, New Mexico, Arizona and Colorado Its name is derived from Aragon in Spain (E S C S.)

ARANEINA. Arthropoda, Arachnida. The spiders.

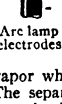
ARAPAIMA. Pisces, Teleostei A large fish, (Pisces) *Arapaima gigas,* of the rivers of northern South America It attains a length of fifteen feet and a weight of more than 400 pounds Also applied to related fishes of several genera (A W L)

ARAUCARIA. Coniferous trees found in southern South America, Polynesia and Australia *Araucaria imbricata,* the "Monkey puzzle" tree of South America, reaches a height of 150 feet *Araucaria excelsa,* the Norfolk Island Pine, is frequently seen in florist windows and in collections of living plants, where it finds place because of its elegant symmetry In its natural habitat it becomes a tree reaching a height of 200 feet or more (R M W)

ARBUTUS. Heath Family.

ARC The electric arc, so called because of the curved shape of the "flame," was discovered by Davy about 1808 This type of discharge differs in several respects from the spark, brush, and glow discharges It is not self-starting, the electrodes must be brought into contact and then drawn apart The cathode, at least, must be hot, a condition secured by passage of the current when the electrodes are in contact, the anode may be hot or cold The arc is thus apparently a **thermionic phenomenon** When the arc is once started, the current density is much greater than in the glow discharge Also the cathode potential-drop is very small These circumstances both indicate a comparatively low resistance The arc discharge may or may not exhibit striations For the arc to start or "strike" on separating the electrodes, a certain minimum or "striking" potential must be supplied, and thereafter, if the current is kept constant, the potential necessary is a linear function of the inter-electrode distance Carbon arcs, formerly much used for lighting, consume the electrodes rapidly, with the formation of a pit or "crater" on the anode, which is the source of most of the light If the carbons are impregnated with a volatile metallic salt, the result is a "flaming arc," useful in producing the arc **spectrum** of the metal If a direct-current carbon arc is placed in parallel with a suitable condenser and an inductance, the circuit so formed may be made to oscillate, as discovered by Duddell, and to serve as a source of undamped electric waves (L D W)

ARC LAMP The electric arc lamp has, as its source of illumination, an electric **arc** struck between two electrodes In contrast to the incandescent lamp, in which the illumination results from a resistance heated filament, and vapor lamps, in which the illumination is derived from a vapor made luminous by electric current, the light from an arc lamp comes from the highly incandescent crater of one of the electrodes, and from the heated, luminous, ionized gases surrounding the arc The positive electrode, having the crater, is mounted above the negative one The light is largely directed downward from the crater To start the arc the electrodes are brought into contact and then separated a short distance The arc which follows vaporizes the electrode material slightly, forming a conducting ionized vapor which bridges the space separating the electrodes The separation distance is maintained by a series-connected solenoid



Arc lamp electrodes.

The principal electrode material employed is carbon containing mineral salts which tend to intensify the flame between the electrodes In any arc lamp using other than plain carbon electrodes, there is the problem of disposing of the fumes of the arc so that the enclosing glass globe will not be discolored, and in all such lamps, carbon or otherwise, there is a steady consumption of electrodes when the lamp is in use, necessitating their replacement every 50 to 150 hours of use The light from arc lamps is very much more intense than that from the incandescent type lamp From the standpoint of current consumption, the illumination is produced efficiently Some arc lamps may not be operated on alternating current, but all types are adaptable to direct current A constant current series type circuit is used to operate street light arc lamps, as that is found to be the most economical way to distribute the electrical energy over a large territory. (F T M)

ARC WELDING. Welding.

ARCH. An arch is a curved beam, made of **brick, stone, concrete** or **steel,** whose supports are able to exert **lateral** as well as vertical forces to resist the action of any applied **loads** These lateral forces are in the nature of thrusts which act inwardly toward the center of the arch span The curvature of the beam must be in an upward direction in order to develop lateral **reaction** forces which will act in the required direction

Brick arches are generally used to support walls above windows or doorways although they may be used for small **bridges** or **culverts** **Masonry** arches are composed of stone blocks called voissoirs They derive their load carrying capacity from the fact that the shape of the arch ring is such that **compression** is the only type of **stress** caused by the **resultant** reaction on the end of any voissoir Reinforced **concrete** arches, as the name implies, are composed of concrete and steel rods, the latter added primarily for the purpose of carrying any tensile stresses which may occur Steel arches are sub-divided into two classes namely, the solid rib and open rib types The solid rib arch is composed of structural shapes similar to those comprising a **plate girder** while the open rib arch is constructed of structural shapes forming triangles like those in a simple **truss**

These structures may be further classified as fixed or hinged arches A fixed arch is a structure which is rigidly connected to its supports in such a manner that they exert vertical and lateral reactions and prevent rotation A two hinged arch is one which is free to rotate about its supports, consequently they are able to exert only vertical and lateral reactions Three hinged arches have an additional hinge midway between the hinges at the supports The tied arch is a structure in which the lateral forces are applied by means of a horizontal **tension** member connecting the ends of the arch (C W C)

ARCH DAM Dams.

ARCHAEOPTERYX Fossil Birds.

ARCHAEOTHERIUM. Fossil Mammals.

ARCHEGONIATES. Those plants in which the female sex organ is an **archegonium** are called Archegoniates (R M W)

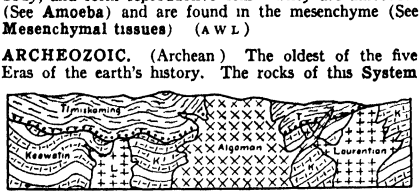
ARCHEGONIUM The multicellular female sex organ characteristic of **Bryophytes, Pteridophytes** and **Gymnosperms** It consists of a swollen basal portion called the venter, and an elongated neck The venter may be a single layer of cells, but is often many cells thick Within the basal portion is contained the single large egg and a second, somewhat smaller, ventral canal cell, while the elongated neck contains a single row of cells which eventually dissociate, leaving an open canal through which the **sperm** may pass to reach the egg (R M W)

ARCHENTERON. Enteric cavity.

ARCHEOCYTE. Cells of **sponges** which ingest and digest food, carry the products to other parts of the

body, and form reproductive cells They are amoeboid (See **Amoeba**) and are found in the mesenchyme (See **Mesenchymal tissues**) (A W L)

ARCHEOZOIC. (Archean) The oldest of the five Eras of the earth's history. The rocks of this **System**



A highly generalized section, about 25 miles long, showing the relations of the Archeozoic group of rocks in the Lake Superior Lake Huron region of Canada The Keewatin system was moderately folded and intruded by the Laurentian granite, after which there was deep erosion Then the Timiskaming rocks were laid down, and later strongly folded and intruded by the Algoman granite, after which there was another period of profound erosion, marked by the upper surface

are **metamorphosed** equivalents of all types of **sedimentary** and **igneous** rocks, but principally the latter No undisputed fossils have been found in the Archean The lower Archean (Keewatin) of North America is composed of a preponderance of metamorphosed, **basaltic** lava flows and tuffs with some metamorphosed sediments, such as **quartzite** and **slate.** The general character of the basal Archean proves that the oldest known rocks do not represent the original crust of the earth The upper Archean (Laurentian) contains a preponderance of **granite, gneisses,** and **schists** in the form of **batholiths** intruding the Keewatin The principal areas of Archeozoic rocks are in Canada, Finland, Scandinavia, Australia, Africa and northeastern South America Many of the formations contain rich ore deposits, especially of gold and silver Large amounts of graphite suggest the former existence of life Length of time since the beginning of the Archeozoic, possibly 2000 million years Owing to the lack of fossils, structural complexity, high degree of **vulcanism** and **metamorphism,** geologists have found great difficulty in deciphering the history of this earliest recognizable portion of the "crust" of the earth The structural history of the Archean is therefor not so well known as that of the succeeding periods and intercontinental correlation is particularly difficult On the other hand, the search for ore deposits has been an important stimulus to the study of the Archean formations, especially in Canada (R M F)

ARCHIANNELIDA. A class of **annelid** worms including small marine species of simple structure (A W L)

ARCHIMEDES PRINCIPLE. **Buoyancy.**

ARCTURUS, (α **Bootes**) Arcturus was probably one of the first stars to be named It probably received its name because of its proximity to the constellation of **Ursa Major,** the name indicating that it is the "watcher of the bear" The name Arcturus is one of the few star names to be referred to in the Bible, being found in Job IX, but from the remainder of the verse there is evidence that the name Arcturus in this quotation actually refers to the constellation of Ursa Major rather than to the actual star itself References to Arcturus are to be found in the writings of many of the ancient poets, including Virgil **Astrologically,** the star portended honor and riches

Arcturus is one of the few stars whose diameter has actually been measured with the stellar **interferometer** The angular diameter is found to 0″020 which, when combined with its **stellar parallax** of 0″080, indicates a linear diameter of about 27 times that of our **sun** (W K G)

AREA ON A CURVED SURFACE With a very few exceptions, the area of a portion or all of a given curved surface can only be found by use of methods of the **calculus.**

If an arc of a **curve** whose equation in **rectangular coordinates** is $y = f(x)$, between **ordinates** $x = a$ and $x = b$, is revolved about the X-axis, the area of the **surface of revolution** generated is given by

$$S = 2\pi \int_a^b y ds = 2\pi \int_a^b y \sqrt{1 + \left(\frac{dy}{dx}\right)^2}\, dx$$

If an arc of a **curve** whose equation is $x = \phi(y)$, between **abscissas** $y = c$ and $y = d$, is revolved about the Y-axis, the area of surface generated is given by

$$S' = 2\pi \int_c^d x ds = 2\pi \int_c^d x \sqrt{1 + \left(\frac{dx}{dy}\right)^2}\, dy.$$

If the equation of a surface in rectangular coordinates is $z = f(x, y)$, the area of a portion S of the surface is given by the **double integral**

$$S = \int\int_S \left[1 + \left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2\right]^{\frac{1}{2}} dx dy$$

If the equation of the surface is $F(x, y, z) = 0$, the area of S is given by

$$S = \int\int_S \frac{\sqrt{\left(\frac{\partial F}{\partial x}\right)^2 + \left(\frac{\partial F}{\partial y}\right)^2 + \left(\frac{\partial F}{\partial z}\right)^2}}{\left[\frac{\partial F}{\partial z}\right]} dS.$$

(L L S)

AREA UNDER A PLANE CURVE One of the simplest interpretations of the **definite integral** is by the area under a plane curve

If $y = f(x)$ is the equation in **rectangular coordinates** of a **plane curve,** the area between this curve, the X-axis and two **ordinates** $x = a$ and $x = b$, is given by the **definite integral**

$$A = \int_a^b y dx = \int_a^b f(x) dx.$$

If the equation in rectangular coordinates of the curve is $x = \phi(y)$, the area between this curve, the Y-axis and two **abscissas** $y = c$ and $y = d$ is given by

$$A = \int_c^d x dy = \int_c^d \phi(y) dy$$

If the equation of the curve in **polar coordinates** is $r = f(\theta)$, the area bounded by the curve, two fixed radii vectores $\theta = \alpha$ and $\theta = \beta$ is given by

$$A = \tfrac{1}{2} \int_\alpha^\beta r^2 d\theta$$ (L L S)

ARENACEOUS. A textural term applied to sediments or **sedimentary** rocks which are composed of grains of sand Psammitic has the same meaning (R M F)

AREOLA The circular area surrounding the nipple, darker in color than the surrounding skin In women following pregnancy the areola becomes darker and larger in size (R S M)

ARGALI. **Sheep.**

ARGAND'S DIAGRAM. **Complex Numbers.**

ARGENTITE. The mineral argentite, sometimes called silver glance, is naturally occurring **silver** sulfide, corresponding to the formula Ag_2S It crystallizes in the **isometric system** in cubes, octahedrons and dodecahedrons, or may be massive Hardness, 2 to 2 5, specific gravity, 7 2 to 7 36, luster, metallic, streak, gray, color, black, blackish gray or gray, opaque and sectile to such an extent that it cuts like wax with a knife, Heated upon charcoal it yields a malleable mass of silver The name is derived from the Latin word for silver, *argentum*

Foreign localities for fine crystals are Sonora, Mexico, and Freiberg, Saxony, in the United States at Butte, Montana, Tonopah, Nevada, and Aspen, Colorado

Argentite is probably the most abundant ore of silver Acanthite a rare **orthorhombic** silver sulfide has the same chemical composition and recent studies seem to show that it is a low temperature form while argentite is the high temperature form of this compound (E S C S)

ARGENTUM. Silver.

ARGILLACEOUS This term is used to designate **sedimentary** rocks composed of fine particles of the nature of clay or mud Pelitic has the same meaning (R M F)

ARGILLITE. A dense, fine-grained, hard, **sedimentary** rock of various colors (usually white, gray or red) Composed of minute grains of both **clay** and **quartz.** Certain types of argillites are easily confused with certain types of fine-grained acid **lava** flows, such as felsites, unless studied microscopically (R M F)

ARGININE. Aminoacids

ARGON. Symbol A Atomic number 18 Atomic weight 39 944 Density 1 784 grams per liter, 0° C, 760 mm, or 1 380 when air is taken as 1 000 Melting point —189 2° C Boiling point —185 7° C Isotopes 36 (0 33%), 38 (0 05%), 40 (99 62%)

Argon is a colorless, odorless gas, which does not react chemically under ordinary conditions Discovered by Rayleigh and Ramsay in 1894, in ordinary air to the extent of 0 94% The discovery was due to the investigation into the discrepancy of the density of **nitrogen** from the atmosphere and from chemical compounds It appears that Cavendish a century earlier had made the observation that a small portion of air remained when nitrogen was sparked with oxygen Argon shows a pale red glow in a vacuum electric discharge tube Commercially, argon is used instead of nitrogen as the atmosphere of **tungsten** electric light bulbs (R K S)

ARGONAUTA Mollusca, Cephalopoda The genus to which the paper nautilus belongs This species is not a true nautilus but is more closely related to the octopus (A W L)

ARGYRIA Poisoning from the use of **silver** preparations over too long a period, causing a ghastly bluish discoloration of the skin over the entire body (R S M)

ARIES (The ram) (Map, page 306) This **constellation** is far more famous from its classical significance than because of its appearance in the sky It contains no bright stars and has no conspicuous features Two thousand years ago the **vernal equinox** was located in the constellation of Aries and the symbol for the vernal equinox is the symbol for the constellation (i e, the ram's head) **Precession** has caused the position of the vernal equinox to move backwards into the constellation of **Pisces** so that now the "sign of the first of Aries" is to be found in that constellation (W K G)

ARIL. In many plants there is formed in the developing fruit an outgrowth from the funiculus, or seed stalk, one which completely or partially surrounds the seed In the litchi nut it is the thick translucent pulp surrounding the seed, in the nutmeg it is a mesh-like envelop which when removed and dried is ground up to become mace (R M W)

ARISTOGENESIS A principle of **evolution** formulated by Henry Fairfield Osborn, based upon observation of successive changes in fossil series It postulates the origin of new characters in living things in adaptation to the environment and was expressed by its author as "the creative origin of the adaptive" (A W L)

"ARISTOL." A trade-name for thymol iodide (See **Phenols**), which is commonly used as an **antiseptic** powder for ulcers and wounds (R S M)

ARISTOTLE'S LANTERN. The masticating apparatus of the sea-urchin (**Echinoidea**) It consists of five jaws, each bearing a tooth, and five radial pieces (rotulae) which unite the bases of the jaws (A W L)

ARITHMETIC. Arithmetic, as generally understood, deals with the operations with numbers and their practical applications, it may be described as the art of computation and the applications of this art (L L S)

ARITHMETIC MEANS. Arithmetic Progressions.

ARITHMETIC PROGRESSION. An arithmetic progression is a succession of **numbers** such that each member of the set differs from the preceding one by a constant called the common difference The term "arithmetic progression" is often abbreviated A P

There are two fundamental formulas for arithmetic progressions,—one for the general term and one for the sum of any number of terms

The general term or n^{th} term of an arithmetic progression whose first term is a and whose common difference is d is given by the formula

$$l = a + (n-1)d$$

The sum of the first n terms of this arithmetic progression is given by

$$S = \frac{n}{2}(a + l)$$

The terms of an arithmetic progression between the first and last terms are called arithmetic means

The arithmetic mean of two numbers is the middle term of an arithmetic progression whose first and last terms are the given numbers, it is given by half the sum of the given numbers The arithmetic mean of two numbers is the same as the so-called arithmetic average of the two numbers (L L S)

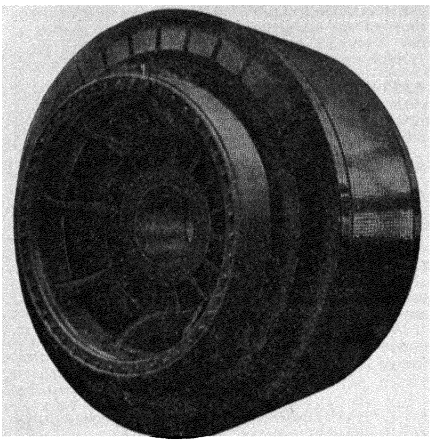
ARIZONITE. A term proposed by Spurr and Washington in 1917 for a **dyke** rock largely composed of **quartz** but with an appreciable amount of **orthoclase.** (R M F)

ARKOSE. Arkose is a relatively coarse grained feldspathic **sandstone,** derived from the rapid disintegration of granite or other **feldspathic** rock It is characterized by its content of fresh, unaltered, **euhedral** feldspar The term was proposed by Brongiart in 1823, and has been in constant use ever since Arkose is an important type of sediment especially in relation to the study of **unconformities, Paleoclimatology, "fossil" soils,** etc. (R M F)

ARM. An extended lobe or appendage of a body The radiating lobes of the starfish are called arms or rays and the term is also applied to the branches of the **lophophore** in **brachiopods** and to other special structures Its most familiar use is in application to the pectoral appendages of **vertebrates** when freed from the usual functions of support and locomotion, as in man and the other primates In most of these species the arms are used for locomotion through the trees and some are still quadrupedal on the ground, but even in these species the arms can be used to some extent for handling objects (A W L)

ARMADILLO. Mammalia, Edentata Burrowing animals with many bony plates in the skin which form a more or less complete armor when the animal rolls up Several species occur from Argentina northward through South America and one, the nine-banded armadillo, is found in Texas They range in size from the five-inch pichiciago to the three-foot giant armadillo (A W L)

ARMATURE. The armature is one of the two essential parts of the dynamo electric machine. In a **generator,** the armature is the winding in which **electromotive**



Armature of a generator.

force is produced by magnetic induction. In the motor armature, conductors carry the input current which, in the presence of a **magnetic field,** produces a **torque** and effects the transmission of electrical into mechanical energy; consequently, the armature of a motor must always be the rotor. On the other hand, the armature is not necessarily the rotor of a generator. The armature is in the stator in an **alternator,** but is mounted on the rotor in the direct current **generator.** The reluctance of the magnetic circuit, the flux of which the conductors of the armature must cut in order to generate electric energy, is decreased by providing a core of soft iron or steel, on the surface of which the conductors are embedded in slots suitably provided in the core. The armature windings of a direct current generator are terminated at the segments of a **commutator,** by means of which the alternating e.m.f.'s induced in the armature are rectified and transferred by brushes from the moving rotor to stationary terminals. The conductors must be separately insulated, as must be also the commutator segments, and must be well braced and anchored in their slots to resist the electric and mechanical forces which tend to displace them. (F.T.M.)

ARMATURE REACTION. This term refers to the reaction of the magnetic field produced by the current flowing in **armature** windings upon the main magnetic field of a dynamo machine. The result is a distortion of the **magnetic field,** increasing the flux density at some pole tips, decreasing it at others. The extent of armature reaction depends on the **reluctance** of the magnetic circuit, the arrangement of the armature winding, and the phase relation (See **Alternating Current Circuits**) between voltage and current in the armature winding. (F.T.M.)

ARMY-WORM. Insecta, Lepidoptera. An economically important **caterpillar,** *Cirphis unipuncta,* named from its habit of migrating from field to field in large numbers. When severe outbreaks occur these insects completely strip fields of grain of all kinds. When migrating they are trapped in barrier ditches dug around the fields to be protected. They are also killed by poison baits. (A.W.L.)

ARNICA. Composite Family.

AROIDS. A large group of monocotyledonous plants, mostly tropical, having a characteristic flower habit. The numerous small inconspicuous flowers are borne on a fleshy stalk or spadix, which is surrounded, more or less completely, by a large, expanded, often brightly colored **bract** called a spathe. The spadix and spathe together are often but incorrectly considered to be the flower of the plant. The aroids are perennial plants, generally having tubers or **rhizomes** from which rise large leaves. Many tropical members are climbing plants. Well-known species are the Skunk Cabbage, whose foul-scented flowers open so early in the spring, the Jack-in-the-Pulpit, and the wild arum, *Calla palustris,* of cold wet swamps, as well as the Sweet Flag, *Acorus Calamus,* of the marshes. The cultivated Calla Lilies are all aroids and not lilies at all; some of them are delightfully fragrant. On the other hand, in species of *Amorphophallus,* which are sometimes seen in collections of cultivated plants, the vile odor of the flower structure prevents them from becoming popular; the flowers of some of them are of gigantic size. In the tropics several species of *Colocasia* are cultivated for the edible rhizomes which appear under the name of dasheen or taro. (R.M.W.)

AROMATIC HYDROCARBONS. Benzenoid **hydrocarbons.**

AROMATIC OILS. Volatile **oils.**

ARRHYTHMIA. Any variation in the **normal rhythm** of the **heart.** (R.S.M.)

ARROW WORM. Small marine animals sometimes classified with the **annelid** worms but more often included in the separate phylum **Chaetognatha.** (A.W.L.)

ARROYO. This term is applied to dry stream channels with nearly vertical walls and flat bottoms which are characteristic of semi-arid regions. They may suddenly become filled with torrential waters after heavy rains.

The word arroyo is of Spanish origin. (E.S.C.S.)

ARSENIC. Symbol: As. Atomic number: 33. Atomic weight: 74.91. Density: gray 5.73; black 4.7; yellow 2.0. Hardness: 3.5.

Arsenic is a gray metal, brittle; sublimes on heating; is unchanged in dry air but a film of oxide is formed in moist air; heated in air at 180° C. forms arsenic trioxide of the odor of garlic, poisonous; insoluble in **hydrochloric acid** but soluble in concentrated **nitric** or concentrated **sulfuric acid** to form arsenic acid; soluble in hot **sodium** hydroxide solution; heated with chlorine forms arsenic trichloride; heated with metals forms metallic arsenides. When arsenic is heated in a tube and the vapor cooled (1) slowly (that is, in the hot part of the tube) black arsenic is formed, and this form is converted into the gray at 360° C., (2) rapidly (that is, in the cold part of the tube) yellow arsenic is formed, and this form is quickly converted into the gray by the action of light. Yellow arsenic is soluble in **carbon disulfide.** Arsenic element was discovered by Schröder in 1649.

Arsenic occurs as arsenide in many sulfide ores, e.g., of zinc, iron, cobalt, nickel, and as the mineral sulfides, **realgar** (arsenic monosulfide, AsS), red colored, **orpiment** (arsenic trisulfide, As_2S_3), yellow-colored—these two minerals when powdered are used as paint pigments —**arsenopyrite,** mispickel (iron arsenosulfide, FeAsS). The primary arsenic containing material is arsenious oxide obtained by separation from roaster or smelter flue gases, and is most largely produced in Montana and Utah. Arsenic is obtained as a sublimate by heating the oxide with carbon. The use of free arsenic is practically limited to the manufacture of chilled shot—addition of arsenic (0.1%) lowers the melting point and increases the surface tension of lead so that chilling of the liquid drops yields spherical shot.

SCHEME SHOWING INTERRELATIONSHIPS OF ARSENIC-FUNCTION ORGANIC COMPOUNDS

ARSINES

Methyl arsine
CH_3AsH_2
B P 2° C.

Phenyl arsine
$C_6H_5AsH_2$

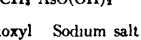
Phenyl arsine dichloride
$C_6H_5 \cdot AsCl_2$

Phenyl arsenoxide
C_6H_5AsO

ARSONIC ACIDS

Methylarsonic acid
$CH_3AsO(OH)_2$

Atoxyl Sodium salt of para-amino phenylarsonic acid



Dimethylarsine
$(CH_3)_2AsH$
B P 36° C
(747 mm.)

Diphenyl arsine
$(C_6H_5)_2AsH$

Cacodyl oxide
$(CH_3)_2As$
$(CH_3)_2As$ O

Cacodyl chloride
$(CH_3)_2AsCl$

Cacodyl
$(CH_3)_2As$
|
$(CH_3)_2As$

Dimethylarsonic acid (cacodyl acid)
$(CH_3)_2AsO(OH)$

Trimethyl arsine
$(CH_3)_3As$
B P 140° C
(736 mm)
Reacts with
1 Oxygen
2 Chlorine
3 Sulfur
4 Methyl iodide

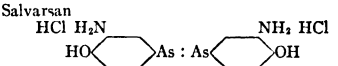
Triphenylarsine
$(C_6H_5)_3As$
M P 57° C.

Trimethyl arsine oxide
$(CH_3)_3AsO$

Quaternary arsonium compounds
$[(CH_3)_4As]I$
$[(CH_3)_4As]OH$

Arsenobenzene
$C_6H_5As \quad AsC_6H_5$

Salvarsan



Neosalvarsan
Sodium salt of salvarsan condensed with formaldehyde sulphoxylate (one or two hydrosulfite (—OSONa) groups)

Acids arsenious acid is the name sometimes applied to solutions of arsenious oxide, but the acid has not been isolated, arsenic acid ($H_3AsO_4 \cdot \frac{1}{2}H_2O$), white solid, soluble, by heating arsenious oxide with **nitric acid** and crystallization, (1) orthoarsenic acid (H_3AsO_4 or $As_2O_5 \cdot 3H_2O$), heating these crystals at 100° C, (2) pyro-arsenic acid ($H_4As_2O_7$ or $As_2O_5 \cdot 2H_2O$) by heating ortho-acid to 140°–180° C, (3) meta-arsenic acid ($HAsO_3$ or $As_2O_5 \cdot H_2O$) by heating pyro-arsenic to 200° C While salts of these acids are known the only hydrates identified are $As_2O_5 \cdot 4H_2O$ and $3As_2O_5 \cdot 5H_2O$

Arsenates sodium arsenate, sodium ortho-arsenate, trisodium arsenate ($Na_3AsO_4 \cdot 12H_2O$), sodium dibasic arsenate, disodium hydrogen arsenate ($Na_2HPO_4 \cdot 7H_2O$), sodium monobasic arsenate, sodium dihydrogen arsenate ($NaH_2AsO_4 \cdot H_2O$) and the corresponding potassium salts are white soluble solids, the former used as a mordant in textile dyeing and printing, **silver** arsenate (Ag_3AsO_4), reddish-brown precipitate, by reaction of silver nitrate solution and sodium arsenate solution, soluble in nitric acid or ammonium hydroxide, **magnesium** ammonium arsenate ($MgNH_4AsO_4$), white precipitate, by reaction of sodium arsenate solution and "magnesia mixture"—a reagent made by adding ammonium chloride to ammonium hydroxide and then to magnesium salt solution without the formation of a precipitate of magnesium hydroxide Many pyro-arsenates and meta-arsenates have been described

Arsenides metallic arsenides are formed (1) by heating the finely powdered metal with arsenic, e g, iron arsenide ($FeAs_2$), (2) by reaction of the metallic salt solution and arsine, e g, copper arsenide (Cu_3As_2).

Arsenites sodium arsenite, sodium meta-arsenite ($NaAsO_2$) and potassium arsenite ($KAsO_2$) are white soluble solids, and the former is used as an insecticide, a weed killer, and poison, silver arsenite, silver ortho-arsenite (Ag_3AsO_3), yellow precipitate, by reaction of sodium arsenite solution and silver nitrate solution, soluble in nitric acid or ammonium hydroxide, copper arsenite ($Cu(AsO_2)_2$), green solid, used as the arsenite-acetate as an insecticide and poison ("Paris green").

Arsine See Hydrides

Chloride arsenious chloride, "butter of arsenic" ($AsCl_3$), colorless liquid, boiling point 130° C, by reaction of arsenic containing solutions with concentrated hydrochloric acid, and applied in the analysis of arsenic containing substances by distilling in a current of hydrogen chloride gas below 108° C (**Germanium** tetrachloride is volatilized similarly)

Hydrides arsenic hydride, arsine (AsH_3), colorless gas, garlic odor, very poisonous by reaction of a solution of any arsenic containing material with (a) a metal, e g, zinc, magnesium for iron, and hydrochloric or dilute sulfuric acid, or (b) a metal, e g, zinc or aluminum, and sodium hydroxide solution Arsine (1) when heated in a glass tube yields a metallic mirror of arsenic, (2) when passed into a solution of silver nitrate yields black precipitate of metallic silver and arsenious acid solution, (3) when passed over solid silver nitrate yields yellow solid ($Ag_3As \cdot 3AgNO_3$), (4) when passed over solid mercurous chloride or solid mercuric chloride, or into mercuric chloride solution yields brown solid mercurous arsenide, (5) when passed into copper sulfate solution yields black precipitate of copper arsenide (Cu_3As_2) The formation

and detection of arsine are important in estimating small amounts of arsenic (March's test, Gutzeit's test, Fleitmann's test) Arsine burns in air with a bluish flame forming arsenious oxide and water, is unchanged in solution of sodium hydroxide, arsenic dihydride (As_2H_2), brown solid, formed by partial burning of arsine, and by electrolysis of water using an arsenic cathode

Oxides arsenious oxide, arsenic trioxide, "white arsenic," "arsenic" (As_2O_3), white solid, moderately soluble, sublimes at 218° C, soluble in alkalis to form arsenites, known in three forms, (1) octahedral, by rapid cooling of the vapor (that is, in the cold part of the condenser), density 3 63, (2) amorphous, by slow cooling of the vapor (that is, in the hot part of the condenser), density 3 74, melting point 200° C, and three times as soluble as octahedral, (3) monoclinic (needle-like crystals), by heating either of the above forms to 200° C for a long time, density 4 15 The oxide is formed by burning arsenic or arsenides in air By-product in the fumes of metallurgical smelters Used as insecticide, rat poison, preservatives of skins and hides, and as the principal source of arsenic compounds Freshly precipitated ferric hydroxide absorbs arsenious oxide, and is used as an antidote in cases of arsenic poisoning

Sulfides arsenic monosulfide, arsenic disulfide (AsS or As_4S_4), red solid, by heating arsenious oxide and **sulfur**, melting point 307° C, used with sulfur and **potassium** nitrate in pyrotechnic powder for producing blue flame, arsenious sulfide, arsenic trisulfide (As_2S_3), (1) yellow precipitate by reaction of solution of arsenite and hydrogen sulfide, in the absence of acid, alkali or salt the precipitate does not coagulate but large quantities may be formed in yellow **colloidal** solution, insoluble in concentrated hydrochloric acid and formed in its presence, soluble in sodium or ammonium sulfide to form thioarsenite, (2) yellow solid by distilling arsenious acid and sulfur from a retort Used as a paint pigment but the color is not permanent in the light, arsenic sulfide, arsenic pentasulfide (As_2S_5), yellow precipitate, by reaction of solution of arsenate and hydrogen sulfide (in the presence of concentrated hydrochloric acid)

Numerous organic compounds containing arsenic ("arsenicals") have been prepared, among these are salvarsan, neosalvarsan, atoxyl

Nitric acid readily transforms all arsenic containing substances (other than arsenic acid) to arsenic acid

Solutions of arsenic containing substances, when boiled with **hydrochloric acid,** deposit a gray film on a bright strip of copper This film of arsenic or copper arsenide, when dried and heated in air in a glass tube, sublimes as arsenious oxide, tiny white crystals

Arsenic in any form may be detected by the Marsh or Gutzeit tests Arsenites give a yellow precipitate with silver nitrate solution, arsenates a chocolate brown precipitate (R K S)

ARSENOPYRITE—MISPICKEL. The mineral arsenopyrite is a sulfarsenide of iron corresponding to the formula FeAsS A variety in which some of the iron is replaced by cobalt is known as danaite It crystallizes in the **orthorhombic system.** Its hardness is 5 5–6, specific gravity, 5 9–6 2, color, silvery white to steel gray, but usually with a yellow to gray tarnish, streak, black, luster, metallic Arsenopyrite is a common mineral with tin and lead ores and in pegmatites, probably having been deposited by action of both vapors and hydrothermal solutions It is a widespread mineral, well known deposits occurring in Austria, Saxony, Switzerland, Sweden, Norway, Cornwall and Devonshire, England, Bolivia In the United States at Roxbury, Connecticut, Franklin, New Jersey, Paris, Maine, Emery, Montana, and Leadville, Colorado Danaite was first found in Franconia, New Hampshire, by J D Dana, for whom it was later named Mispickel is an old German term whose exact derivation is unknown. (E S C S)

ARSPHENAMINE. "Salvarsan" An **arsenic** preparation given intravenously in the treatment of **syphilis, yaws, Vincent's Angina** (trench mouth), etc. It was first discovered by Ehrlich and is also known as 606 It is a yellowish powder, unstable when exposed to the air Its chemical name is Diaminodihydroxyarsenobenzene dihydrochloride (OH $C_6H_3(NH_2 \cdot HCl)As)_2$

Silver arsphenamine is arsphenamine with **silver,** combining the therapeutic properties of both

Neo-arsphenamine is used in the same way, but is less toxic and more soluble than arsphenamine (R S M)

ARTEMISIA. Compositae Many of the 280-odd species of Artemisia have been cultivated or used by man Southernwood, *Artemisia Abrotanum,* is cultivated in gardens for its delicate foliage and aromatic odor Another and a homely species, *Artemisia vulgaris* or Mugwort, is also frequently cultivated, as is *Artemisia Absinthium,* a native European perennial plant All contain volatile oils That from *Artemisia Absinthium,* oil of wormwood, is a powerful drug, capable of causing violent convulsions when taken even in small doses. It is used to flavor the alcoholic beverage absinthe, a liquor capable of producing much the same effects as the drug The sage-brushes of the western United States are all species of Artemisia, like other species they contain an abundance of aromatic oil From *Artemisia dracunculus,* a European species, tarragon is obtained This is used as a condiment, and for flavoring vinegar and mustard (R M W)

ARTERIOSCLEROSIS (Hardening of the **arteries**) A degenerative disease, usually of later life It is characterized by loss of elasticity, fibrous replacement and degeneration of the walls of the arteries The process usually involves all the arteries in the body but some vessels may be more involved in the process than others. A variety of signs and symptoms accompany this form of degenerative disease, including disturbances in function in the structures most involved

Many factors are involved in the causation of such a disease Heredity is a prime factor, some individuals are born with better quality arteries than others Age first shows its effects on the **vascular system** ("a man is as old as his arteries") Chronic disease and infection play a part Hypertension and the causes producing it contribute to degenerative **lesions** in the arteries Various foci of **infection** over long periods of time are factors in its production **Gout, diabetes,** and **nephritis** are usually accompanied by arteriosclerosis There is no evidence that alcohol, tobacco, coffee and tea produce this condition Chronic worry and mental strain are, outside of heredity, the chief causes of degenerative diseases

The symptoms produced by arteriosclerosis are caused by impairment of blood supply to a part of the body. The brain, kidneys, and heart are often involved in more or less localized arterial changes and symptoms referable to these organs are more apt to be noticed than symptoms referable to other organs

Early symptoms are insidious and not often noticeable They are merely the signs of age showing after the age of fifty has been reached Physical and mental fatigue, impairment of memory, depression and irritability, insomnia, constipation, indigestion, headache—all are symptoms of arteriosclerosis and old age Cardiac symptoms are frequent, such as **angina pectoris, dyspnoea** and various cardiac irregularities Sudden death may occur from sudden interference of the circulation of the brain or heart—the so-called stroke Coronary occlusion is common

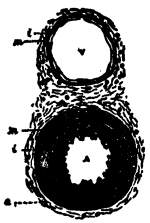
In uncomplicated arteriosclerosis occurring after middle life, the individual may live until old age When complications are present, especially other diseases, and when the changes associated with arteriosclerosis occur before middle age, the prognosis is generally poor

No treatment can restore youthful conditions to the

damaged arterial walls. Medical measures are directed toward retardation of the degenerative process and toward relief of the symptoms referable to organs whose blood supply has been compromised.

Arteriosclerosis causes the death directly or indirectly of the majority of individuals that live beyond the age of fifty years. (R.S.M.)

ARTERY. A vessel leading away from the heart. See **Circulatory system.** (A.W.L.)



Transverse section through a small artery and vein, showing the relative difference in the thickness of their walls. *A*, artery showing *i*, the endothelial lining which with the thick layer of elastic tissue next to it constitutes the *intima*. The endothelial cells appear thick because the artery is contracted. *m*, the circular muscular coat or *media* constitutes the chief part of the wall of the vessel. Outside this is *a*, part of the outer coat or *adventitia*. *V*, vein showing *i*, a thin endothelial membrane, *m*, a few circular muscle cells. (From Kimber and Gray, *Textbook of Anatomy and Physiology* — Macmillan & Co.)

ARTESIAN WELL. Ground water.

ARTHRITIS. Inflammation of or about a **joint.** When more than one joint is involved, the condition is usually called multiple arthritis.

There are many varieties of acute arthritis. Many cases are a part of certain specific diseases, that is, such diseases as **gonorrhea,** acute **rheumatic fever, gout,** etc. Less commonly arthritis may appear as a complication of almost any acute disease or infection. Those diseases in which accompanying arthritis most often occurs are **scarlet fever,** cerebro-spinal fever, **sepsis** in any form, **pneumonia, endocarditis, influenza, typhoid, dysentry, tuberculosis** and **syphilis.** Arthritis is also seen as a manifestation of some **allergic, metabolic,** or **endocrine** disorders. Other forms of arthritis involving a single joint are the results of injury. Acute suppurative arthritis, a serious acute infection of a joint with formation of **pus,** is usually caused by the *Streptococcus* or *Staphylococcus.* The infection is carried to the joint by the blood stream or directly to the joint as may occur following an injury. Treatment of this form is usually surgical.

Besides the forms of arthritis already mentioned, there are two other large groups, one rheumatoid arthritis which seems to be an acute infectious disease, and osteo-arthritis, which is apparently a form of degenerative disease. Both forms may be combined.

Rheumatoid arthritis (chronic infectious arthritis, arthritis deformans) is a chronic disease of joints characterized by inflammatory changes in the joint membranes and atrophy of the surrounding bone structure of chronic arthritis cases; this form includes two-thirds of the total number. It begins in early adult life, usually around the age of 35, and is most common in temperate climates.

The cause of this disabling disease is believed to be infection probably by a strain of the **Streptococcus** group and resulting from some focus of infection in the body. There are many predisposing conditions that favor its development such as (1) injury to a joint, (2) mental and physical strain over prolonged periods which favor its development just as they favor the development of many other infections, (3) shock, physical or nervous strain, (4) repeated exposure to cold and dampness, (5) a poor non-nourishing diet with lack of **vitamins.**

The disease, untreated, runs a long course and is disabling in that it causes deformities around the joints. Remissions are common. Early treatment is the most important factor in the prognosis of the disease. The disease is more amenable to treatment in the young than in the old and is more amenable in those where the joint structures have not been seriously damaged. The main forms of treatment involve treatment of local infection. improvement of general health, **physiotherapy** and orthopedic measures, **vaccine** therapy and certain medications. Dietary measures concern only reduction of the overweight and an adequate high vitamin diet in all cases.

Osteo-arthritis (degenerative arthritis, hypertrophic) is a form of arthritis not usually due to infection; it occurs in middle aged or elderly people. It is characterized by degeneration of the cartilage lining the bone surface in the joint with the production of rough bony outgrowths into the joint. The main predisposing causes to this disorder are (1) advancing age with resulting disturbance in the circulation of the joints, (2) chronic injury to the joints, (3) overweight, producing too big a load for weight bearing joints (moreover, overweight subjects usually have bad posture which puts an unnatural strain on certain joints). This form of arthritis progresses slowly with age and usually does not produce deformity. Treatment involves weight reduction, rest, physiotherapy and other general medical measures. Injections of all kinds are practically useless in this form.

In certain cases both rheumatoid and osteo-arthritis may co-exist. (R.S.M.)

ARTHROBRANCHIAE. **Gills** attached to the joint membranes of certain **crustaceans.** (A.W.L.)

ARTHRODIRE. **Fossil fishes.**

ARTHROPODA. The largest and most diversified division of the animal kingdom, including **crustaceans,** horseshoe crabs (See **Xiphosura**), **insects, scorpions, spiders, centipedes,** millipedes (See **Diplopoda**) and other forms.

This phylum is characterized by the following structures: 1. The body is **tripoblastic** and metameric (See **metamere**), and is further subdivided into regions of which there may be a maximum of three: **head, thorax,** and **abdomen.** 2. Supporting structures are developed from the integument and constitute an exoskeleton made up of plates connected by flexible regions for freedom of movement. 3. Jointed appendages, fundamentally a pair to a segment, give the phylum its name. 4. The **circulatory system** is a combination of tubes and open spaces; the coalescence of the latter to form a haemocoel is accompanied by extreme reduction of the coelom. 5. The **eyes** are of a form peculiar to the group. 6. The **respiratory system** consists of air tubes or **tracheae,** of gills, or of **lung books** formed of leaf-life expansions of the body wall located in a cavity narrowly open to the exterior. Some species have no special respiratory organs.

The phylum is divided into several classes as follows:

Class **Onychophora.** Soft-bodied worm-like animals. Commonly called **Peripatus,** the name of one genus.
Class **Tardigrada.** The bear animalcules.
Class **Pentastomida.** Parasites known as pentastomids or linguatulids.
Class **Pycnogonida.** The sea-spiders.
Class **Crustacea. Crabs, lobsters, crayfishes, shrimps, barnacles, woodlice** or pillbugs, and other forms.
Class **Xiphosura.** The king crab or horseshoe crab. Also given the name Palaeostraca.
Class **Arachnida. Spiders, mites, ticks, scorpions,** etc.
Class **Diplopoda.** The millipedes.
Class **Pauropoda.** Rare forms allied to the preceding.
Class **Chilopoda.** The **centipedes.**
Class **Symphyla.** Rare forms allied to the preceding.
Class **Insecta.** The insects. (See also **Invertebrate Paleontology.**) (A.W.L.)

ARTICHOKE, GLOBE. *Cynara scolymus.* **Composite Family.**

ARTICHOKE, JERUSALEM. *Helianthus tuberosum.* **Composite Family.**

ARTICULATION. This term has three common meanings (1) A **joint**, such as the knee or elbow, etc , (2) Enunciation, (3) In dentistry, the contact of the teeth (R S M)

ARTIFACT. Paleontology of Man.

ARTIFICIAL PNEUMOTHORAX. Tuberculosis treatment (R S M)

ARTIFICIAL SILK. Cotton, Textiles.

ARTIODACTYLA. Hoofed animals which retain an even number of toes, the axis of the foot passing between the third and fourth digits The species included are the **pigs, cattle** and related species, **antelopes, camels, hippopotami, giraffes, deer,** and some less familiar forms The group constitutes an order of the class **Mammalia**, often called the even-toed **ungulates.** (A W L)

ART MOBLIER. Paleontology of Man.

ARYL. Radical of benzenoid **hydrocarbon**

ASAFETIDA. *Ferula fetida* Umbelliferae Asafetida is a perennial herb found in Persia and Afghanistan It grows six to ten feet tall, and bears large compound leaves of bluish-green color, and large compound umbels of pale yellow **flowers** The roots contain a milky juice which oozes out when they are cut, and hardens to a gummy substance bitter in taste This substance, although extremely foul-smelling, is much used in the East and in France as a condiment In small quantities its unpleasant odor is not apparent As a drug, asafetida stimulates the nervous system (R M W)

ASBESTOS This is the popular name for several fibrous minerals used for fireproofing and heat insulating material Most of the commercial asbestos is a variety of **serpentine** called chrysotile A fibrous kind of **amphibole** is called asbestus Both terms asbestos and asbestus are derived from the Greek word meaning unquenched, which was applied to minerals that resisted fire (E S C S)

ASCARIS. Nemathelminthes, Nematoda, *Ascaris* Parasitic roundworms of relatively large size found in the intestines of man and other animals (A W L)

ASCENT OF SAP. The loss of water from a living plant presents an important problem in the life of that plant From the fact that an acre of corn plants, for instance, transpires nearly 400 barrels of water daily, that a mature maple tree loses nearly 100 gallons per day, we perceive the magnitude of the problem of replenishing this water to prevent the plant from wilting and possible death

Apart from almost negligible amounts, all the water taken into the living plants enters the roots The greater part of this water is lost through the green leaves The problem is to find an explanation of the manner in which the water moves from root to leaf It is rather generally admitted that the movement is through the xylem elements of the stem, that is, through the vessels and **tracheids**

Several theories have been advanced to explain how the movement of water in the stem occurs It is a common observation that the severed stems of many plants "bleed"—that is, that sap continues to flow from the cut stump for some time Obviously there is some force causing this flow This force, called root pressure, should push water up the undamaged stem Probably it does at times But certain objections are found to this explanation of the rise of water in the stem For one thing the amount of root pressure is not proportional to the loss of water, which may be greatest when the root pressure is least Root pressure may even be negative Furthermore such a force is utterly inadequate in many cases it would not explain the elevation of water to the tops of trees 300 feet or more in height

Another explanation, atmospheric pressure, is equally inadequate It could only account for a rise of water to a height of approximately 32 feet, obviously insufficient to reach the tops of most trees

Another theory advanced is that capillary forces (See **Capillarity**) cause water to rise in the stem The elements through which the water passes, either vessels or tracheids, are admittedly capillary tubes, which however are of relatively limited length, and closed by frequent cross-walls Through them water could probably rise a few feet by this force alone, but not to the heights observed in many plants Furthermore, when the greatest movement of water occurs, in the spring, the tubes are of greatest diameter, and would then have the least lifting power, since capillary forces are inversely proportional to the area of the cross-section of the tubes So this explanation of water movement seems insufficient

Another force which has been advanced as an explanation, and one still held by some, is imbibition, the soaking up of water by the walls of the cells Against this explanation is the fact that when the lumina of the cells are plugged with substances like paraffin movement of water through them becomes very slight, indicating that most of the water actually passes through the lumen and not in the wall of the cell

Another theory centers around the living cells of the outer parts of the stem In some way they must play a part in the movement of the water, rhythmically contracting and pushing water up Opposed to this explanation is the evidence that even though the cells of a considerable length of stem are killed, movement of water continues through the dead tissue No experiment has clearly demonstrated rhythmic changes in the living **cells**

Another theory, and one in great favor by most students of this problem, is based on the cohesive force of water, the tenacity with which a column of water resists breaking Water is constantly evaporating from the surfaces of the cells within the leaf This evaporation sets up within the cells a tension which is transmitted to adjacent cells This cohesive force (See **Adhesion**) is transmitted from cell to cell in the leaf and then stem, and down to the root Measurements with columns of water cooled in sealed glass tubes demonstrate very conclusively that the cohesive force of water is ample to account for the rise of water to the tops of the tallest **trees**

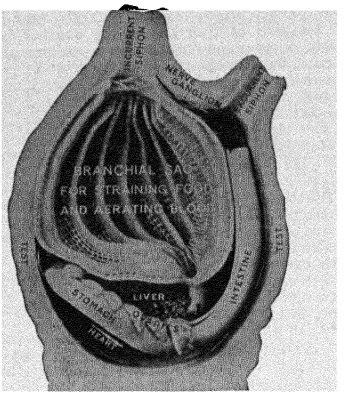
While the last theory seems best to explain the ascent of sap in the plant, it is quite possible that many other factors play a part The living cells of the root take water from the soil, osmotic forces cause the water to move inward to the conducting tissues, and evaporation from the leaf sets up a pull which lifts the continuous column of water through the stem And in this column of water the various substances necessary to the vital activities of the plant are carried along (R M W)

ASCHHEIM-ZONDEK TEST. A laboratory test that indicates the presence of early pregnancy This test is done with a specimen of urine from the supposedly pregnant woman During pregnancy there is an overproduction of **hormones** from the anterior portion of the **pituitary gland** which are excreted in the urine The urine is injected into mice, rabbits, or other suitable animals and the animals examined after a suitable time If the **ovaries** are enlarged and **corpora lutea** found, the result is said to be positive and the woman is pregnant

The test is used early in pregnancy when it is difficult to make a positive diagnosis by physical examination (R S M)

ASCIDIACEA. Chordata, Tunicata. The **tunicates,** sea squirts, or ascidians (**ascidiacea**), constituting a class of the subphylum **Tunicata** They begin life as **larvae**

which resemble tadpoles in form and later become **sessile** animals invested in a covering called the test or **tunic**. Some species are solitary and others form colonies.



Internal anatomy of the adult sea squirt. (*Courtesy of American Museum of Natural History.*)

The class contains four orders:

Order Krikobranchia. Sessile colonial forms. Body elongate, usually with transverse constrictions.

Order Dictyobranchia. Mostly solitary species. Body without constrictions. Tunic translucent.

Order Ptychobranchia. Solitary or colonial. Tunic opaque.

Order Pyrosomida. Colonial, the entire colony free-swimming. (A.W.L.)

ASCITES. The presence of fluid in the abdominal cavity, popularly called dropsy of the **abdomen**. Two causes of the condition are known; one is the obstruction of the venous return to the **heart** in diseases of the heart, **liver** and **kidney**, and the other is local inflammation of the **peritoneum**, as in tuberculous peritonitis. It is also seen when **cancer** has metastasized to abdominal structures. (R.S.M.)

ASCOMYCETES. Sac Fungi. Fungi. Many of the 40,000 species of **fungi** comprising the Ascomycetes are very common plants, but few are conspicuous. The great part of the species are small, often minute, while a few attain heights of three or four inches, with a diameter of one to two inches. Occasional individuals are even larger. All are characterized by the **ascus**, or spore-sac, commonly an elongate cylindrical body containing eight **spores**. In some species the ascus is spherical, or short cylindrical, while the number of spores may vary from two to many. Usually the asci are grouped together in a dense layer, called the hymenium. This may be composed entirely of asci, or may contain in addition numerous slender sterile filaments, called paraphyses. In some cases at least it seems the function of the paraphyses to protect the asci, since the outer tip of each paraphysis is a flattened cap which partially covers the ascus. Ascomycetes are found wherever suitable food-yielding materials exist. Many species are parasites, living on living plants; among these are species of great economic importance. Other species are saprophytes, wood-destroying species being particularly numerous.

The life-history of an Ascomycete comprise the very important but inconspicuous **mycelium** composed of slender branching septate hyphae which penetrate throughout the substratum, and extract from it nutrient materials which are elaborated and stored up within, and the fruiting stage in which the asci are formed. Two types of reproduction occur. One of these is the asexual type, in which asexual cells called conidia are cut off in various ways from the tips of hyphae, known as conidiophores. These conidia are single-celled spores which are disseminated by air currents. The other method of reproduction is sexual, and leads to the formation of asci. In *Pyronema confluens* this process has been carefully studied, and may be considered as typical in the main details for the process as it occurs in all the fungi of this class. The first step in this process is the formation of a multinucleate much-branched structure, which presently becomes septate. Some of the tips of this structure enlarge and become **oögonia**, called in this case ascogonia, while other tips become **antheridia**. From the oögonium a slender curved body called the **trichogyne** grows out. This is separated from the oögonium by a cross-wall. Since the oögonia and antheridia develop close together, the trichogyne comes in contact with the antheridium. All three bodies, oögonium, antheridium and trichogyne, are multinucleate. When the trichogyne comes in contact with the antheridium the walls between them at once break down, as does the wall between the trichogyne and the oögonium. The nuclei of the antheridium pass into the trichogyne, through it and into the oögonium. After this a new wall forms separating the trichogyne from a oögonium. In the oögonium the nuclei from the antheridium pair up with the nuclei of the oögonium, the nuclei of the trichogyne disintegrating early in the period of nuclear migration. Following the pairing of the nuclei in the ascogonium, coarse hyphae grow out from the latter. Into these the paired nuclei migrate. These coarse hyphae are the ascogenous hyphae, from which the **asci** eventually develop. In many Ascomycetes this process is considerably shortened, the ascogenous hyphae arising directly from the mycelium, no sex cells being formed; while other species have **sex** cells but no fusion, the oögonium alone developing.

The life cycles of the various ascomycetes are remarkably uniform, suggesting that they are all derived from a common ancestor. Two different views are held by botanists as to what the ancestral form may have been. According to one group, they are derived from red **algae**; favoring this view is the very great similarity in the development of the ascogonium and that of the **carpospore** formation in the algae; another favorable point is the presence of the trichogyne and the behavior of the antheridial nuclei. On the other hand, the other group holds that the ancestors of the Ascomycetes are to be found in the Phycomycetes, basing this contention on the similarity of the Phycomycete sporangium and the ascus, the latter being merely a sporangium in which the number of spores has been greatly reduced, becoming stable at eight in most species.

Many members of this class of fungi are of great importance to man because of their destructive parasitic habit. A few species are of value as food, or in the production of foodstuffs, and other products used by man.

Among the injurious species may be mentioned the Chestnut Blight fungus, *Endothia parasitica*, a disease probably introduced from China at the beginning of the twentieth century. In China the native chestnut trees had developed immunity; this the American trees did not have, so the fungus, which attacks the cambial tissue, was particularly destructive, nearly wiping out the native chestnut trees in a few years. Another disease caused by an Ascomycete is the Brown Rot of stone fruits, caused by *Sclerotinia cinerea*. This fungus is particularly destructive in wet seasons. Often infected fruits become shriveled up and dry, in which condition they are known as "mummies." A large group of Ascomycetes are known as Powdery Mildews, because of the abundant conidiophores which are formed by the mycelium on the surface of the leaves of infected plants. Often these are so abundant as seriously to impair the functional efficiency of the leaf.

Another group of Ascomycetes contains species which are destructive and also those which are commercially of great value, these are the ubiquitous blue and green molds, species of *Aspergillus* and *Penicillium* The destructive species attack foodstuffs everywhere, causing rotting and spoilage Citrus fruits become covered with the bluish-green conidial masses, as does moist bread, pie crusts and many other foodstuffs Species of the genus *Penicillium* give to Camembert and Roquefort cheese their characteristic properties Other species of this group are the causal organisms for skin diseases of animals, including man

Among the largest of the Ascomycetes are species of truffles and morels, which are considered by mushroom fanciers to be particularly finely flavored Truffles are fruit-bodies of the order Tuberales, and grow entirely underground This makes it a matter of some difficulty to find them Since they do not lend themselves to artificial cultivation, truffles must be sought in their wild habitat To aid in locating them, man has trained dogs and pigs to find them by their superior sense of smell

Another important Ascomycete group is the genus *Claviceps*, which grows parasitic on many grasses, including several cereal grains This fungus forms a hard black sclerotium which is known as ergot, and which completely replaces the grain in the infected flower The sclerotia are poisonous to livestock, causing the animals which have eaten them to become emaciated and covered with sores, another result is abortion in females

Another very important group of Ascomycetes is the **Yeasts** (R M W)

ASCON. Porifera.

ASCULTATION. This term is applied to the examination of the sounds within the chest, abdomen, heart, or larger blood vessels It is carried out by listening with the stethoscope, or by applying the ear directly to the surface of the body (R S M)

ASCUS. The spore sacs characteristic of the **Ascomycetes** Typically each sac contains eight **spores**, but many species are found where the ascus contains less than eight, while in others there are many more The ascus develops from an ascogenous **hypha** The latter is a septate hypha which grows in the form of a hook or crosier Each segment contains two nuclei, those of the apical hook-like segment divide simultaneously so that four nuclei are present Septations cut off two of these nuclei, leaving a segment containing two nuclei which now fuse The segment now elongates conspicuously and becomes the ascus while the fusion nucleus divides successively to form eight nuclei which eventually become set off in eight separate spores Subsequent development of the segments cut off during ascus formation may lead to the development of additional asci from the same ascogenous hypha (R M W)

ASEPSIS. Absence of infection, sterility. (R S M)

ASEXUAL REPRODUCTION. In asexual **reproduction**, a part of the parent organism, when removed, becomes a plant identical with the parent

Different types of asexual reproduction are met in the different groups of plants, necessitating separate treatment In green **algae** the characteristic method is by the formation of **zoöspores**, which are unicellular motile bodies formed from the **protoplast** of a single **cell** Each zoöspore, after swimming around for a time, becomes quiet and grows to form a new individual of the parent type. In mosses and ferns, where a definite **alternation of generations** occurs, the unicellular **spores** which mark the end of one generation are an asexual means of reproduction In flowering plants there are many methods of asexual reproduction, some of great importance to man A common type is found in the strawberry, where long slender branches grow out from the short stem of the plant and take root at their tip There a new plant forms This reproductive structure is called a stolon. Many other plants produce similar branches which run along the surface of the ground or just beneath it, and send up one or more new plants from the nodes· these prostrate branches are called runners Other plants, like the tiger lily, bear small buds in the axils of their leaves the buds or bulblets are easily detached and readily grow to form new plants Similar bulblets are formed at the base of many bulbs. Another very common method of asexual reproduction is through the formation of suckers, branches formed at the base of the parent plants, and gradually growing to replace them Man propagates extensively date palms, pineapples, and bananas, for example, by means of suckers The familiar potato tuber is another type of asexual reproduction which is of tremendous value to man

All the methods so far enumerated are from the stem of the plant. However, any part of the plant may be a means of asexual renewal Many plants are known which reproduce by means of the leaves Several of these are now cultivated extensively as objects of beauty or of curiosity For example, many of the ornamental begonias are readily propagated by leaves, in several ferns, little plants form on the leaf surface, from which they fall to the ground and grow Less widely known but equally interesting are species of *Bryophyllum* and *Kalanchoe* In the notches of the leaves of these plants, while still attached to the parent plant or after being severed therefrom, tiny plants readily form and grow

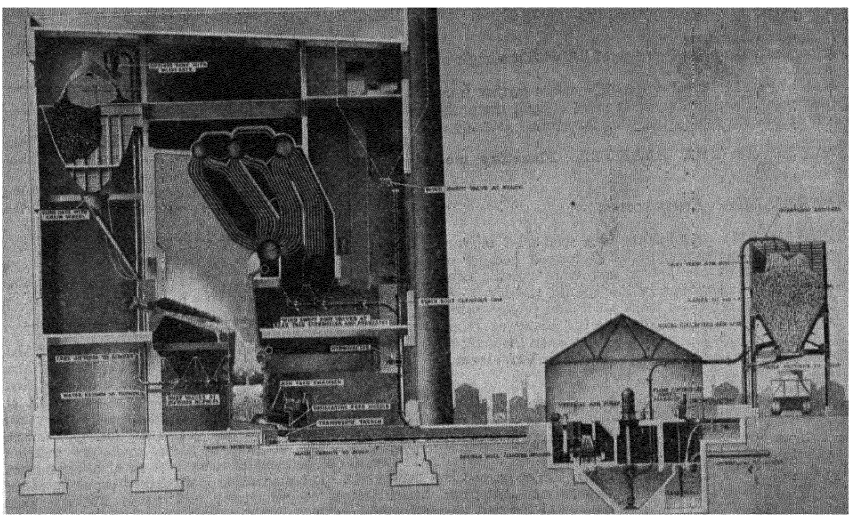
Many plants readily root when cut up into segments Most people are familiar with the habit of the willow twig of striking root and growing when stuck in the ground Equally well known is the geranium cutting, which is merely a branch removed from the parent plant and placed in a favorable environment

Asexual reproduction is of tremendous importance to man New and improved forms of plants are constantly being made by asexual means they are reproduced in the great quantities necessary for commercial use Without such reproduction their formation in quantity would be practically impossible (R M W)

ASH DISPOSAL. All coal has more or less ash, and since coal is the principal fuel for domestic and industrial use, the disposal of ashes is an important and widespread activity The combustion of coal in a **furnace** results in the accumulation in an ash hopper, or ash pit, of the refuse, which, with proper technical handling of the **combustion**, will be principally ash, but may in some cases contain up to 20%, by weight, of carbon in the unburned state All the ash should be in the ash pit or hopper, but as a matter of fact, from 5% to 40% may leave the furnace in the flue gases—carried in suspension While little can be done about this in domestic and industrial practice, the large amount of coal consumed by public utility plants is potentially capable of discharging from the stack so much ash to the surrounding territory that the endeavor is made to reduce the percentage of ash leaving with the gas, and to separate the residual ash from the gas and return it to the hopper

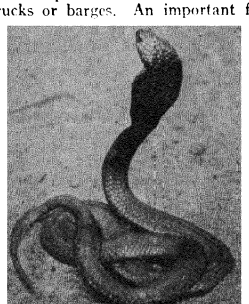
Removal of ashes, and their disposal, is no simple problem because, first, the ash is dusty, hence irritating and annoying to handle, second, it may contain clinkers which must be broken before given to any reasonably sized conveying equipment, and third, it is abrasive and will wear all conveyor parts in contact with it if there is any relative motion Ash disposal systems are designed for continuous or intermittent operation, as the case may be, and consist of some means of removing ash from the furnace, loading it on a conveyor system, unloading from the conveyor to storage, and a means of disposing of stored ash Ashes can be raked from ash pits to boiler room floors, and then shoveled into wheelbarrows or cars, or raked to gratings where they will fall into a conveying system The large furnace will often be designed so that the ash may be handled by gravity directly from the hoppers to cars or conveying system

Present-day conveying systems variously employ bucket conveyors, scrapers, pneumatic conveyors, steam jets, and water jets. Of these, one of the most popular as well as interesting methods is the hydraulic or water jet system. It is essentially a large-plant system, but has the advantage of being clean and dustless. When



"Hydrojet" ash-handling system.

the hopper is to be emptied, the ashes are hydraulically undercut with an oscillating feed jet. The mingled ash and water flows into a trench along which the ash is carried under the influence of jets of water directed along the run of the trench. At the end of the trench the flow is dropped into a sump where the ash settles to the bottom and the sluicing water overflows to a clear well, ready for recirculation. A wet ash pump or clam shell bucket will deliver the wet ash to an elevated ash bin, where it can be further dewatered. The ultimate disposition of industrial ash is to railroad cars, trucks or barges. An important factor in ash disposal is its use as a building material, particularly to form cinder blocks. In all larger cities this demand places a potential value on ash, which must be considered in the choice of fuel-burning equipment, since the ash recovery from pulverized coal furnaces would have much less value than from stokers. (F.T.M.)



Asp. (*Courtesy of N. Y. Zool. Soc.*)

ASP. Reptilia, Sauria. A poisonous **snake** found in northern Africa and southwestern Europe, also called the southern viper and the Egyptian **cobra.** (A.W.L.)

ASPARAGUS. Liliaceae. A genus of about 125 species of lilaceous plants native to temperate and tropical regions of the Old World. All are characterized by having the leaves reduced to minute scales or bristles, while small, often very leaf-like branches called cladophylls function as leaves. The flowers are small, yellowish or white in color, and the fruit is a berry, often brightly colored. *Asparagus officinalis,* a native of the marshes of Europe, is the cultivated garden form with thick and fleshy young stems. Other species are widely grown for their delicate beauty, as the familiar Asparagus ferns, *Asparagus plumosus* and *Asparagus Spengeri* (which are not properly ferns at all), and the smilax, *Asparagus asparagoides.* (R.M.W.)

ASPARAGUS BEETLE. Insecta, Coleoptera. An introduced European **beetle,** *Crioceris asparagi,* which is sometimes an important pest on asparagus. A related species, also introduced from Europe, is known as the twelve-spotted asparagus beetle. They are held in check by hand-picking and by dusting plants with lead arsenate and lime. (A.W.L.)

ASPARAGUS STONE. **Apatite.**

ASPARTIC ACID. **Aldehydes, Ketones, and Related Compounds.**

ASPECT RATIO. Aspect ratio is one of the most important dimensions of a **wing,** and measures its shape. It was long ago discovered that two wings of the same area, and built with the same **airfoil** section, did not have the same aerodynamic characteristics unless their area was of the same shape.

The term aspect ratio was then introduced to define this shape. The aspect ratio for a simple rectangular wing is the long dimension, i.e., the span perpendicular to the windstream, divided by the short dimension, the chord. However, many wings are not rectangular in plan form, and their aspect ratio is the span divided by the average chord. Since this average chord is the area

of the wing divided by the span, it follows that for non-rectangular wings the aspect ratio is the

$$\frac{\text{span}^2}{\text{wing area}}$$

In general, the larger aspect ratios are better from the aerodynamic standpoint, but poorer from the structural standpoint, since increasing the aspect ratio has the following results

1 It decreases the drag
2. It increases the rate of change of lift with the angle of attack
3 It displaces the lateral center of pressure farther from the fuselage, and hence makes more difficult the problem of bracing rigidly the wing structure (F T M)

ASPECTS OF THE PLANETS. Planetary motion.

ASPERGILLUS. Ascomycetes.

ASPHALT(UM). Asphaltum is a semi-solid mixture of several **hydrocarbons**, probably formed because of the evaporation of the lighter and more volatile constituents It is amorphous, of low specific gravity, 1–2, with a black or brownish black color and pitchy luster Notable localities for asphaltum are the Island of Trinidad and the Dead Sea region, where Lake Asphaltites were long known to the ancients (See also **Petroleum.**) (E S C S)

ASPHYXIA OR SUFFOCATION. This condition develops as a result of insufficient **oxygen** in the blood The patient becomes **cyanotic** and unconscious, and if the causative factor continues, death results

Local asphyxia is limited to a part of the body, and is due to an interruption of the blood supply to that part If total for any length of time **gangrene** of the part develops (R S M)

ASPIDOBRANCHIATA. Gasteropoda.

ASPIDOCHIROTA. Holothuroidea.

ASPLENIUM. Paleobotany.

ASS. Mammalia, Perissodactyla Animals of several species related to the horses and zebras and belonging to the same genus (*Equus*) In addition to the domestic ass, *E asinus*, wild asses are known in arid parts of Asia, from Persia to Mongolia, and in the deserts of northeastern Africa (A W L)

ASSASSIN-BUG. Insecta, Hemiptera Any **bug** of the large predacious species constituting the family Reduviidae (A W L)

ASSOCIATIVE LAW OF ALGEBRA. Addition and Multiplication.

ASSOCIATION AND POLYMERIZATION: DISSOCIATION. The simplest formula for water is H_2O, **molecular weight** 18 By measurements of the **specific volume** and **surface tension** of liquid water at two different temperatures it is possible to estimate the molecular weight of this substance as liquid in terms of its molecular weight as vapor, and, consequently, the degree of association or dissociation, as the case may be Water is estimated to be associated 2 7 to 2 0 times at 100° C; 3 0 to 2 2 times at 60° C, 3 6 to 2 4 times at 20° C. Dihydrol $(H_2O)_2$, and trihydrol $(H_2O)_3$, are believed to be the individual molecules concerned and to be present in proportions that vary with temperature. Substances believed to be associated as liquids to the degree of 2 to 3 times are methyl **alcohol** (3 3), ethyl **alcohol** (2 5), **acetic acid** (3 2), **acetamide** (2 3), **benzamide** (2.2), and slightly: **acetone** (1 3), **phenol** (1.3).

Normal liquids may be regarded as those whose molecules have a constant $\frac{\text{Molecular Weight} \times \text{Heat of Vaporization}}{\text{Absolute Temperature}}$ when observed under the condition of the same concentration of molecules in the vapor phase (Hildebrand, 1915), e g, a concentration of 0 005 gram mol of vapor per liter Such results are given in the following table:

Normal Liquids	$\frac{M W \times Ht Vap}{T}$
Nitrogen	27 6 (at 55° Abs)
Oxygen	27 6 (at 75° Abs)
Chlorine	27 8 (at 194° Abs)
Pentane	27 0 (at 256° Abs)
Hexane	27 2 (at 286° Abs)
Benzene	27 4 (at 298° Abs)
Mercury	26 2 (at 560° Abs.)
Average	27 approx.

Associated Liquids	$\frac{M W \times Ht Vap}{T}$
Water	32 0 (at 325° Abs)
Ethyl alcohol	33 4 (at 307° Abs)
Ammonia	32 4 (at 200° Abs)

Of two substances having the same elementary percentage composition but multiple or sub-multiple molecular weights, the substance of higher molecular weight is known as the polymer of the substance of lower molecular weight Polymerization is a marked property of certain groups of chemicals, e g, olefin **hydrocarbons** Amylene (C_5H_{10}) in the presence of sulfuric acid or zinc chloride polymerizes to $C_{10}H_{20}$, $C_{15}H_{30}$, $C_{20}H_{40}$ Monovinyl **acetylene** (CH_2 CH — C CH) is the polymer of acetylene (CH CH) and is made from the latter **Formaldehyde** is polymerized spontaneously at ordinary temperature, and **acetaldehyde** upon the addition of a small percentage of hydrochloric acid, sulfuric acid, or zinc chloride

Dissociation may be electrolytic or thermal Electrolytic dissociation is discussed in articles on **Electrochemistry, Reactions Involving Recombination of Ions** Thermal dissociation, an **equilibrium** phenomenon and not decomposition, is observed in the cases of such substances as the following

Nitrogen tetroxide (N_2O_4) into nitrogen dioxide (NO_2)
at 27° C, 80% N_2O_4, 20% NO_2 by weight
at 100° C, 20% N_2O_4, 80% NO_2 by weight
Calcium carbonate ($CaCO_3$) into calcium oxide (CaO) plus carbon dioxide (CO_2)
at 600° C, 20 mm pressure CO_2.
at 920° C, 760 mm pressure CO_2
Mercuric oxide (HgO) into mercury (Hg) plus oxygen (O_2)
at 400° C, 230 mm. pressure O_2.
at 500° C, 800 mm pressure O_2
Trilead tetroxide (Pb_3O_4) into lead monoxide (PbO) plus oxygen (O_2)
at 450° C, 5 mm. pressure O_2
at 635° C, 760 mm pressure O_2.
Ammonium chloride (NH_4Cl) into ammonia (NH_3) plus hydrogen chloride (HCl)
at 350° C, 41% NH_3, 41% HCl by volume
Sulfuric acid (H_2SO_4) into sulfur trioxide (SO_3) plus water (H_2O)
at 450° C, 0 03% SO_3 by weight
Sulfur trioxide (SO_3) into sulfur dioxide (SO_2) plus oxygen (O_2)
at 600° C, 20% SO_3 to 80% SO_2 by volume
at 700° C, 50% SO_3 to 50% SO_2 by volume

Carbon dioxide (CO_2) into carbon monoxide (CO) plus oxygen (O_2)
at 1230° C , 0 04% CO_2 dissociated
at 1730° C , 1 77% CO_2 dissociated
Water (H_2O) into hydrogen (H_2) plus oxygen (O_2)
at 1230° C , 0 02% H_2O dissociated
at 1730° C , 0 59% H_2O dissociated (R K S)

ASSOCIATIONS, PLANT. External factors such as wind, temperature, nature of the soil and abundance of water have a profound effect on the growing plant Every plant by its nature is adapted to grow best in a definite environment So one finds that in any particular type of environment there appear certain groups of plants Such a group, fitted for a particular habitat, and ordinarily composed of one dominant species together with one or more species which may exist with and perhaps be dependent on the dominant plant is called a plant association

Usually a plant association is not a static thing especially is this true when man is present and interferes with natural processes The region changes and new plants come in, gradually forcing the old ones out or being themselves overcome The change which occurs may be so gradual as to pass unnoticed, as for example the gradual elimination of a pond by natural processes Slowly the marginal flora creep outward from the shore, catching debris which gradually builds up a firmer soil, while in the deeper regions filling in by silting or by the accumulation of organic debris continues Eventually the pond becomes a wet marsh with its characteristic flora of marsh plants, which grow in water-saturated soil, often deficient in mineral matter The process goes steadily on, plant remains gradually building up the soil level and becoming more compacted and drier, until the marsh flora gives way to grasses and other plants adapted for the drier habitat Finally trees invade the region and all outward trace of the original pond is lost The forest thus formed may be a stable condition and persist as such, being known as a climax association

The succession of plants may be much more rapid An excellent example is an abandoned farm, in which the cultivated plants are rapidly replaced by annual weed-plants, and then by perennials such as asters, ragweeds, etc , as well as bushes Soon gray birches and poplars appear and gradually overcome the weeds, themselves in turn to be pushed out by slower growing, more sturdy trees adapted to the region These will persist indefinitely as the climax association Such a succession may be completed in a single generation, while the obliteration of a pond may be a matter of hundreds of years

Plant associations may be extensive, covering vast areas of prairie or forest, or may be very local, as is seen in the flora inhabiting the margin of a stream, the top of a mountain, or even the epiphytic flora inhabiting a single jungle tree (R M W)

ASTER. See **mitosis** under **cell division**

ASTEROID. The name asteroids (or planetoids) is given to a group of small objects which are members of the **solar system** and whose **orbits** lie, in general, between the orbits of **Mars** and **Jupiter** The very name asteroid (star-like) describes adequately the appearance of the objects Only one of them is ever bright enough to be seen with the naked eye and even this one, Vesta, is never a conspicuous object

The first asteroid discovered, Ceres, was found accidentally by Piazzi on January 1, 1801 His attention was directed to it by noticing the motion of the object through the stars As the object approached the position of the sun there was danger of its being lost, for the methods of orbit computation were not well developed at that time. The mathematician Gauss went to work on the problem and invented his well-known method for orbit computation by means of which he was able to predict positions permitting the rediscovery of Ceres after it had passed the sun Since the orbit was found to lie in the gap between the orbits of Mars and Jupiter and the object was found to have a mean distance from the sun of 2 8 **astronomical units**, strong support was given by it to **Bode's Law**

Up to the middle of the nineteenth century only five more asteroids were discovered, but, with the application of photography to astronomy, the discoveries became more and more frequent until at the present time more than 1300 asteroids are under observation The objects are first detected by noticing the movement of a star-like object through the stars Photographically, if the camera is arranged to follow the motions of the stars the star images will appear as dots on the plate while the asteroid image will be trailed out into a short line The most extensive program of search for asteroids was carried on by Wolf at Heidelburg during the period following 1891 From this time on through the first two decades of the present century Wolf and his assistants are credited with no less than five hundred discoveries

When an asteroid is first discovered it is designated with the year of discovery followed by two letters which indicate the half of the month in which the object was found and the chronological order within that half month After the orbit of the object has been determined and it proves to be a new asteroid, it is assigned a permanent number, in chronological order of discovery, and the discoverer is privileged to name the object as he may choose In general, asteroids are given Latinized names with the feminine endings

Little is known regarding the physical characteristics of the asteroids themselves The diameters of the four brightest, and presumably the largest, have been measured with large telescopes and found to run from 480 miles for Ceres down to 120 miles for Juno Estimates of the sizes of the other planetoids may be made from the amount of sunlight which they reflect, after making certain assumptions regarding the reflecting power and shape of the objects The results of the survey indicate that perhaps 150 asteroids have diameters greater than 50 miles, but the majority are between 50 and 20 miles in diameter, with some even smaller than that Masses and densities can only be estimated from statistical studies but the indication is that the total mass of all of the objects combined can not be more than 1/500 part of the mass of the earth

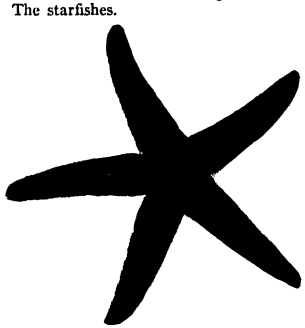
The problem of the determination of the shapes of the asteroids is still one of considerable interest, but for which there is no definite solution It is well known that the reflected sunlight from many of these objects varies in a periodic manner which can only be adequately explained on the basis of a rotating object In the case of Eunomia it has been quite definitely proven that the object must be spherical, and that the variation in light is due to different reflecting powers on different parts of the surface On the other hand, **Eros** has been quite definitely proven to have a "dumb-bell" shape, with the light variations due to rotation of this irregular object

The orbits of the asteroids have been studied with great zeal ever since the discovery of Ceres In fact, this group of objects may be considered as a laboratory in which the workers in the field of **celestial mechanics** may test out various theories Since the orbits lie between the orbits of Mars and Jupiter, and the masses of the asteroids are very small, the planets exert large **perturbations** on the asteroids, while they themselves are virtually unaffected by the asteroid attractions Many of the methods of computing perturbations were developed as the result of the researches on the orbits of the minor planets One particularly interesting result is found in the case of the so-called **Trojan Group** of asteroids, which is discussed in more detail elsewhere

There are two theories for the origin of the asteroids One is that these objects represent a planet that was "spoiled in the making," i e , never developed into its

solid form. The other theory postulates that the asteroids represent the remains of a planet which was formed but disintegrated later on. The latter theory is the older of the two but has gained some considerable strength on the basis of the so-called families of asteroids. Theoretically, it may be proved that, if a planet should be broken up by a series of explosions, the centers of the orbits of the asteroids which are products of any particular explosion, should lie along a line between the sun and Jupiter. In addition to the locations of the centers of the orbits along this line, the mean distances of the products of each explosion from Jupiter would be approximately the same, and also the inclinations of the orbit planes should be similar. As a result of a statistical study of the orbits of the asteroids, five such families of asteroids have been identified and the families each contain from 15 to 44 members. Within the past few years a theory has been gaining weight that the asteroids may be connected in some manner with comets, but as yet the evidence is far from conclusive. (W.K.G.)

ASTEROIDEA. A class of the phylum **Echinodermata.** The starfishes.



Common Starfish. (*Courtesy of N. Y. Zool. Soc.*)

The starfishes are distinguished from other echinoderms by the presence of radiating arms or rays, usually five or in multiples of five, which contain part of the internal organs and are usually not sharply separated from the central disc. There are many species but the economic importance of the group is limited. They are sometimes serious pests in oyster beds since they feed largely on shellfish.

The class is divided into three orders: **Phanerozonia,** Spinulosa, and Forcipulata. (A.W.L.)

ASTHENIA. Weakness, lack or loss of strength. (R.S.M.)

ASTHENOSPHERE. A term proposed by Barrell, in 1914, for the zone beneath the relatively rigid **lithosphere,** or approximately 60 miles below the surface of the earth The asthenosphere is considered to be the level of no strain in which there is maximum plasticity, and in which the **igneous** rock magmas originate. (R.M.F.)

ASTHMA. An allergic disease marked by attacks of obstruction to the flow of air in and out of the lungs. This is caused by **spasm** of the bronchial muscles and swelling of the lining membrane of the bronchi.

Asthma was first described by John Flager in 1698, but the relation of hay-fever and asthma to plant **pollens** and **protein** substances given off by animals was not discovered until 1905 by Dunbar. Following this the entire picture of the allergic diseases was correlated and the role of protein sensitivity was demonstrated by means of the pollen skin-sensitivity tests.

Asthma is a common disease. The asthmatic tendency or sensitivity is often inherited, some member of the family of an asthmatic having symptoms in at least forty percent of the cases.

The same group of substances that cause hay-fever are responsible for the symptoms of asthma. These substances such as pollens, animal proteins that are inhaled, those that are ingested such as certain foods and drugs, and protein substances that may be injected, to any of which the patient is hyper-sensitive, may initiate the symptom complex known as asthma.

It is usually the inhalation of air-borne substances that cause asthma in an adult. In children foods are most likely to be the cause. Of the foods, egg-white is the principal offender. Next comes cereal proteins and cow's milk. Often a subject is sensitive to several different agents, as may be determined by the history of the case and by the skin tests.

In another group of asthmatics, external agents are not responsible and the cause is found to be within the body. Here the asthma is always present; change in localities, climate and diet do not help. Such cases may be classified as bacterial asthma, and the cause is some chronic infection of some part of the body. Usually the infection is in the respiratory tract, although other systems may be responsible. Asthma in a syphilitic or diabetic often clears up when these diseases are treated.

The symptoms of an attack of asthma are wheezy breathing with some degree of obstruction to inspiration or expiration. When in contact with the offending protein, the eyes water, the nose runs, sneezing is present, and the obstruction in the bronchial passages may be so great that great effort is required to inhale or exhale air. The severity of an attack depends on the hyper-sensitivity of the individual, and the amount of protein taken into the system. The attack may last minutes or hours. In between attacks the patient is well and the physical examination is usually negative.

The diagnosis is made in the free interval between attacks by the history, especially in relation to the circumstances under which an attack occurs. The offending substance or substances to which the individual is sensitive is verified by skin tests in which the substance in sterile form is applied to the skin or within the skin layers. A sharply defined wheal with irregular borders, surrounded by a red zone, indicates that the patient is sensitive to the substance. In obscure cases, elimination diets may be tried to find the specific food causing the attacks.

Adrenalin given by hypodermic usually aborts an attack. Swallowing of stramonium leaves, the chief element in asthma powders and asthma cigarettes often relieves the spasm. **Ephedrin,** both orally and by hypodermic, is of great value. Often dust-free rooms, where the air is washed and filtered, are of great help to the asthmatic.

The permanent cure of asthma is difficult. Where there is one offending substance that can be avoided or eliminated as in the diet, the attacks may cease. Often, when the cause is within the body, the removal of a focus of infection as an infected **gall-bladder, sinus,** or tube, will effect a cure. Inoculation with minute doses of the offending protein and gradually increasing the amount has in some instances given excellent results by desensitizing the individual. Where more than one substance is involved this form of treatment does not give much relief. In some cases, nothing can be done to cure the condition, and complete change of climate is advisable. (R.S.M.)

ASTIGMATEA. Chordata, Thaliacea. An order of salpian **tunicates.** (A.W.L.)

ASTIGMATISM. When an optical system fails to bring the rays to a well defined **focus,** it is said to be astigmatic. The term is, however, commonly applied to cases in which the fault is due to a lack of sym-

metry of the optical system about its axis, so that it has different focal lengths in different meridians. This would be true, for example, of a lens, one of whose surfaces is not a true surface of revolution but is slightly ellipsoidal or spoon shaped. The defect is, unfortunately, quite common in the human eye, usually due to radial asymmetry of the cornea. When the patient looks at the optometrist's "clock face" or "wheel," the radiating lines along one diameter may appear blurred. The remedy is a spectacle lens having an astigmatism of its own at right angles to that of the eye, and to this end use is made of cylindrical or toric surfaces. (L D W)

ASTROID. Hypocycloid.

ASTROLABE. The astrolabe is an ancient form of portable astronomical instrument invented during the 2nd or 3rd century B C probably either by **Hipparchus** or Appollonius. In its most common form the astrolabe consists of a circular disk which may be suspended by a ring so that it will hang in the plane of a **vertical circle.** A pointer, or alidade, is pivoted at the center of the disk and angular graduations are marked about the edge. In addition to the alidade and angular graduations many other astronomical materials such as **constellation** configurations, lists of **planets,** etc., are engraved on the disk. This ornamental engraving is very intricate and beautiful on many of the instruments and makes them interesting museum pieces.

The instrument was undoubtedly intended primarily for the purpose of measuring **altitude** of celestial bodies. For this purpose the ring was suspended by the thumb of one hand and the other fingers employed to steady the disk as the alidade was moved by the other hand until it pointed directly at the object under observation. The altitude could then be read directly on the disk.

The astrolabe was used by navigators for the determination of **latitude** from the 15th century down to the invention of the **sextant** in the 18th century. It has recently been revived for teaching purposes in elementary classes. (W K G)

ASTROLOGY. Astrology is the ancient art of divining the future of human affairs from observations of the celestial objects. We find records of astrological methods back through the earliest recorded history and during the 14th and 15th centuries astrologers held important positions at many of the courts of Europe. Since observations of the celestial objects form an important part of astrology, the art may be considered as the parent of astronomy although the separation of the art of prophesy from the science of observation certainly took place long before the Christian era.

In the most commonly practised type of astrology a horoscope is drawn up for a person. Such a horoscope consists of a map of the heavens drawn at the instant of birth of the person interested. This map shows the aspects (See **Planetary Motion**) of the planets, the location of the **sun, moon,** and **planets** on the **zodiac** and other correlated phenomena. The signs of the zodiac, or "houses," in which the various objects are located at the time of birth are supposed to indicate all sorts of influence on the future of the person. Such words as lunatic, saturnine, ill-starred, etc., indicate the influence of astrology on general culture of past eras. (W K G)

ASTRONOMICAL REFRACTION. In making any type of astronomical observations the light from the distant object must pass through the atmosphere of the earth and suffer a change of direction known as **refraction.** The amount of change of direction depends upon two fundamental factors: the relative **refractive index** of the atmosphere and the angle which the ray from the distant object makes with the normal to the surface of the atmosphere. Since the normal to the atmosphere is the direction of the astronomical **zenith** the amount of refraction will depend upon the **altitude** of the object, being greatest when the altitude is least, or when the object is on the **horizon.** The effect of refraction is to make the altitude of an object appear greater than it would be if no atmosphere were present.

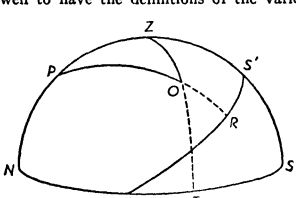
To calculate the amount of astronomical refraction the index of refraction of the atmosphere is needed and, unfortunately, this quantity varies with meteorological conditions. Various theoretical methods for computing the amount of astronomical refraction have been proposed but none of them are very satisfactory for altitudes less than 20°. A fair approximation to the true value may be obtained from the expression

$$R = \frac{983\,B}{460 + T} \operatorname{cotan} h$$

in which B is the reading of the **barometer** in inches, T is the **temperature** of the air in degrees **Fahrenheit,** h is the apparent altitude of the object, and R is the amount of refraction in seconds of arc. More accurate values may be obtained by using refraction tables such as those published in Bowditch American Practical Navigator. These tables give the amount of refraction in terms of observed altitude, and various meteorological conditions such as temperature and barometric pressure. This refraction must be subtracted from any observed altitude to obtain the apparent altitude. In case changes due to refraction in other **spherical coordinates** than altitude are desired the **astronomical triangle** must be solved.

Sudden and irregular changes in astronomical refraction are produced by varying meteorological conditions and produce effects of twinkling in the stars. (W K G)

ASTRONOMICAL TRIANGLE. The spherical triangle formed on the **celestial sphere** between the observer's **meridian,** the **hour circle,** and the **vertical circle** through an object, is known as the astronomical triangle. Since practically every problem of **nautical astronomy** deals with the solution of this triangle it will be well to have the definitions of the various parts



Astronomical Triangle

well in mind. In the figure (drawn for an observer in the northern hemisphere) we have

N, W, and S, the north, west, and south points of the observer's **horizon.**

S', R W is the celestial **equator.**

Z is the observer's astronomical **zenith.**

P is the north pole of rotation.

O is the object under consideration.

PZO is the astronomical triangle, the various parts of which are defined as follows:

The vertex angles are

ZPO = the **hour angle** of the object

PZO = 180°—the astronomical **azimuth** of the object

ZOP = the parallactic angle

The sides (measured in angular units) are:

PZ = 90°—observer's astronomic **latitude.**

ZO = 90°—**altitude** of the object = zenith distance of the object

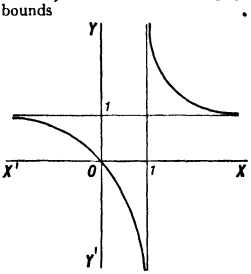
PO = 90°—**declination** of the object. (W K G)

ASTRONOMICAL UNIT. The astronomical unit is a unit of distance principally employed in expressing dis-

tances within the **solar system**, but is also used to some extent for measuring interstellar distances Technically defined, one astronomical unit is the mean distance of the **earth** from the **sun**. To express this in miles it becomes necessary to determine the distance of the earth from the sun in miles or, in other words, to determine the **solar parallax** The value accepted at present for the length of the astronomical unit is 92,897,000 miles (149,504,000 km) (W K G)

ASYMMETRIC ATOM. Isomerism.

ASYMPTOTE TO A PLANE CURVE. An asymptote of a curve is a straight line which the curve approaches arbitrarily near as its tracing point recedes beyond all bounds



Asymptotes

Thus, in the curve whose equation is $y = \frac{x}{x-1}$, as shown in the accompanying figure, the lines $x = 1$ and $y = 1$ are asymptotes (L L S)

ASYMPTOTIC SERIES A divergent series of the form

$$A_0 + \frac{A_1}{x} + \frac{A_2}{x^2} + \quad + \frac{A_n}{x^n} +$$

is said to be an asymptotic representation of a function $f(x)$ if

$$\lim_{x \to \infty} x^n \left[f(x) - S_n(x) \right] = 0,$$

for any value of n, where $S_n(x)$ is the sum of the first $n+1$ terms of the series (L L S)

ATACAMITE This mineral consists partly or entirely of **copper** oxychloride, $CuCl_2Cu(OH)_2$, probably, the exact formula is uncertain Crystallizes in thin, orthorhombic prisms, may occur massive Hardness, 3 –3 5, specific gravity, 3 76–3 78, luster, adamantine to vitreous, color, green, streak, green, transparent to translucent

It is a secondary mineral found associated with **malachite** and **cuprite**; originally found at Atacama, Chili, whence its name Other localities are Bohemia, South Australia, and in the United States in Arizona, Utah and Wyoming (E S C S)

ATAVISM. The appearance through **heredity** of characters which have not been developed in the parents of the organism in question The strict meaning of the word is the reappearance of grandparental characters but it has been used also to designate the reappearance of characters from more remote generations. (A W L)

ATAXIA. Lack of muscular co-ordination due to disease of the brain or spinal cord Locomotor ataxia is the degeneration of portions of the spinal cord occurring in the later stages of syphilis (R S M)

ATAXIC A term applied by Keyes, in 1901, to all unstratified ore deposits in contradistinction to sedimentary, stratified or **eutaxic** ore deposits. (R M F)

ATELECTASIS. Partial collapse of the lung, due to continual shallow breathing or to a mucous plug obstructing one of the bronchial passages This is thought to be the preliminary stage in the development of most **pneumonias** following surgical operations (R S M)

ATHLETE'S FOOT. Dermatophytosis.

ATLANTIC SUITE. A term proposed by A Harker, in 1896, for the chemically and structurally related **igneous** rocks of the Atlantic coast line Chemically the rocks of this suite are described as **alkaline** and are represented by such types as **granite** and its magmatic relatives, as compared with the calc-alkali igneous rocks of the **Pacific Suite.** (R M F)

ATMOSPHERE. The gaseous envelope surrounding an object of planetary or stellar proportions is known as the atmosphere of that object The atmosphere of the earth will be found discussed in the article on **Air.**

If we know the mass and radius of any object, it is possible to compute, on the basis of the kinetic theory of gases, whether or not it may be expected to retain an atmosphere If a particle is moving away from the surface of a **star** or a **planet**, it will leave the object in case the velocity is greater than a certain limiting value known as the velocity of escape This velocity of escape is a function of the mass and radius of the star or planet From the kinetic theory of gases we find that all molecules of a gas are in random motion with velocities which depend upon the temperature and pressure of the gas The average velocities are such that the average **kinetic energies** of all the molecules are the same Since kinetic energy varies directly with the mass and the square of the velocity, the heavy molecules should have lower velocities, on the average, than the lighter ones This is probably the explanation of the observed distribution of the gases in the atmosphere of the earth in which we find that the lighter molecules (**hydrogen** and **helium**) are found in the upper air Computations of the velocities of escape from different objects indicate that all of the stars, and all of the planets except Mercury (data are incomplete for Pluto) should have atmospheres The moon, the satellites of the other planets, and the asteroids cannot be expected to have atmospheres All observational evidence is in support of the theoretical results

The amount of atmosphere which a planet can be expected to retain can be approximately computed on the basis of the kinetic theory The theoretical value can be checked, roughly, by measuring the **albedo** of the planet, objects with greater albedo having denser atmospheres than those which reflect a smaller proportion of the incident sunlight In the case of Mars, the only planet which is known to have an atmosphere and on which we can also see the surface, the **twilight** arch can be observed and the height to which the atmosphere extends with sufficient density to produce twilight can be computed to be about 20 miles

The composition of the atmosphere of the earth is discussed in the article on **Air,** and the compositions of the atmospheres of the other planets and the stars will be found in the various articles on the individual objects To determine the constituents of the atmospheres of the objects external to the earth requires the use of the **spectroscope.** In the case of the study of the quality of the atmospheres of the stars the problem is relatively simple for the interior of a star radiates a **continuous spectrum,** and the cooler gases of the stellar atmosphere produce absorption lines characteristic of the elements in the atmosphere. The analysis of the atmospheric constituents of the planets is a far more difficult task, for the planets are visible only by reflected sunlight and this itself is crossed by the myriad **Fraunhofer lines,** many of which are due to the elements to be expected in the planetary atmospheres The sunlight penetrates the planetary atmosphere to a certain, undetermined depth and is then reflected to the earth

In traversing the planetary atmosphere there should be a certain intensification of the absorption lines due to elements in the planetary atmosphere Furthermore, at certain times there is an appreciable component of the planet's orbital motion in the line of sight from the earth At such times the **Doppler effect** will produce a slight displacement of the absorption lines due to planetary atmosphere from those due to solar or terrestrial atmospheres The application of high dispersion spectrographs has yielded the results discussed in the articles on the individual planets (W K G)

ATOKE. **Epitoke.**

ATOLL. **Coral Reef.**

ATOM. The atom may be considered as the smallest particle into which matter can be broken up by chemical means Though atoms can be further broken up into **electrons, protons, neutrons,** etc, by methods of modern physics, they retain their individuality in chemical reactions and are used as fundamental units in the organization of theory and facts of chemistry The atomic theory of chemistry is based on the following experimental laws

1 Law of Conservation of Mass—matter is not created nor destroyed in a chemical reaction

2 Law of Definite Proportions—compounds contain a definite fixed proportion by weight of the component elements—this proportion being characteristic of the compound

3 Law of Multiple Proportions—when an element combines with another to form more than one compound, the weights of one element which combine with a fixed weight of the other stand in the ratio of small whole numbers

On the basis of the above laws Dalton (1808) postulated the atomic theory which states that

1 All matter consists of small indivisible particles called atoms

2 Atoms of the same element have the same weight, those of different elements different weights so that the atomic weight can be used to characterize an element

3 Chemical combination is the union of different elements The combining weight of an element is therefore an integral multiple of the atomic weight

On the basis of recent discoveries modifications have to be introduced in to the original theory of Dalton

1 Atoms are not indivisible Some atoms can be made to decompose under the influence of processes involving enormous energies and others decompose spontaneously (radioactivity) Such phenomena do not occur in the ordinary chemical reactions and therefore the usefulness of the Dalton theory in chemistry is not impaired

2 Atoms of the same element often do not have the same atomic weight but may have several values which differ by several integral units from each other (isotopes) Since different isotopes usually occur in the same ratio, the atomic weight is still characteristic of the element For further discussion of atomic weights see **Chemical Composition.** (R K S)

ATOMIC DISINTEGRATION. **Radioactivity.**

ATOMIC HEAT. **Dulong and Petit's Law of Specific Heats.**

ATOMIC NUMBER. **Chemical Composition.**

ATOMIC SPECTRA. An atomic spectrum is the spectrum of radiation emitted by an excited **atom,** due to changes within the atom, in contrast to radiation arising from changes in the condition of a **molecule.** Such spectra are characterized by more or less sharply defined "lines," corresponding to pronounced maxima at certain frequencies or wave lengths, and representing radiation quanta of definite energy

The lines are not spaced at random In the spectrum of hydrogen, for example, there is a prominent red line (H_α) and, far from it, another (H_β) in the greenish-blue, then after a shorter wave length interval a blue-violet line (H_γ), and after a still shorter interval another violet line (H_δ), etc One has only to plot the frequencies of these lines as a function of their ordinal number in the sequence, to get a smooth curve which shows that they are spaced in accordance with some law In 1885, Balmer studied these lines, now called the Balmer series, and arrived at an empirical formula like the following

$$w = 109678\left[\frac{1}{2^2} - \frac{1}{(n+2)^2}\right]$$

This represents the wave number (number of waves per centimeter) for any line, numbered n, in the series. As n increases, the wave number w approaches the "series limit" 27419, toward which the series "converges"

Other series have since been discovered in the hydrogen spectrum, including the Lyman series in the ultra-violet, represented by

$$w = 109678\left[\frac{1}{1^2} - \frac{1}{(n+1)^2}\right],$$

and the Paschen series in the infrared.

$$w = 109678\left[\frac{1}{3^2} - \frac{1}{(n+3)^2}\right].$$

The coefficient 109678 (cm^{-1}) is known as the **Rydberg constant** It appears in the series formulae for all atomic spectra, a study of which has led to the **combination principle** of Ritz and its interpretation in terms of the **quantum theory,** though in general these formulae are not so simple as in the case of hydrogen A study of the spectrum of a single element often reveals certain interesting relations between the most prominent series of lines composing it For example, two series may have the same limit, or the limit of one may equal the limit of the other minus the wave number of the latter's first line, as is seen to be the case with the Paschen and the Balmer series above Kossel and Sommerfeld noted that if an element is singly ionized, its spectrum resembles that of the element preceding it in atomic number, a fact explained by their having the same number of extra-nuclear electrons

See **Hyperfine Structure, Pressure Shift and Broadening,** and **Doppler Effects.** (L D W)

ATOMIC STRUCTURE. According to Bohr the **atom** is built up of two units—a positively charged nucleus and a number of negatively charged **electrons** The nuclear positive charge is equal to the atomic number while the mass is equal to the atomic weight The electrons have a negative unit charge and a negative mass (1/1840 of the lightest nucleus) The number of electrons is equal to the charge on the nucleus measured in electron units of electrical charge, thus making the atom as a whole electrically neutral The atom is essentially hollow with its mass concentrated at the nucleus and a cloud of orbital electrons revolving around it at various distances On the basis of chemical and spectroscopic evidence these electrons are classified into shells called the K, L, M, N, O, P, Q shells The following table gives the arrangement of the electrons among the electron shells for the various atoms

Atomic Number of Element	K	L	M	N	O	P	Q
1 Hydrogen	1						
2 Helium	2						
3 Lithium	2	1					
4 Beryllium	2	2					

Atomic Number of Element	K	L	M	N	O	P	Q
5 Boron	2	3					
6 Carbon	2	4					
7 Nitrogen	2	5					
8 Oxygen	2	6					
9 Fluorine	2	7					
10 Neon	2	8					
11 Sodium	2	8	1				
12 Magnesium	2	8	2				
13 Aluminium	2	8	3				
14 Silicon	2	8	4				
15 Phosphorus	2	8	5				
16 Sulphur	2	8	6				
17 Chlorine	2	8	7				
18 Argon	2	8	8				
19 Potassium	2	8	8	1			
20 Calcium	2	8	8	2			
21 Scandium	2	8	9	2			
22 Titanium	2	8	10	2			
23 Vanadium	2	8	11	2			
24 Chromium	2	8	13	1			
25 Manganese	2	8	13	2			
26 Iron	2	8	14	2			
27 Cobalt	2	8	15	2			
28 Nickel	2	8	16	2			
29 Copper	2	8	17	2			
30 Zinc	2	8	18	2			
31 Gallium	2	8	18	3			
32 Germanium	2	8	18	4			
33 Arsenic	2	8	18	5			
34 Selenium	2	8	18	6			
35 Bromine	2	8	18	7			
36 Krypton	2	8	18	8			
37 Rubidium	2	8	18	8	1		
38 Strontium	2	8	18	8	2		
39 Yttrium	2	8	18	9	2		
40 Zirconium	2	8	18	10	2		
41 Niobium	2	8	18	12	1		
42 Molybdenum	2	8	18	13	1		
43 Masurium	2	8	18	13	2		
44 Ruthenium	2	8	18	15	1		
45 Rhodium	2	8	18	16	1		
46 Palladium	2	8	18	17	1		
47 Silver	2	8	18	18	1		
48 Cadmium	2	8	18	18	2		
49 Indium	2	8	18	18	3		
50 Tin	2	8	18	18	4		
51 Antimony	2	8	18	18	5		
52 Tellurium	2	8	18	18	6		
53 Iodine	2	8	18	18	7		
54 Xenon	2	8	18	18	8		
55 Cesium	2	8	18	18	8	1	
56 Barium	2	8	18	18	8	2	
57 Lanthenum	2	8	18	18	9	2	
58-71 Cerium to Luthecium	2	8	18	19-32	9	2	
72 Hafnium	2	8	18	32	10	2	
73 Tantalum	2	8	18	32	11	2	
74 Tungsten	2	8	18	32	12	2	
75 Rhenium	2	8	18	32	13	2	
76 Osmium	2	8	18	32	14	2	
77 Iridium	2	8	18	32	15	2	
78 Platinum	2	8	18	32	16	2	
79 Gold	2	8	18	32	18	1	
80 Mercury	2	8	18	32	18	2	
81 Thallium	2	8	18	32	18	3	
82 Lead	2	8	18	32	18	4	
83 Bismuth	2	8	18	32	18	5	
84 Polonium	2	8	18	32	18	6	
85 ————	2	8	18	32	18	7	
86 Radon	2	8	18	32	18	8	
87 ————	2	8	18	32	18	8	1
88 Radium	2	8	18	32	18	8	2
89 Actinium	2	8	18	32	18	9	2
90 Thorium	2	8	18	32	18	10	2
91 Protactinium	2	8	18	32	18	11	2
92 Uranium	2	8	18	32	18	12	2

The inert gases occupy a unique position in the table in that the outer shell of electrons contains two electrons in the case of helium and eight in the case of the other inert gases An outer shell of eight electrons is therefore correlated with chemical inertness This correlation can be further extended to the other groups of the periodic table where we find in the same group of the periodic table the same arrangement of the electrons in the outer shell of all members of the group In this way the chemical characteristics of an atom are associated with the number of electrons in the outer shell (**Valence, Spectra.**) (R K S)

ATOMIC WEIGHT. Chemical composition.

ATRACHEATA In some systems of classification of plants, the **Bryophytes** are called Atracheata in distinction to all other plants above the Thallophytes, because they lack a definite **vascular system.** (R M W)

ATRIUM. Literally an entrance chamber, and so applied to various organs 1 The main part of the cavity of the middle **ear** 2 The vestibule of the female genital passages 3 A chamber into which the genital organs open in the flatworms 4 A cavity formed of folds of the body wall in **Amphioxus** and the **tunicates,** which partially surrounds the **pharynx** and opens to the exterior by an atriopore 5 The chamber at the end of an air tube in the lungs, with which the ultimate air sacs or alveoli communicate 6 The chamber of the **heart** in **vertebrates** which empties into the ventricle In this sense the term atrium is frequently replaced by auricle, although in strict terminology the auricle refers only to a small appendage of the atrium (A W L)

ATROPHY Wasting of, or decrease in size of a portion of the body This occurs with any interference with the function or use of a particular part It may be temporary, as occurs following a fracture when for a period of time the affected part can be but little used It also occurs when nerves are injured or affected by disease, or as the result of circulatory accidents as in the brain when conduction along nerve pathways can no longer take place If the damage is of permanent character, as in some cases of **infantile paralysis, apoplexy,** or in traumatic injury of nerves that cannot be repaired, the atrophy is progressive Atrophy may also result where a part may not be used as a result of pain, as may occur in **arthritis.** (R S M)

ATROPINE An **alkaloid** derived principally from the leaves and root of **belladonna.** It is used to allay abnormal contraction and spasm of smooth muscle, especially the smooth muscle of the intestinal tract, and to check secretion of the skin, digestive and respiratory tracts When given in adequate doses it produces dryness of the mouth and dilation of the pupil of the eye Except in therapeutic doses, the drug is a poison (R S M)

ATTAR OF ROSES, OR ROSE OIL. An oil produced from a few kinds of **roses,** principally from *Rosa damascena* Bulgaria leads other European countries in production

In the preparation of the oil, the rose flowers are gathered early in the morning and immediately put into large copper stills Water is added and then boiled until about five quarts have distilled over, carrying with it the rose oil Fresh roses are added and distilled in the same water The rose water thus obtained is redistilled separately, yielding the desired rose oil Recently steam distillation has begun to replace this more primitive method At best, about two tons of roses are necessary to produce one pound of the oil Quite naturally, rose oil is very expensive, so adulteration by

cheaper oils is a common practice The oil is used principally in **perfumes.** (R M W)

ATTRITION. From the Latin *attritio* meaning a grinding or rubbing down, is used in the terminology of geological science to refer to the grinding of particles through the transporting power of wind, running water, or by the movement of glaciers (E S C S)

AUDIO FREQUENCY. Audio **frequency** is a wave frequency that is audible to the human **ear.** The average ear detects sounds within a frequency range of 20 to 20,000 cycles per second, but the extremely high frequencies have little use in the broadcasting of speech or music, and the limits of frequencies reproduced by the radio **receiver** are more like 50 to 7,000 cycles per second The audio frequency is the frequency of the modulation of the carrier waves which are **oscillating** at radio frequency In the receiving set the detector separates and demodulates the incoming wave and passes the audio frequency electromotive force into the audio frequency **amplifier.** (F T M)

AUDITORY ORGANS. Organs sensitive to stimulation by sound waves True auditory organs occur in **arthropods** and **vertebrates** In the former they vary considerably but in the latter they are the ears and can be traced through their variations to a common structural foundation

The simplest **arthropod** auditory organ is known as a chordotonal organ It consists of a nerve ending with accessory cells connected with the body wall, which is apparently the immediate source of the vibrations to which the organ responds More elaborate auditory organs are found in **grasshoppers, katydids, mosquitoes,** and related species In the grasshoppers they are located on the sides of the first abdominal segment, in the katydids in the front tibiae, and in the mosquitoes at the base of the **antennae** In all forms the **scolophore** is the essential sensory ending, accessory structures vary to a greater degree but usually include a modification of the **cuticula** which serves as a resonating membrane, or tympanum

The essential auditory portion of the vertebrate ear is the cochlea, a spiral organ of elaborate structure containing terminations of the auditory nerve This organ is part of the inner ear In the mammals the outer ear includes the pinna, usually called the ear, and the external auditory canal leading inward to the tympanum or ear drum which vibrates in response to sound waves Between these two regions lies the cavity of the middle ear, derived from the **pharynx** and connected with it by the **Eustachian tube** The middle ear is bridged by a series of small bones, the hammer, anvil, and stirrup, which convey the vibrations of the tympanum mechanically to the liquid in the inner ear These parts are variably developed in vertebrates below the mammals, all of which have simpler ears than described

Vibrations ranging in frequency from 30 to 30,000 per second are perceived by man as sound Other animals perceive higher or lower frequencies, merging with variable pressures which must be regarded as tactile stimuli (A W L)

AUGEN-GNEISS. A **gneissoid** rock that contains **lenticular** crystals or mineral aggregates resembling "eyes" Derived from the German *augen,* eyes (E S C S)

AUGITE. This mineral is a common **monoclinic** variety of **pyroxene** whose name is derived from the Greek word meaning lustre, in reference to its shining cleavage faces Chemically it is a complex metasilicate of **calcium, magnesium, iron** and **aluminum.** Color, dark green to black, may be brown or even white, hardness, 5–6 , specific gravity, 2 93 to 3 49 Augite is important as a primary mineral in the **igneous** rocks and also as secondary mineral. The white augite is called leucaugite from the Greek word meaning white Chemical analysis reveals this variety as containing little or no iron. Augite is of widespread occurrence (E S C S)

AUK. Aves, Charadriiformes Marine birds (**Aves**) of several species related to the guillemots and puffins They have a large compressed **beak** with oblique grooves toward the tip One species, the **razorbill,** *Alca torda,* occurs on both sides of the Atlantic, nesting on rocky ledges Another, the great auk or **garefowl,** was a flightless species which became extinct through wanton destruction about the middle of the nineteenth century (A W L)

AURA. A peculiar sensation which may precede the onset of an epileptic attack The phenomenon is composed of a group of mixed feelings as a rule—such as apprehension, fear and oppression (R S M)

AUREOLE. The contact **metamorphic** zone of varying width that often surrounds an **igneous** intrusion Such areas of contact metamorphism often contain valuable ore deposits, especially when surrounding **batholiths** which have intruded sedimentary formations (R M F)

AURIC. **Gold.**

AURICLE. 1 The outer ear (See **Auditory Organs**) 2 An appendage of the **atrium** of the mammalian **heart** The term is frequently used as if it were synonymous with atrium (A W L)

AURICULAR CANAL. 1 The external auditory canal, **ear.** 2 the passage between the **atrium** and ventricle of the **heart.** (A W L)

AURICULARIA The form of dipleurula **larva** found in the **sea cucumbers.** It is more elongate and compact than the other types and the ciliated band follows an intricately curved path, outlining a conspicuous lobe before the mouth (A W L)

AURIGA. (The charioteer) (Map, page 306) This **constellation** is best known because it contains the bright star **Capella** (the she goat) and her kids The kids are three fainter stars forming to the naked eye a small triangle and which always serve to distinguish Capella from other bright stars on a clear night Capella is a bright star, yellowish in appearance, and of the same **spectral type** as our sun The star, however, is so much larger than our sun that in spite of its great distance (49 **light years**) it appears as 1st **magnitude,** whereas the sun at the same distance would be 6th magnitude, or barely visible to the naked eye on a clear moonless night Capella is a spectroscopic **binary** with a period of 104 days (W K G)

AURIGNACIAN. **Paleontology of man.**

AUROCHS The wild **ox** of Europe, *Bos primigenius,* ancestor of domestic cattle It is now extinct but in some parks of England are half-wild cattle supposed to be descended from this species (A W L)

AURORA BOREALIS. This well known phenomenon of the upper **atmosphere** in middle and higher latitudes is now recognized as an electrical discharge in the ionized **air,** exhibiting, as it does, characteristic **spectrum** lines of the rarer atmospheric gases The aurora appears in a variety of aspects, sometimes as a faintly luminous streak or arch, sometimes as bright streamers like a search-light beam, sometimes resembling folds of a luminous curtain waved by the wind Its intensity is greatest in an indefinite region apparently encircling the magnetic pole, toward which the streamers seem to converge The occurrence of the phenomenon is intermittent, but with distinct evidence of several periodicities **Sunspot** maxima, with their eleven-year period, are always accompanied by maxima in the frequency and brightness of the aurorae There are also smaller auroral maxima in March and October each

year. Aurorae, like sunspots, are practically always attended by disturbances of **terrestrial magnetism.** A corresponding display in the southern hemisphere is called *aurora australis.*

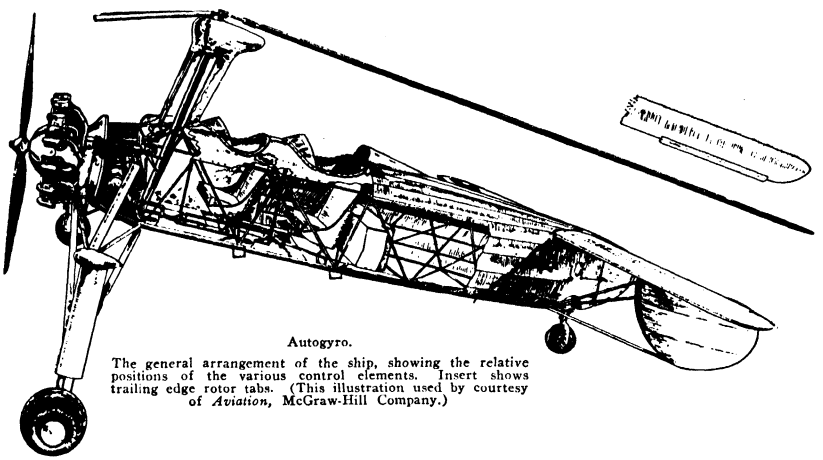
The direct cause of the aurora is not known, but a widely accepted theory attributes it to electrons expelled with great velocity from the **sun,** especially during violent solar disturbances, and entering the upper terrestrial atmosphere, exciting the gases to luminosity like **cathode rays** in a **Crookes** or **Geissler tube.** Such high-speed particles would move in spiral paths along the lines of force of the earth's magnetic field, and hence converge toward the magnetic poles. (L.D.W.)

AURUM. Gold.

AUSTRALIAN RAT. Mammalia, Rodentia. Any of several species of the Australian region constituting the genus **Hydromys.** One large aquatic species is known as the beaver-rat. (A.W.L.)

AUTOGENOUS. Self-generated — originating within the body. The term is usually applied to **vaccines** that are made from a patient's own bacteria as opposed to stock vaccines which are made from cultures grown from standard strains. (R.S.M.)

AUTOGYRO. The autogyro is an aircraft on which the lifting airfoil surface is not rigidly fixed to the body. In consequence of this fact, it has been possible to operate the **airfoil** with wind velocities greatly exceeding those of the **airplane** as a whole. As a result, the airfoil surfaces, or vanes, are a great deal smaller in area than those required for a conventional fixed-wing airplane. The autogyro was developed in Spain by Juan de Cievra, and first successfully flown in 1923. It has been under continuous development since that time.



Autogyro.

The general arrangement of the ship, showing the relative positions of the various control elements. Insert shows trailing edge rotor tabs. (This illustration used by courtesy of *Aviation,* McGraw-Hill Company.)

AUSTRALOPITHECUS. Paleontology of man.

AUTECOLOGY. The division of **ecology** that treats single factors or species in the association of organisms and environment, in contrast with synecology, in which the association of various factors and of species with species is considered. The subject of autecology is closely related with purely physical and chemical studies of environmental factors and with the physiological study of individual animals or plants. (A.W.L.)

AUTHIGENOUS, or AUTHIGENIC. A geologic term proposed by Kalkovsky in 1880, meaning generated on the spot, and referring particularly to the primary and secondary minerals of **igneous** rocks and the cements of **sedimentary** rocks. (R.M.F.)

AUTOCHTHONOUS. A geologic term proposed by Gümbel in 1888 for **sedimentary** rocks which have been formed in place. (R.M.F.)

AUTOCLASTIC. A term proposed by Van Hise in 1894 for crush **breccias** or fault breccias which have been fragmented in place. (R.M.F.)

AUTOGAMY. A process of nuclear reorganization in **protozoa** in which the **nucleus** divides, each half undergoes a maturation, and the two persisting functional nuclei reunite. In the modified process known as paedogamy the individual forms a cyst within which it divides into two **cells** which reunite after the nuclear transformation is completed. (A.W.L.)

The present design consists of a wingless **fuselage** mounting a **pylon** which contains a rotating head to which are affixed three or four balanced vanes of airfoil section. The angle of the rotor to the fuselage is controlled by the pilot and this takes the place of the normal control surfaces of the conventional airplane. The vanes rotate at speeds which give an average air velocity over them considerably in excess of the autogyro's air speed, and so the autogyro may be flown at speeds lower than the stalling speed of the airfoil section. This is a great advantage, as it permits the autogyro to land in small fields, with short landing runs, to descend almost vertically, and to approach "hovering" flight. The vanes are put into initial rotation by being connected before the take-off by clutch and gearing to the engine. However, the rotor is spinning freely during take-off and flight since the clutch is disengaged before the start of the take-off. The blades are caused to rotate during flight by the forces produced by **aerodynamic** action upon them. The vanes are hinged to the rotor in the horizontal plane, and therefore are free to flap. They are held from collapsing while at rest by a wire suspension. During rotation centrifugal force tends to hold them outward in a horizontal plane but, in flight, the wind velocity which adds to the relative velocity of the advancing blade, and subtracts from that of the retreating blade, has an effect on the position assumed by the vanes. If the blades were not hinged

at the root, this would cause a lateral overturning moment which would render flight impossible It was not until Cievra struck upon the idea of allowing a degree of freedom of the vanes that the autogiro was successful The advancing blade rises slightly under the increased lift imparted to it, and so decreases its effective angle of incidence, and the opposite holds true for the receding blade The result is an automatic balance of lateral forces, and there is no tendency of the machine to roll during flight (F T M)

AUTOINTOXICATION. Poisoning by a toxin generated within the body, which the body is unable to eliminate A much abused term covering many undiagnosed mild diseases of other origins (R S M)

AUTOMOBILE. Motor Vehicle.

AUTOMOBILE ENGINE. Otto Cycle Engine.

AUTONARCOSIS. Literally self-numbing **Anaesthesia** resulting from accumulated products of the animal affected (A W L)

AUTONOMIC NERVOUS SYSTEM. (Involuntary nervous system, vegetative nervous system) This nervous system is not under voluntary control, it is influenced to a great degree by the **endocrine glands** and these glands, as well as the involuntary (smooth) muscle are in turn influenced by it

In general the autonomic nervous system may be divided into two groups both of which may send nerves to the same organs but act antagonistically producing opposite results One is known as the parasympathetic and is stimulated by the drug **pilocarpine** and inhibited by **atropine.** The other is known as the sympathetic and is stimulated by **adrenalin**

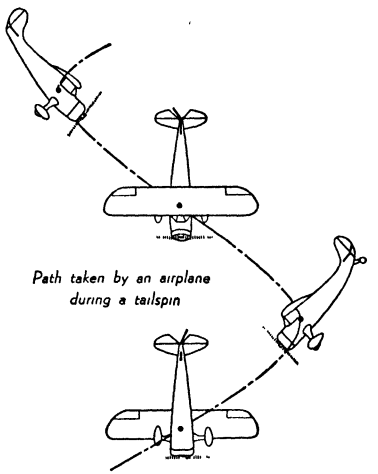
Under normal conditions there is a balance between the two systems allowing for perfect function of a bodily organ For instance the heart is slowed by the parasympathetic system and accelerated by the sympathetic Movement of the stomach is increased by the parasympathetic and is inhibited by the sympathetic The pupil of the eye is contracted by the parasympathetic and dilated by the sympathetic (R S M)

AUTO-OXIDATION. Oxidation.

AUTO-ROTATION. Auto-rotation, more commonly known as the tailspin, is a property of the motion of an **airplane** under a special set of circumstances The attitude of an airplane, when spinning, is with the longitudinal axis rather steeply inclined to the horizontal, indeed, some airplanes spin almost "nose down" Furthermore, the airplane has a rolling motion which makes a vertical **helix** of the flight path during spinning The peculiar significance of auto-rotation is that it is uncontrolled flight, and that recovery from it is not to be accomplished without the loss of 200–600 feet of altitude, consequently, when spinning begins within this height above the ground level, a crash is very likely to ensue

The action of auto-rotation is briefly described as follows It is essentially a stalled maneuver, and can not be intentionally or unintentionally gotten into when the speed of the airplane exceeds that of its stalling speed But when the airplane is flying at a speed equal to that at which it will **stall,** and a slight gust or change of angle of attack causes either a slight **roll** or a **yaw,** unless the pilot immediately and forcibly corrects the same to bring the ship again on the level keel with a slight increase of speed, the yaw will induce a roll (or the roll a yaw) It is the property of the conventional type of airplane that a roll produced by a yaw increases that yaw, and so results in an increasing roll At the stalling speed **ailerons** become inoperative, and the pilot has no control which will permit him to correct this roll, so the airplane goes into a tight spiral dive which is almost immediately followed by the auto-rotative condition, in which the wings are operating at an **angle of attack** above that of the stall

Recovery from auto-rotation is ordinarily accomplished by operation of the elevators and rudders, so as to decrease the angle of attack of the wings, allowing



Path taken by an airplane during a tailspin

them to recover their lifting power, and giving to the tail surfaces the required maneuverable power to cause the pilot to be able to stop the rotation, and bring the airplane to an even keel It has been possible to build airplanes which either will not spin, or which can be prevented from spinning at any time by the use of controls, especially of ailerons which are operative at the stall. (F T M)

AUTOTOMY. Self-mutilation Through the presence of a special modification near the base of the limb, some crustaceans and insects are able to drop off appendages by which they are seized The autotomy of the arms of starfish and of the tail of lizards are other common examples Autotomy is followed by regeneration (A W L)

AUTOZOOID. Members of **polyp** colonies whose function is to feed the colony (A W L)

AUTUNITE or CALCO-URANITE. This mineral is a hydrous **phosphate** of **calcium** and **uranium,** crystallizing in the **orthorhombic system,** usually in thin tabular crystals Good basal cleavage, hardness, 2–2 5; specific gravity, 3 1, luster, subadamantine to pearly on the base, color, lemon yellow, streak, yellow, transparent to translucent, strongly fluorescent

Originally from near Autun in France, whence the name, it is a secondary mineral associated commonly with **uraninite.** In the United States occurs sparsely in the pegmatites of Connecticut, New Hampshire and North Carolina (E S C S)

AUXIN. Growth substance. Substances which occur in growing parts of plants and in animals They have been particularly studied in young seedlings, notably oats, where their presence seems responsible for the extreme sensitiveness to light Numerous experiments lead to the conclusion that these substances cause the cells on the unlighted side of the stem (or coleoptile) of the seedling to elongate more rapidly than the others

and so cause a definite bending towards the light That one is dealing with a definite substance formed in the tip of the seedling and diffusing downward from the tip is shown by stimulating suitable tips with light, cutting them off, and placing these tips on tiny blocks of **agar**, into which the growth substance diffuses Subsequently the block of agar is placed on a decapitated stem and causes bending just as the tip would have done Agar blocks without the growth substance cause no response It is possible that the substance formed is a fatty acid Its presence has been demonstrated in many plants, including the **fungi**. (R M W)

AUXOSPORE An auxospore is a special type of **spore** which occurs in **diatoms** and which seems to be a means of rejuvenating the cells Rejuvenescence is necessary, since in the normal process of **cell division** one of the two daughter cells is always smaller than the parent cell Consequently very small cells are ultimately formed In some species of diatoms, auxospore formation is preceded by the escape of the protoplast from the walls of the cell The free **protoplast** then enlarges and secretes about itself a wall In time new valves more or less like those of the original diatom are formed In other species of diatoms, auxospore formation is preceded by the union of the protoplasts of two similar diatom cells, the process being therefore sexual (R M W)

AVAHI Mammalia, Primates The woolly **lemur**, *Avahis laniger*, of Madagascar (A W I)

AVAILABLE ENERGY. Energy which can be converted into mechanical work by means at human disposal While incalculable quantities of **energy** exist all about us, only an insignificant fraction of it is in such form that human invention has been able to utilize it for the performance of work For example, water stored behind a dam has a supply of potential energy, some portion of which can be made to drive our machinery as it descends to the sea But when it reaches the ocean level, though it still possesses energy, what is left is not available for use, because it cannot flow to a lower level as it might if the ocean basin were empty Again, there is an abundance of the kinetic energy called **heat**, since the air, the ground, and bodies all about us are at temperatures far above **absolute zero.** But the second law of **thermodynamics** requires that to utilize any of this supply we must have a region colder than these bodies, into which heat would naturally flow from them And even when such a region is at hand, as in the case of the relatively cool atmosphere surrounding an engine boiler, our best engines manage to capture only a small percentage of the thermal energy on its way from hot to cold

A most disconcerting aspect of the subject is the fact that even if energy is available, it is not content to remain so until we are ready to use it, but takes every opportunity to escape and become unavailable This is equivalent to the **least energy principle,** which may be expressed by saying that a system cannot be in stable **equilibrium** until it has got rid of all the available energy that it can Any process in which available energy thus becomes unavailable is said to involve "degradation" or "dissipation" of energy (See **entropy.**)

Cosmic physicists long have recognized that the continued operation of this dissipative principle can result in only one ultimate condition, namely, that the entire universe will become in the end an absolutely cold, motionless lump of matter (if, indeed, the "proper energy" composing matter itself does not succumb, in which case there would be no matter) This fate, significantly expressed by the German term *Warmetod* ("heat death"), must surely overtake the cosmos unless, as some think, compensating influences are operating somewhere to prevent it (L D W)

"AVERTIN." A proprietary name for tribromethylalcohol, a basal **anesthetic** used a good deal at present The anesthetic, in liquid form, is given rectally, and after a few minutes, the patient goes into a deep sleep lasting from one to four hours The state of unconsciousness is not deep enough to permit operation without the addition of some form of inhalation anesthetic The advantage of avertin lies in the fact that it may be given in bed before going to the operating room, less inhalation anesthetic need be given, and the patient often sleeps for a varying but prolonged period after being returned to his bed (R S M)

AVES. The birds A class of the phylum **Chordata** which is marked chiefly by a high degree of specialization for flight The great beauty of many species of birds, their songs, their interesting nesting habits, and the fact that few regions are so inhospitable as to be without birds, have led to wide interest in the group

Birds are distinguished by several structural characteristics, although the first alone is sufficient for their recognition 1 The skin is clothed with feathers 2 The jaws are ensheathed in a horny **beak** and bear no teeth 3 The pectoral appendages are usually modified for flight, forming **wings,** although they are rudimentary in some species and aid in swimming in some 4 The **skeleton** is made rigid by the fusion of bones 5 The **heart** is four-chambered 6 Birds are warm-blooded (Homoiothermal)

As is true of all extensive groups, the birds are very diverse in habits They are both herbivorous and carnivorous and are further specialized as seed-eating, fruit-eating, insect-eating, fish-eating and other types They are also specialized as swimming, wading, walking, running and diving forms, in addition to their usual ability in the air, and in a few cases they burrow effectively Their nesting habits also vary remarkably and the construction of the nest is in many cases a source of wonder

The seasonal **migrations** of birds are almost unique No other group of animals is so generally characterized by this tendency The subject has been widely studied and has aroused much speculation without being clearly understood It is obviously correlated with seasonal variation in the food supply and with climatic conditions, and is made possible by high specialization for flight, but exact knowledge of cause and effect in migration is lacking

The economic importance of birds is great, and is chiefly to their credit Insect-eating species destroy countless pests and seed-eating species aid in checking the spread of many weeds, although they may also rob the farmer of a small part of his crops Scavengers like the turkey **vultures** are useful, although the degree of their usefulness is difficult to estimate On the other hand a few **hawks** and **owls**—and only a few—do some harm by destroying useful birds and the **crow** is given a very bad reputation by conservation experts as a robber of the nests of other birds It is scarcely necessary to mention the value of birds as food and game The domestic species, **chickens, ducks, turkeys, geese,** are too well known as food, and their eggs are too common a culinary material to be readily overlooked

Probably because specialization for flight overshadows other adaptations, the classification of birds has been subject to some difficulty The birds are divided into two subclasses by some writers, the Ratitae including flightless birds whose **sternum** is without the deep keel to which the powerful flight muscles are attached, and the Carinatae with a keeled sternum These divisions are not, however, clean cut, hence the classification in twenty-five orders now in common use is given below.

Order Struthioniformes **Ostriches.**
Order Rheiformes **Rheas.**
Order Casuariiformes The **emu and cassowary.**
Order Crypturiformes The **tinamous.**
Order Apterygiformes **Kiwis.**

Order Sphenisciformes **Penguins.**
Order Gaviiformes The **loons.**
Order Colymbiformes **Grebes.**
Order Procellariiformes **Albatrosses** and **petrels.**
Order Pelecaniformes **Pelicans, gannets, darters, cormorants,** etc
Order Ciconiiformes **Herons, spoonbills, flamingos, storks, bitterns,** etc
Order Anseriformes **Swans,** geese, **ducks,** etc
Order Falconiformes **Eagles, falcons, hawks, vultures,** etc
Order **Galliiformes Turkeys, pheasants,** etc
Order **Gruiformes. Cranes, rails, gallinules, coots**
Order Charadriiformes **Gulls, plovers, curlews, auks,** etc
Order Columbiformes **Pigeons**
Order Psittaciformes Parrots and related species
Order Cuculiformes **Cuckoos,** etc
Order Strigiformes The **owls.**
Order Caprimulgiformes The goatsuckers, including the **whip-poor-will** and **nighthawk**
Order Micropodiformes **Swifts** and **hummingbirds.**
Order **Coraciiformes Kingfishers, hornbills,** etc
Order Piciformes **Woodpeckers, toucans,** etc
Order **Passeriformes.** An immense order including over half of the known species of birds, among them the more familiar land species The **thrushes, sparrows, warblers, swallows, flycatchers, larks, wrens,** titmice and many others (A W L)

AVIARY. A building or other enclosure for the maintenance of birds in captivity (A W L)

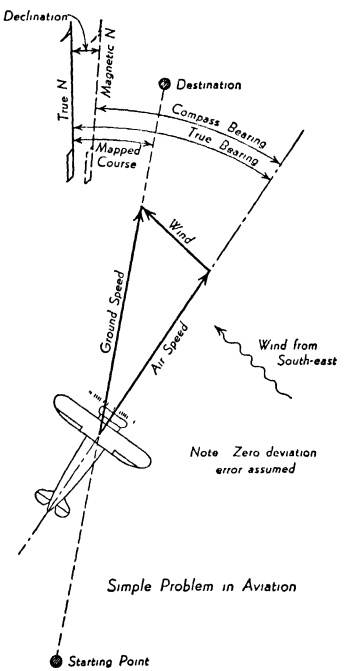
AVICULARIUM A modified individual resembling the head of a bird, occurring in **bryozoan** colonies (A W L)

AVIGATION. Avigation is the operation of directing an aircraft to its destination over some predetermined course This course may be the shortest distance between two points, or it may be a path in which factors other than distance take a prominent part The shortest course between two points is usually taken for long distance flights, especially transoceanic, but such considerations as location of suitable emergency landing fields, poor weather conditions, mountain ranges, etc, will often cause an avigator to select other than the shortest course between two points when some other course offers distinctly better flying conditions There are three general methods of avigation

1 Visual observation of the ground
2 Dead reckoning
3 Celestial observation

The first of these is employed on short flights only, and is carried out by visual observation of the country over which the plane is flying with simultaneous reference to the same area plotted on a map in the aviator's possession, showing the surface features In this way the experienced airman may locate himself continuously by means of railroads, towns, highways, rivers, and other surface features The disadvantage of this system is that when flying over unfamiliar territory, the avigator must continuously orient himself with respect to the map, and any prolonged interruption of view of the ground may result in a complete loss of position This system is also unsuitable for high altitude flight, due to difficulty of observing accurately the surface features of the ground

The greater bulk of cross-country flying is done under control of **dead reckoning** avigation This type of control is suitable for cross-country flights of medium length, say up to 500, or perhaps 1,000 miles, and does not require that the ground be continuously in view, or that the ground be in view at all if the wind velocity is constant Its chief drawback is, that for accuracy it depends upon the avigator's knowledge, at all times, of the direction and velocity of the wind While these may be obtained both by ground and air observations, the use of ground observations while in flight is impossible unless the plane is radio-equipped, and the observation of the velocity while in the air is somewhat tedious, necessitating the use of instruments and plotting board Briefly, dead reckoning consists of determining the desired course between the starting point and the destination by plotting it on a map and reading the course bearings from the map The air speed of the plane being known from the air speed indicator, a common airplane instrument, it is combined vectorially with the wind velocity in such a way that the air speed, wind velocity, and ground speed, form a closed triangle



The accompanying figure shows a simple problem in dead reckoning It is desired to fly between a certain starting point and a destination in a straight line The starting point and destination are located on the map, a straight line drawn between them Its bearing from the North of the map, which is true North, is determined by a protractor This is the mapped course Knowing the mapped course, the wind velocity and direction and air speed of the plane, solution of the triangle gives the direction the plane should head, and the ground speed In this particular case, the result gives the angle that the plane should head with respect to true North The pilot, however, orients his plane by means of a magnetic compass, and he must take into consideration two compass errors which will cause the compass bearing to be different from the true bearing The first of these compass errors is caused by the fact that the magnetic North Pole does not coincide with the true North, but is a certain angle easterly or westerly of true North, depending upon location This

angle is called the **declination,** and can be found on isogonic charts Easterly declination is considered negative, westerly positive Another error is caused by the iron and steel in the airplane itself affecting the compass, and this is called **deviation** Deviation is different in different compass bearings, and so must be marked on a card placed near the compass, for several different points around the compass The total compass error is the algebraic sum of the declination and deviation, and is applied to the true bearing to give the compass bearing In the illustration, the deviation error has been assumed to be zero

Avigation by celestial observation consists of locating the position of the aircraft with respect to latitude and longitude by means of observations made on the sun with a sextant, or similar instrument The position thus found can be located on the map on which the course has previously been plotted, and the actual position compared with the desired one Between celestial observations, the avigation is accomplished by dead reckoning

While for short flights it is sufficiently accurate to draw on the map a straight line between the start and destination of a flight, this procedure would not give the shortest course on long flights, due to the curvature of the earth, and the fact that the ordinary flying map is not a true representation of the earth A plane surface passed through the center of the earth intersects the surface in a great circle If the starting point, the destination, and the center of the earth be the three points that locate this plane, the great circle will pass through the starting point and destination, and its arc included between these points will be the shortest course It is this course that should be taken on long distance flights, climate and topography permitting (F T M)

AVITAMINOSIS. Deficiency or absence of **vitamins** in the diet or inability to assimilate them through the gastro-intestinal tract Absence or deficiency of the different vitamins cause the various deficiency diseases, such as **beri-beri, scurvy,** etc Avitaminosis untreated causes death (R S M)

AVOCADO or ALLIGATOR PEAR. *Persea americana* Lauraceae This tree, a native of the lowlands of tropical America, has been extensively cultivated in tropical and sub-tropical regions It has been introduced into Florida and California, where, due to its non-hardy character, it is often injured by frosts It is an attractive tree with large oval to elliptical leaves and small yellowish flowers The large green to brownish fruit varies in shape from nearly spherical to pear-shaped It is extremely nutritious and rich in oil, and is becoming increasingly popular in American markets The thick yellowish flesh of the fruit has only a faint flavor, and therefore is usually served with salt, vinegar, or oil (R M W)

AVOCET. Aves, Charadriiformes *Recurvirostra* Wading birds (**Aves**) of several species found in the Old and New World The **beak** is curved upward at the tip and the feet are fully webbed (A W L)

AVOGADRO'S LAW. The well recognized principle known by this name was originally a hypothesis suggested by the Italian physicist Avogadro in 1811, to explain the puzzling rule of proportional volumes observed in chemical reactions of gases and vapors It states simply that equal volumes of all gases and vapors at the same temperature and pressure contain the same number of molecules Though this assumption accords with the facts and aids the kinetic theory of gases, just why it should be true is by no means self-evident; unless one starts with the much more recent Maxwell-Boltzmann law of **equipartition of energy,** which also requires proof That Avogadro's law is true cannot be said to have been positively established until the experiments of J J Thomson, Millikan, Rutherford, and others determined the value of the **electron** as an electric charge and thereby made it possible to count the number of atoms of different elements in a gram. It is now known that one cubic centimeter of any gas at normal temperature and pressure consists of close to $2\ 705 \times 10^{19}$ molecules (Loschmidt's number), and that the number of molecules in a mol of gas is $6\ 064 \times 10^{23}$ (Avogadro's number) (See **Chemical Composition.**) (L D W)

AWN. An awn is a slender projection found on the **lemmas** of many grasses In some forms the awn arises from the tip of the lemma, in others from a point near the base Commonly they are barbed, and not infrequently spirally twisted They are particularly well developed in **barley** (R M W)

AXIAL GRADIENT. An axis of organization characterized by progressive metabolic (See **Metabolism**) dominance As formulated by C M Child the bilaterally symmetrical body is organized on a primary axis from head to tail, a secondary axis from dorsal to ventral and paired tertiary axes from the median plane to the lateral extremities In any axis, beginning at the point mentioned first, and in the entire body proceeding from axis to axis in the order named, metabolic dominance is evident in functions and in development over lower levels or subordinate axes (A W L)

AXIAL ORGAN An **organ** of peculiar structure and unknown function found near the axis of the body in all **echinoderms** except the **sea cucumbers** (A W L)

AXIAL SINUS A portion of the body cavity in **echinoderms** into which the pores of the **madreporite** open (A W L)

AXIL The angle between the upper side of a **leaf** and the **stem** to which the leaf is attached is called the axil of the leaf (R M W)

AXILLA. The armpit (R S M)

AXINITE This mineral is an **aluminum-boron-calcium silicate** with **iron** and **manganese**

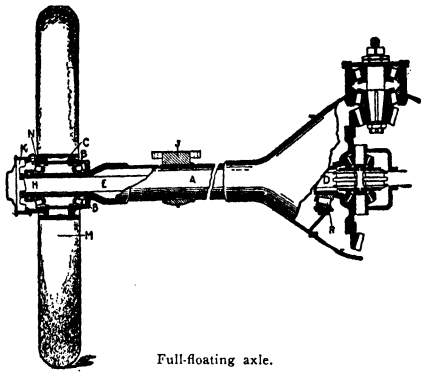
Crystallizes in the **triclinic system** yielding broad sharp edged forms, which has led to its name, derived from the Greek word meaning axe

Axinite breaks with a **conchoidal** fracture, hardness, 6 5 to 7 , specific gravity, 3 27 to 2 29, luster, vitreous, colors, brown, blue, yellow and gray Transparent to translucent Occurs in granites or more basic rocks along contacts and in cavities in Saxony, Switzerland, France, England, Tasmania and Japan In the United States, in New Jersey, Pennsylvania, and California (E S C S)

AXIS OF INSTANTANEOUS ROTATION. Dynamics of Rotation.

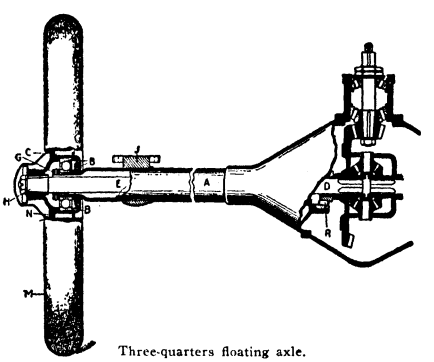
AXLE. An axle is a support for the rotation of wheels In the dead axle, the wheel turns on the axle which is inserted in the hub portion, and forms the center of rotation The contact surface between the wheel and the axle forms the bearing surface In the live axle type the wheel is rigidly fixed to the axle which turns in bearings The distinction between shaft and axle is this a shaft is, in general, the support of rotating objects, whereas axle is more definitely applied to a shaft used with wheels

The powered axle of an automobile offers an example of the live type Three types of axles are shown in the illustration They are, respectively, the full floating, the three-quarter floating, and semi-floating axles In the full floating type the wheel is supported entirely on the axle housing, *A*, and the axle shaft, *E*, transmits **torque** only The axle shaft, *E*, needs to be positively connected to the wheel, but not rigidly. The three-quarter floating axle has the wheel supported on one set of bearings on the axle housing, and the shaft *E*



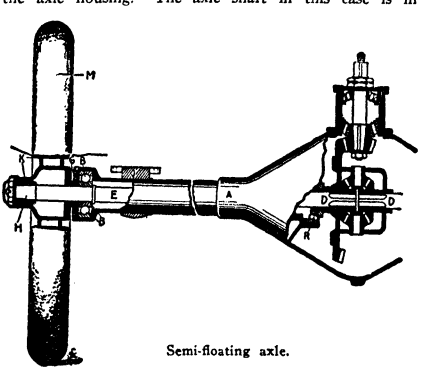
Full-floating axle.

must be rigidly fixed in the hub of the wheel to maintain alignment. Except when rounding turns, or when on roads which are not level, the shaft transmits pure



Three-quarters floating axle.

torque only. The semi-floating axle is rigidly fixed in the wheel, and the axle shaft rotates on bearings in the axle housing. The axle shaft in this case is in



Semi-floating axle.

bending as well as **torque**, since it must support all of the weight which is transferred to its wheel. (F.T.M.)

AXOLOTL. Amphibia, Urodela. A **salamander**, *Amblystoma tigrinum*, found near Mexico City which, although related to some of the terrestrial salamanders, retains its **larval** form throughout life, becoming sexually mature in this stage. Under experimental conditions the animal has been caused to undergo the usual **metamorphosis.** (A.W.L.)

AXON. Neuron.

AYE-AYE. Mammalia, Primates. A **lemur**, *Chiromys madagascariensis*, of Madagascar, resembling a squirrel in form, with large ears and a bushy tail. (A.W.L.)

AZALEA. Heath Family.

AZIDES. Hydrazoic Acid and Azides.

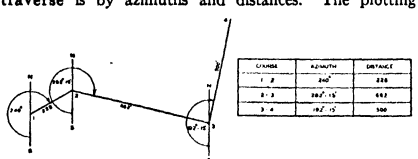
AZILIAN. Paleontology of Man.

AZIMUTH. Azimuth is the coordinate of a celestial object in the horizontal system of **spherical coordinates** measured in the plane of the **horizon** from the **meridian** to the vertical circle through the object. Astronomical azimuth is measured from the south to the west through 360°. Terrestrial azimuth of an object is the angle measured between the local meridian and a line drawn on the surface of the earth (considered as a plane) to the object.

The azimuth of a celestial object may be computed by solving the **astronomical triangle** provided three parts of the triangle such as astronomical **latitude** of the observer, and **hour angle** and **declination** (or latitude, altitude, and declination) of the object are known. Azimuth tables are published by various governments giving azimuth of celestial objects tabulated for latitude of the observer, hour angle, and declination of the object. For navigational purposes azimuth determination is of great importance for the checking of **compass corrections** and also for plotting **Sumner lines** either by the tangent method or the method of **St. Hilaire.**

Terrestrial azimuth is usually determined by measuring the azimuth difference between some celestial object and a fixed azimuth mark on the surface of the earth. This azimuth difference may be determined by means of an **altazimuth** instrument. The celestial object most commonly used for this purpose is **Polaris** (the north star) which is so close to the pole of rotation that its azimuth changes but very slowly. Tables are published for determining azimuth by Polaris which require the knowledge of local **time** only to the nearest ten minutes. In case Polaris is not used either the azimuth of the celestial object must be computed or taken from azimuth tables.

After the azimuth of some fixed terrestrial azimuth mark has been accurately determined, the azimuth of other points may be immediately determined with reference to the mark. Azimuths are always measured in one direction from the reference line through 360°, and in this respect differ from **bearings**, which are measured in each of the four quadrants through 90°. Astronomers use South for zero azimuth, but surveyors use both South and North. One way of running a **traverse** is by azimuths and distances. The plotting



Plotting Traverses by Azimuths.

of a traverse by azimuth is shown in the accompanying figure. (W.K.G., C.W.C., F.T.M.)

AZINES. Pyridine and Related Compounds.

AZO-, DIAZO-, AND RELATED COMPOUNDS. Compounds related to aniline, either directly or by oxidation, and to nitrobenzene, by reduction are numerous and important See **Aniline; Hydrazines; Hydroxylamines; Nitro-** and **Nitroso-compounds** Azo and Diazo compounds are considered here See table at end of this article

When **nitrobenzene** is reduced in the presence of **hydrochloric acid** by tin or iron, the product is aniline (colorless liquid), in the presence of water by zinc, the product is phenylhydroxylamine (white solid), in the presence of methyl **alcohol** by sodium alcoholate or by **magnesium** plus **ammonium** chloride solution, the product is azoxybenzene (pale yellow solid), by **sodium** stannite, or by water plus sodium amalgam, the product is azobenzene (red solid), in the presence of sodium hydroxide solution by zinc, the product is hydrazobenzene (pale yellow solid) The behavior of other nitrocompounds is similar to that of nitrobenzene

Hydrazobenzene is converted by oxygen of the air or by ferric chloride solution into azobenzene, and by strong acids into benzidine hydrochloride ($(4')H_2N\ C_6H_4\ C_6H_4\ NH_2(4)\ HCl$) Benzidine is prepared by reducing nitrobenzene to hydrazobenzene as above, and then treating the product with acid Benzidine and its toluene relative, orthotolidine, are important intermediates for dyes The counterpart of aniline is toluidine in its three forms, ortho, meta, para

Azoxybenzene is converted by distillation with iron into azobenzene (ferrous oxide also formed), and by concentrated sulfuric acid warm into para-hydroxyazobenzene ($(4)HO\ C_6H_4N\ N\ C_6H_5$), which is a dye

Diazonium salts are usually colorless crystalline solids, soluble in water, moderately soluble in alcohol, and when dry are violently explosive by percussion or upon heating These salts are generally used in cold (near 0° C) acid solution, without separation of the salt, and are prepared by reaction of the desired benzenoid primary **amine** with **nitrous acid** (from **sodium** nitrite plus **hydrochloric acid**) Alkyl amines with nitrous acid yield the corresponding alcohol

(A) By treatment of benzene diazonium chloride $\left(\begin{matrix}C_6H_5N—Cl\\ \vdots\\ N\end{matrix}\right)$ solution with **silver** oxide, or of the diazonium sulfate solution with **barium** hydroxide, the hydroxide (benzene diazo hydroxide, $C_6H_5N\ N—OH$) is obtained, which is intermediate in basicity between ammonium hydroxide and sodium hydroxide Most diazo hydroxides are unstable, and are spontaneously transformed into nitroamines (group —NH NO), yellow neutral compounds With sodium hydroxide, diazonium salt solutions yield sodium benzene-diazoate, more active chemically when first formed than upon standing, due to change from syn-diazoate $\left(\begin{matrix}C_6H_5N\\ \vdots\\ NaO\ N\end{matrix}\right)$, which evolves nitrogen readily, to anti-diazoate $\left(\begin{matrix}C_6H_5N\\ \vdots\\ NONa\end{matrix}\right)$ which is more stable Sodium benzene-syn-diazoate reacts with phenols in alkaline solution to give **azo-dyes**, e g , para-hydroxyazobenzene, wherein hydrogen para (or ortho but not meta) to the hydroxyl group is reactive Other reactions of diazonium salts are

(B) Replacement of the diazo-group with loss of **nitrogen**, (1) by hydroxyl-group, forming **phenols** by warming with water, (2) by alkoxy-group, forming ethers, by warming with an **alcohol**, (3) by acyl-group, forming **esters** with an acid, (4) by **hydrogen**, forming **hydrocarbons** or substituted hydrocarbons, e g , tribromobenzenediazonium chloride forms tribromobenzene, with alcohol or sodium stannite solution, (5) by **chlorine**, forming, for example, chlorobenzene, by warming with **cuprous** chloride (Sandmeyer's reaction), (6) by **bromine**, forming, for example, bromobenzene, by warming with cuprous bromide (Sandmeyer's reaction), (7) by **iodine**, forming, for example, iodobenzene, by warming a solution of the diazonium iodide, (8) by **cyanide**, forming, for example, cyanobenzene, by warming with cuprous cyanide (Sandmeyer's reaction), (9) by fluorine, forming, for example, fluorobenzene, by warming a solution of the diazonium borofluoride Gatterman's modification of Sandmeyer's reactions above is to use copper powder plus the corresponding sodium or potassium salt instead of the cuprous salt Nitro-compounds, since they are readily reduced to the corresponding amine, form an important group of compounds for the preparation of various derivatives by means of the diazo-reaction

(C) Reduction, to form the corresponding **hydrazine**, for example, benzene diazonium chloride to form beta-phenylhydroxylamine hydrochloride

(D) Bromination followed by treatment with **ammonia** to form azides, for example, benzene diazonium bromide plus bromine forms benzene diazonium perbromide ($C_6H_5Br_3$), which upon treatment with ammonia forms phenylazide $\left(\begin{matrix}C_6H_5N\\ \vdots\\ N\end{matrix}\right)$

(E) Amines, (1) primary or (2) secondary amine to form diazoamino-compounds, e g , benzenediazonium chloride (a) plus aniline forms diazoaminobenzene, benzene diazoaniline ($C_6H_5N\ N—NH\ C_6H_5$), (b) plus methylaniline forms benzenediazomethylaniline

$$\left(C_6H_5N\ \ N—N\langle^{C_6H_5}_{CH_3}\right)$$

Diazoamino-compounds readily change into aminoazo-compounds upon standing in alcohol solution or in the presence of amine hydrochloride, thus, benzenediazoaniline changes into para-amino-azobenzene, benzeneazoaniline-4 ($C_6H_5N\ N\ C_6H_4NH_2(4)$), benzenediazomethylaniline changes into methyl-para-aminobenzene, benzeneazomethylaniline-4

$$\left(C_6H_5N\ \ NC_6H_4N\langle^{H}_{CH_3}(4)\right)$$

(3) tertiary amine to form aminoazo-compounds directly, e g , benzenediazonium chloride plus dimethylaniline forms dimethyl-para-aminoazobenzene, benzeneazodimethylaniline-4 $\left(C_6H_5N\ \ NC_6H_4N\langle^{CH_3}_{CH_3}(4)\right)$ In this manner are prepared the azo-dyes, which contain the chromophore azo-group (—N N—) plus an auxochrome amino-group $\left(—NH_2,\ —N\langle^{H}_{CH_3},\ —N\langle^{CH_3}_{CH_3}\right)$

The simplest azo-dyes are yellow, but by increasing the number of auxochrome groups, or by increasing the percentage of carbon, the color darkens to red, violet, blue, and in some cases brown Naphthalene residues darken to red, violet, blue and finally black These amino-azo-dyes, together with the hydroxyazo-**dyes** (containing auxochrome hydroxyl-group —OH), are generally only slightly soluble in water In order that the dye may be soluble it is desirable that it contain one or more sulfonic acid groups ($—SO_2OH$) This group may be introduced either by treating the dye with concentrated sulfuric acid, or by using sulfonic acid derivatives in preparing the dye, e g , methyl orange, sodium dimethyl-para-aminoazobenzene-para-sulfonate ($(4)\ (CH_3)_2N\ C_6H_4N\ NC_6H_4SO_2ONa\ (4)$) from dimethylaniline and diazotized sulfanilic acid (para-amino-benzene sulfonic acid, $(1)\ H_2N\ C_6H_4\ SO_2OH\ (4)$), and then the sodium salt made from the product. Other azo-dyes are

chrysoidine $\left(C_6H_5N\cdot NC_6H_3\langle^{NH_2(2)}_{NH_2(4)}\right)$

Bismarck brown $\left((3)H_2N\cdot C_6H_4N:NC_6H_3\langle^{NH_2(2)\cdot HCl}_{NH_2(4)}\right)$

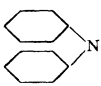
Congo red $\left(\begin{matrix}(4)HOO_2S\\ (1)\ \ H_2N\end{matrix}\rangle C_{10}H_5N:NC_6H_4\cdot C_6H_4N\cdot NC_{10}H_5\langle^{SO_2OH(4)}_{NH_2(1)}\right)$

(R K S)

AZO-, DIAZO-, AND RELATED COMPOUNDS

Aniline (phenyl amine)
M P −6° C , B P 184° C

Phenylhydrazine
M P 20° C , B P 243° C.

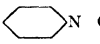


Unsym -diphenyl hydrazine
M P 34° C

Beta-phenylhydroxylamine
M P 81° C

Rearrangement into

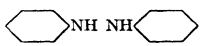
Para-aminophenol
M P 185° C decom.



Nitrosobenzene
M P 68° C ,
B P 58° C (18 mm)

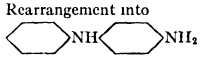
Nitrobenzene
M P 6° C , B P. 211° C.

Condensed with aniline

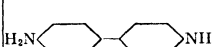


Hydrazobenzene (yellow)
(sym -diphenyl hydrazine)
M P 131° C

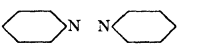
Rearrangement into



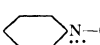
Para-aminodiphenylamine
(intermediate)
M P 66° C



Benzidine (final)
(Para-para prime-diamino-biphenyl)
M P 128° C B P 400° C
(740 mm)



Azobenzene (red)
M P 68° C , B P 297° C

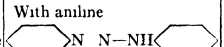


Benzene-diazonium chloride

Benzenediazohydroxide

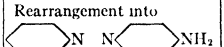
Sodium benzenediazoate

With aniline



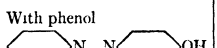
Diazoamino benzene
(Yellow)
M P 97° C Expl 180° C

Rearrangement into

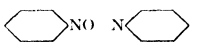


(Para) Aminoazobenzene
("Aniline yellow")(Azo-dye)
M P 126° C , B P 225° C
(120 mm)

With phenol



(Para) Hydroxyazobenzene
(Orange) (Azo-dye)
M P 155° C B P 225° C
(20 mm)



Azoxybenzene (yellow)
M P 36° C.

AZOLES. Pyrrol and Related Compounds.

AZOXY-COMPOUNDS. Aniline; Azo-, Diazo and Related Compounds.

AZURITE OR CHESSYLITE. This mineral is a basic carbonate of copper, $2CuCO_3 \cdot Cu(OH)_2$ so called from its beautiful azure blue color It is a brittle mineral with a conchoidal fracture, hardness, 3 5–4 , specific gravity, 3 77–3 89, luster, vitreous, color and streak, blue, transparent to translucent

Azurite like malachite is a secondary mineral, but far less common than that mineral It has been formed by the action of carbonated waters on compounds of copper or solutions of copper compounds, probably most abundantly by rich solutions reacting with limestones Azurite almost always occurs associated with malachite Found in Siberia, Greece, Rumania, at Chessy, France, whence the name Chessylite, in South West Africa, Australia and elsewhere Azurite occurs in the United States at Bisbee, Arizona and Kelly, New Mexico It is used as an ore of copper (E S C S)

B

BABBITT. Babbitt's metal is a tin-base bearing **alloy** which is found in a variety of forms. The name is derived from that of the inventor, who used a bearing composition of 88.9% tin, 3.7% copper, and 7.4% antimony. Tin, copper, and zinc alloys also go by the name of Babbitt metal. Lead is also frequently an alloying element.

Babbitt metals are poured at temperatures between 600–850° F. When used as a **bearing,** and this is its principal use, it is poured into a shell or backing, to which it is anchored or locked by means of grooves or holes in the shell. Babbitt is an excellent bearing metal, and being softer than the shafting which turns in it, takes all the wear. It must be well lubricated (F.T.M.)

BABBLER. Aves, Passeriformes. Birds (**aves**) of the Ethiopian and Indian regions, particularly those of the family Crateropodidae but sometimes more loosely applied (A.W.L.)

BABINGTONITE. This mineral is a relatively rare **calcium-iron-manganese** silicate, occurring in small black **triclinic** crystals, found in Italy, Norway and in the United States at Somerville and Athol, Massachusetts and in Passaic County, New Jersey. It was named for Dr. William Babington.

BABIRUSA. Mammalia, Artiodactyla. A wild **pig,** *Babirusa alfurus,* of Celebes with unusually long curved tusks, resembling the horns of some deer, which are the source of the name. Babirusa means pig-deer. (A.W.L.)

BABOON. Mammalia, Primates. The true baboons are characterized by the elongate, dog-like muzzle with nostrils at the tip. The head is large and they walk on all fours. These animals constitute the genus *Papio* but the term baboon is also applied to the gelada baboon, *Theropithecus gelada,* of southern Ethiopia, also a dog-like species although the nostrils are some distance from the tip of the snout. Baboons are also called dog-faced monkeys.

Among the baboons several species are known by special names, including the mandrill (*P. sphinx*), the drill (*P. leucophaeus*), and the chacma (*P. porcarius*). All are found in the Ethiopian region.

Baboons include some of the most hideous of animals and are correspondingly ferocious in disposition. Individually they are able fighters and their defenses are augmented by their habit of living in bands. A group of males is said to be a good match for some of the larger predators. (A.W.L.)

BACILLARY DYSENTERY. An infectious acute or chronic disease caused by a group of somewhat related organisms, whose classification has not been definitely agreed upon. Usually they are divided into two groups, the first containing the Shiga bacillus, and the second, the Flexner group of organisms.

The disease occurs principally in the tropics and is quite prevalent during great wars. During the World War it was a great cause of death on every front. The main factors for its spread are bad sanitation, lowered resistance, exposure, poor coarse food, or starvation. Flies increase the spread of the disease from a few isolated cases.

Symptoms vary according to whether the disease is acute, fulminating, relapsing, or chronic in form. The mild forms may be marked by diarrhea only. Several forms occur with sudden onset of abdominal pain and marked diarrhea. The stools are composed of fluid, pus, mucus, and blood. Fever and prostration may be marked with severe toxic symptoms.

Complications are frequent. **Arthritis,** infection of the **paratid** gland, heart involvement, and **neuritis** are common.

There is a chronic form that may last for years.

Serum treatment is quite striking in many cases. It must be given in large doses. Relapses are prone to occur. (R.S.M.)

BACILLUS. **Bacteria.**

BACK-GOUDSMIT EFFECT. **Zeeman Effect.**

BACK-SWIMMER. Insecta, Hemiptera. An aquatic **bug** of boat-like form which lives in an inverted position. The hind legs are broadened by fringes and are used like oars for propulsion. Family Notonectidae (A.W.L.)

Back-Swimmer.

BACTERIA. Bacteria, often called germs or microbes, are microscopic unicellular organisms only obscurely related to other organisms. Their unicellular form, lack of definite nucleus, and method of reproduction by fission remotely suggest relationship with blue-green **algae,** from which they are, however, distinguished by the absence of pigments. This lack of pigments leads many to connect them with **fungi.** The absence of chlorophyll (See **Pigments in Plants,** also **Aminoacids** and **Proteins**) makes it necessary for bacteria to obtain their nutritional requirements from organic sources. Many are parasites causing diseases of living plants and animals; others are **saprophytes** living on dead plants and animals, the chemical constituents of which are broken down by the action of the bacteria. Because of the results of their presence bacteria, whether disease-producing or otherwise, are of tremendous importance to mankind.

The small size of bacteria makes them invisible to the unaided human eye. Although several early philosophers advanced the opinion that such invisible organisms must exist, it was not until the seventeenth century, with the invention of the **microscope,** that the Dutch lens-maker, Anton van Leeuwenhoek, actually saw these minute forms of life and reported them to the Royal Society of London, in 1683. After this the study of bacteria languished for a century. Throughout this early period little was known of the true nature of the organisms and the part they played in various processes, such as decay and **fermentation.** But during the nineteenth century the work of Pasteur definitely demonstrated the great biologic importance of bacteria.

The study of bacteria is closely connected with their culture, which means growing each form under such conditions as to exclude all other organisms, including other bacteria. To do this it is first necessary to clean thoroughly and sterilize all instruments and dishes to be used. Ordinary washing is insufficient. After thorough washing and rinsing the dishes are covered or plugged with some substance which prevents the entrance of any solid particles, however small. A convenient material for plugging is ordinary cotton. All implements and vessels are next sterilized. This means exposure in an oven to a temperature as high as 170°–200° C. for fifteen minutes or more, or treating with steam under pressure for fifteen minutes or more at 120° C. If

possible, such steam pressure treatments are done in an autoclave After sterilizing all objects to be used, it is necessary to prepare a suitable culture medium, which must be a substance on which the bacterium to be studied will grow satisfactorily Many different media are used, such as meat broth and peptone, potato broth, etc If gelatine is added, the medium becomes solid, and the organisms, growing on the surface, are more easily studied However, the fact that gelatin liquefies at 37° C, and many bacteria grow best at higher temperatures, makes it desirable to find other substances which will remain solid at temperatures higher than 37° C **Agar agar,** a vegetable product, is found to meet this requirement, and so is frequently used to prepare a solid medium on which to grow bacteria The media are placed in suitably prepared dishes, sterilized, and then inoculated with the organism to be studied, precautions being taken to prevent the entrance of undesired organisms. On such solid media each species of bacterium forms very characteristic masses or colonies

Several methods are used for the study of bacterial cells Living bacteria may be readily examined under the microscope by the hanging drop method To do this a drop of the culture, growing in a liquid medium, is transferred to a thin slip of glass (a cover slip) and inverted over a special glass slide in which a circular hollow has been ground Bacteria grown on solid media may be transferred to a suitable liquid medium and mounted as a hanging drop Such hanging drops allow one to study the living organism and to determine its motility, spore formation, and form

Often it is desirable to study killed and stained bacteria A thin film of bacteria is smeared on a clean glass slide and allowed to dry, after which it is fixed by passing through a flame, or by dipping in absolute alcohol, which is subsequently washed off A suitable stain is then put on the smear of bacteria gentian-violet is often used After a few seconds the stain is washed off with water, and the preparation examined Many methods of staining, some very elaborate, have been devised. One, known as Gram's method, merits description, since it is frequently used in describing bacteria The stained organism is treated with an iodine solution and then washed in 95% alcohol; with this procedure many organisms give up the stain, and are said to be gram-negative; others retain the stain and are called gram-positive

Bacteria are the smallest of living organisms, varying from large species 1/250 of an inch in length to minute forms only 1/250,000 of an inch in length The average dimensions of the species are 2 microns long and ½ micron in diameter (about 1/12,500 of an inch by 1/50,000 of an inch)

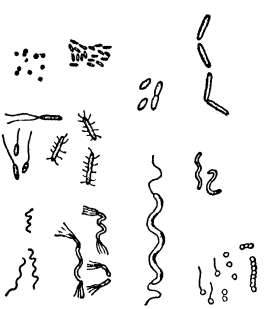
The minute size of the bacterial cell makes it very difficult to determine its structure accurately A definite cell wall surrounds the cell, but does not seem to contain cellulose as does the wall of a plant cell, but rather to be composed of nitrogenous substances Outside this wall there occurs in many species of bacteria a thin gelatinous sheath which swells in water and becomes slimy The **protoplast** of the bacterial cell seems to be of a very simple character There is a definite plasma membrane surrounding it, and within are many granules of various kinds Some seek to be **chromatin** granules, which are the nuclear substance of the cell It is generally held that bacterial cells have no definite nucleus surrounded by a nuclear membrane

Many bacteria possess **cilia,** minute lash-like structures, which vibrate and so cause the cell to move In some species a single cilium occurs at the end of the cell, sometimes there are cilia at both ends, and again the entire surface of the cell may be covered by numerous cilia

Reproduction in bacteria seems to occur solely by the process of fission, or **cell division.** This process occurs with great rapidity, often requiring less than a half-hour for completion, and occurring in many cases as frequently as once an hour Simple calculation will show that under such conditions a single bacterium may give rise by successive divisions in a single day to many millions of cells, and in a few days to unbelievable numbers

Such rapid divisions do not continue indefinitely, however The nutrient supply may become exhausted, or the products of bacterial growth accumulate and become toxic, and divisions cease Often such conditions bring about **spore** formation, each cell generally becoming a spore A bacterial spore is highly resistant, surviving prolonged desiccation, intense cold or high temperatures, as well as the presence of harmful chemicals Spores should therefore be considered not as reproductive bodies, but as a means by which the organism survives unfavorable conditions which would be fatal to the ordinary cell Not all bacteria are capable of forming spores Fortunately many disease-producing bacteria are of this less resistant type.

Bacteria may be classified into three families, according to the shape of the single cell The first contains all those whose cells are globose and which are known as coccus forms—this family is the Coccaceae, and includes, among other genera, the genus *Streptococcus* A second family, the Bacteriaceae, comprises all forms having rod-shaped cells, which may be either straight or slightly bent Such cells are known as bacillus forms This family has three genera, *Bacterium, Bacillus,* and *Pseudomonas* The third family, the Spirillaceae, is a small one, and contains those forms in which the cell is in the form of a spiral, known as a spirillum-form While coccus forms do not possess cilia, most spirillum forms are ciliated Bacillus forms may or may not have cilia, and so belong to either the genus Bacillus, or Bacterium, respectively



Different kinds of bacteria, drawn to approximately the same scale, showing the variations that occur in size, shape and distribution of flagella

Bacteria may also be divided into two classes **saprophytes** and **parasites.** Saprophytes are forms which grow and multiply best on dead tissue or organic matter, reducing it into simple chemical compounds which furnish food for plants, and thus, the saprophytes play an important part in the chemical cycle of living matter They maintain the balance between the plant and the animal kingdoms Ordinarily these forms do not cause disease in man unless potent toxins are produced by the bacteria The parasitic forms live off the living tissues of higher forms of life and, in general, they form the group of pathogenic or disease-producing bacteria

Another classification of bacteria is based on their source of nutrition Organic compounds of all sorts may be a suitable nutrient source Complex nitrogenous bodies are attacked and broken down by many, the process being the familiar one of decay and decomposition Simpler organic substances are attacked by other species Autotrophic bacteria are those which obtain the carbon necessary for **carbohydrate** formation from carbon diox-

ide and their energy from the oxidation of inorganic compounds, such as **ammonia, sulfur** and sulfur compounds, nitrites (See **Nitrous Acid**), etc *Beggiatoa* is a genus of this group Heterotrophic bacteria are those requiring organic sources of both carbon and energy for their existence Nitrogen-fixing bacteria are examples of heterotrophic bacteria

Like all living organisms, bacteria are affected by environmental conditions, particularly by temperature, light, moisture, oxygen supply and food requirements Many bacteria are capable of growing under remarkable temperature conditions Some, like the hay bacterium (*Bacillus subtilis*) can divide at temperatures from 6° C to 50° C, while others, such as the pathogenic species, may have a very narrow range of temperature in which they can grow Bacteria are less sensitive to low temperatures than to high ones

Light is another very important factor in the life of bacteria the germicidal action of direct sunlight is well-known The action of light on bacteria seems due to oxidation processes which are fatal to the well-being of the cell. This fatal effect of light is confined to the ultra-violet region of the spectrum, and is found both in sunlight and also in electric light Moisture is necessary for the continued existence of many bacteria a short period of drying destroys a great many species in the vegetative phase, including fortunately most of the pathogenic forms The spores of spore-producing forms are extremely resistant to desiccation

Bacteria vary greatly in the oxygen requirements There are many species which can exist only when free oxygen is available, such forms being known as obligate aerobes Other species cannot exist except in the complete absence of free oxygen and are known as obligate anaerobes Still other species are indifferent to the presence of oxygen and are called facultative anaerobes

The importance of bacteria is tremendous Of greatest significance to ordinary man are the many pathogenic species which, by their presence in the human body, cause disease **Tuberculosis, leprosy, cholera, typhoid fever, diphtheria** and many other diseases are due to such organisms Bacteria of this type are of highly specific nature, that is, can only attack a single host, or a small group of closely related hosts

As bacteria may cause diseases in animals, so also are they the cause of many diseases in plants, although such diseases are not as numerous as those of animals A common disease of plants which is caused by bacteria is Cucurbit Wilt, which appears in cucumbers, melons, pumpkins and squashes In this case the bacteria gains entrance to the plant through wounds inflicted by insects such as the striped cucumber beetle Once inside the plant body, the bacterium passes to the conducting strands of the stem, which are filled by the accumulating masses of rapidly dividing bacteria These cut off the water supply of the leaves of the host plant so that wilting occurs and subsequently the death of the infected parts A somewhat similar disease is found in Brown Rot of Tomatoes Black Rot of Cabbage, Bean Blight and Crown Gall of many plants are all bacterial diseases of some importance

These disease-producing bacteria are known so much better than are other forms of bacteria as to lead to the idea that bacteria are eminently destructive This, however, is far from the truth Probably the beneficial types of bacteria many times outweigh the injurious forms Some of these beneficial forms are used by man in the industries The souring of milk is caused by the presence in the milk of certain bacteria which result in the formation of **lactic acid.** Bacteria present in cream during its ripening cause the butter presently made to have certain flavors Many cheeses owe their particular characteristics to the presence of certain bacteria However, molds also play a very great part in the development of the much-sought flavors (and also odors) in the many cheeses.

In the tanning of hides and in the curing of tobacco, bacteria are thought to play an important part The oxidation of **alcohol** to **acetic acid** in such weak alcoholic liquids as cider and wine is due to the activities of different species of bacteria In the preparation of **flax** fibers and also **hemp** bacterial action is very important, for by their action the cement substance binding the fibers together is broken down and the fibers freed The action of certain bacteria is important for the proper preservation of ensilage

Of particular importance to man is a certain group of several different bacteria which occur normally in the soil and are instrumental in making available to higher plants the very essential element **nitrogen.** All plants require a considerable amount of this element, which is available to them only in the form of certain soluble compounds, such as nitrates The large percentage of free nitrogen in the atmosphere is unavailable, and few soils naturally contain a sufficient supply of usable nitrogen Commercial **fertilizers** may be used to provide the necessary amount, but are expensive. **Ammonia,** a product resulting from the breaking down of organic matter by bacterial action, is another possible source of nitrogen which is largely unavailable to higher plants There are several species of bacteria which are able to convert ammonia into nitrates and other species which fix the free nitrogen of the air These organisms are of very great importance to man Their activities are collectively included in what is called the nitrogen cycle, and fall in three groups, those comprising the nitrogen-fixing bacteria, the nitrifying bacteria and the denitrifying forms The nitrogen-fixing bacteria, in turn, fall into two groups, those living free in the soil and those which enter the roots of various plants By their activities the fertility of a soil is built up greatly without any attention from man The free-living forms in the soil obtain the energy necessary for their existence from various organic compounds and assimilate free nitrogen of the atmosphere so that it is subsequently available to higher plants Several species of bacteria are included in this group, including *Clostridium pasteurianum* and *Azotobacter chroococcum,* and they are most abundant in light, well-aerated soils The nodule-forming bacterium, *Bacillus radicicola,* normally occurs in the roots of various plants, particularly legumes, such as clover, alfalfa, vetch, etc, causing small lumps or nodules to form at various places on the root The bacteria are highly specific in the hosts they enter, each strain being restricted to a single species or to a small group of species So it is necessary, in spite of the widespread natural occurrence of the bacteria, to inoculate with the proper strain any new plant to be introduced This is particularly noticed in the case of **Alfalfa,** where the seeds are covered with a suitable strain of bacteria before being planted The bacterium enters the root through the root-hairs, a spot on the surface of the latter softening to permit their entrance Once inside the cell, the bacteria pass inward into the **cortex,** where they accumulate in great numbers in the **vacuoles** of the cells Their presence causes definite enlargement of the infected cells, thus producing the conspicuous nodules Within the nodules the bacteria become modified into irregular, frequently somewhat branched objects known as bacterioids In the presence of abundant energy-supplying **carbohydrates** from the host plant the bacterioids assimilate free nitrogen, which is built up into complex nitrogenous compounds These are either utilized by the host plant directly or liberated into the soil on the death of the host plant, so adding to the fertility of the soil

In addition to the various nitrogen-fixing forms described above there are other bacteria which make available to higher plants the necessary nitrogen These are collectively known as the nitrifying bacteria, and are of two kinds The first, *Nitrosomonas,* converts ammonia into nitrites, and the second, *Nitrobacter,* converts the nitrites into nitrates.

The ammonia necessary for the development of the nitrite-forming *Nitrosomonas* results from the activities of another complex and very important group of organisms, largely bacteria, known as denitrifying organisms These bacteria reduce nitrates to nitrites and ammonia, to oxides of nitrogen or to gaseous nitrogen More important in the formation of ammonia are the various organisms causing decay of the dead bodies of plants and animals These attack the complex organic substances which occur in dead bodies and break them down into simpler forms, eventually into ammonia, oxides of nitrogen or even free nitrogen The process is one of great complexity and occurs in many stages, each organism attacking a single substance and reducing it to simpler forms, which will in turn be attacked by other organisms until the lowest stage is reached The great result of the activities of these organisms is the disintegration of what otherwise would accumulate as vast quantities of dead matter, in which large amounts of chemicals necessary for living organisms would be bound Putrefaction is thus a very necessary process for the continuation of life (R S M, R M W)

"BAD LANDS" The literal translation of the phrase *Mauvais Terre* of the French explorers who so described the highly dissected, relatively unconsolidated **sandstones** and **shales** such as occur in the western Great Plains near the Black Hills Small areas also occur in the plateaus of the Rocky Mountain region Thus type of topography develops in arid and semi-arid regions where the underlying formations are relatively soft, and, due to the climate, are not protected by a plant cover (R M F)

BADGER. Mammalia, Carnivora Stoutly built and short legged burrowing animals of several species, found throughout the northern hemisphere The term is extended to the ferret-badgers, which are related to the **skunks,** and to the **ratels** of India and Africa, which are called honey-badgers

Badgers are courageous and able fighters when attacked and are sometimes hunted for sport, but they are peaceful animals unless molested The fur is moderately valuable and the long hairs, especially of the European species, *Meles taxus,* are used in making brushes Badger-hair shaving brushes are a familiar example (A W L)

BAFFLES In the engineering sense, a baffle is an object, usually a partition, placed for some specific purpose in the flow path of a fluid causing it to take some prearranged and circuitous path Thus baffles are found in steam **boilers** to direct the hot gas properly back and forth over the tubes so that the gas will give up its heat to the required degree, and will not short-circuit directly from the furnace to the stack For this service the baffle is composed of refractory material similar to firebrick and will be found in longitudinal or transverse arrangement Transverse baffling is made by building the baffle perpendicular to the tubes This is usually accomplished by constructing a wooden form and ramming in the baffle material in plastic state When the fire is started in the **furnace** the wooden form burns away, leaving the baffle in place Longitudinal baffles are usually precast and laid upon the tubes of the boiler, forming a baffle whose surface is parallel to the tubes

Baffles are built in coagulation basins to impede the flow of liquid, and are also found in exhaust **mufflers** where their purpose is to mix the flow of gases in adjacent exhaust puffs that they may emerge from the muffler in a silent steady stream (F T M)

BAGASSE. In the manufacture of sugar (See **Carbohydrates**) from sugar cane the crushed fibers from which the sap has been expressed are called bagasse Its principal use is as a fuel to run the mills which crush the cane. For this purpose bagasse is mixed with petroleum oil It is also used as a fertilizer and to some extent in manufacturing heavy insulation board and coarse paper (R M W)

BAG-WORM. Insecta, Lepidoptera The **larva** of a **moth** which is encased in a covering of silk mixed with bits of leaves, twigs, etc Only the head and legs protrude from the bag, hence the insect appears to be suspended from the twig on which it walks The adult females are wingless and the eggs are deposited in the silken bag

One species of bag-worm sometimes does great damage to evergreen trees, especially the cedars, and so has been named the evergreen bag-worm, *Thyridopteryx ephemeraeformis* The larvae can be killed by spraying infested trees with lead arsenate and the destruction of the bags in the winter, when they contain eggs, is an important measure of control

These insects constitute the family Psychidae (A W I)

BAILEY'S BEADS. During an **eclipse** of the sun, at the instant when the moon's edge is just tangent to the edge of the sun, i e, at either second or third contact, the thin crescent of the disappearing sun suddenly breaks up into a number of brilliant spots known as Bailey's Beads These are produced because the surface of the **moon** is very rough, and mountains on the moon will completely cover the sun's disk while the sunlight is still coming to the earth through the valleys (W K G)

BAKELITE. Plastics.

BAKING POWDERS. Baking powders are used instead of leavening or **fermentation** agents to make light those baking products made mainly from **flour.** Baking powder, when it is mixed with flour and other ingredients, and the resulting mixture is thoroughly moistened and heated, evolves a gas, **carbon dioxide** (sometimes **ammonia**), thus producing a light porous product To supply carbonate for the production of carbon dioxide, **sodium** hydrogen carbonate ("baking soda," $NaHCO_3$) is universally used To supply acid, three classes of materials are in common use (1) **potassium** hydrogen tartrate ("cream of tartar," $KHC_4H_4O_6$), and infrequently, **tartaric acid** ($H_2C_4H_4O_6$ H_2O), (2) **calcium** dihydrogen phosphate (calcium monophosphate, $Ca(H_2PO_4)_2$ H_2O), (3) sodium **aluminum** sulfate (Na_2SO_4 $Al_2(SO_4)_3$ $24H_2O$) The proportions (approximate only because it is customary to use some excess of carbonate) are, with one part by weight of sodium hydrogen carbonate, (1) 2 2 parts by weight of potassium hydrogen tartrate, (2) 1 0 of tartaric acid, (3) 1 5 parts of calcium hydrogen phosphate, crystallized, or (4) 1 8 of sodium aluminum sulfate or ammonium aluminum sulfate With 7 parts by weight of this finely powdered mixture, there is usually mixed about 3 parts by weight of starch to diminish the effect of moisture in storage In some cases, dry powdered egg albumin is added to decrease the loss of carbon dioxide upon wetting the flour and baking powder mixture when used For some purposes **ammonium** carbonate ($(NH_4)_2CO_3$) is used alone, since, upon heating, this material furnishes both ammonia and carbon dioxide gases to make the product light These gases escape from the product in the baking process

The referee board of consulting scientific experts of the United States government, consisting of Ira Remsen, chairman, Russell H Chittenden, John H Long, Alonzo E Taylor, and Theobald Smith, concluded (1914) after exhaustive experimental investigations, that alum baking powders are no more harmful than any other baking powders, but that it is wise to be moderate in the use of foods that are leavened with baking powder

The Inland Revenue department of the Canadian government has since 1889 conducted periodical surveys of the quality of baking powders sold to consumers in Canada The department regards 10 per cent by weight of carbon dioxide as a minimum, and 12 to 13 per cent as normal.

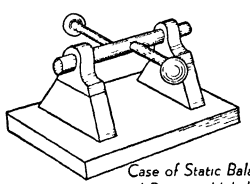
Date of Survey	Number of Samples in which Carbon Dioxide was Determined	Available Gas, Per Cent by Weight
1889	149	8 17
1908	158	10 24
1915	195	11 91

In 1917, the report stated for 185 baking powders purchased in the open market

35 samples below standard (10% carbon dioxide)	
68 alum-phosphate samples	10 78%
46 cream of tartar samples	11 01
31 acid phosphate samples	11 25
5 alum samples	12 40

(R.K.S.)

BALANCE. Mechanical balance consists of the equilibrium of masses, and can be divided into static and dynamic balance Static balance occurs in a system when the **center of gravity** of the system coincides with its reactions For example, a rotating body in static balance has its center of gravity coincident with its axis of revolution A system may, however, be in static balance, but become unbalanced when the system



Case of Static Balance and Dynamic Unbalance

rotates Such a system, for example, as that shown in the accompanying figure may well be in static balance, and satisfactorily pass a balance test which would consist of putting the shaft on absolutely horizontal parallel rails and trying the rotor for equilibrium in any position But when this system rotates, the centrifugal force of the two weights, not being in the same plane perpendicular to the axis of rotation, creates a couple acting on the shaft That couple rotates with the shaft and produces shaking forces at the journals, and vibrations in the foundation The dynamic balancing of this system would involve the addition of a system of counter balances which, by themselves, would be in static equilibrium, but which in rotation would produce a couple equal in magnitude but opposite in direction to the one already considered

Dynamic balance is especially important in high speed or heavy rotating machinery, as the vibrating forces are proportional to the mass and the square of the speed of rotation Manufacturers frequently use balancing machines for testing their product when it is especially important that it be perfectly balanced

Reciprocating balance consists of opposing the shaking forces of a reciprocating mass by equal and opposite forces obtained from another reciprocating mass One particularly difficult job of balancing occurs in a system consisting of both rotation and reciprocation, as exemplified by the **piston, connecting rod,** and **crank** mechanism The difficulty lies in the fact that if perfect balance is secured in the direction of reciprocation by the employment of rotating counter balances, severe unbalance will result in a perpendicular plane The solution of this difficulty is a compromise in which only part of the reciprocating mass is counterbalanced, thus reducing the maximum degree of unbalance, but producing a smaller unbalance in two planes

An electric network is in a condition of balance when so adjusted that an e m f. in one branch produces no current in another branch This is the case, for example, in a properly adjusted **Wheatstone bridge.**

The balance is a well-known instrument used in weighing While any type of "scales" used for weighing may properly be called a balance, the term usually refers to the equal-arm balance familiar in every laboratory

The dynamics of this instrument is relatively simple unless the pans are allowed to oscillate independently of the beam, a condition which should be carefully avoided while taking readings. The balance may then be treated as a gravity pendulum suspended from the central knife edge or pivot, the pans and their loads being regarded as concentrated at the end knife edges Any slight excess weight Δw on one pan causes a change in the equilibrium position The "sensitiveness" of the balance is appropriately expressed as the change in the equilibrium pointer reading per unit excess weight A quantity more useful in practical work is the reciprocal of the sensitiveness, which may be called the "stability" Thus if the change in pointer reading Δr is produced by a change of weight Δw on one pan, the stability is $s = \Delta w/\Delta r$ It is easily shown that unless the three knife edges are exactly in a straight line (which is seldom true), the stability not only depends upon the construction of the balance but is also a function of the load on the pans If the load on each pan is W, the stability is expressed by a linear equation,

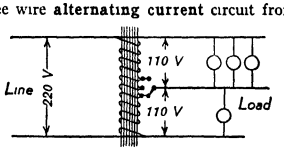
$$s = a + bW,$$

in which a and b are constants to be experimentally determined The instrumental factors affecting the stability and upon which the constants a and b depend are: length of beam, relative lengths of pointer and of scale division, distances of central knife edge above center of mass and above or below line joining end knife edges, and total weight of moving parts, exclusive of load

The pointer and scale are used in refined weighing to interpolate between the smallest weights in the set (commonly milligrams), for which purpose the value of s for the load on the pans must be known, it may be calculated from the above formula Balances usually have also a rider scale, along which a small, hairpin-shaped weight may be moved to secure equilibrium, or to secure any desired pointer reading The rider may be used in determining the stability constants a and b

The arms of a balance, supposedly equal in length, are never exactly so The result is that if the pointer stands at the zero of the scale with the pans empty, it will not do so when equal loads are placed on the two pans This defect is compensated by the method of "double weighing" See **Weighing Methods.** (F.T.M., L.D.W.)

BALANCE COIL. A balance coil is a coil for supplying a three wire **alternating current** circuit from a two



Balance Coil

wire circuit A 220 volt single phase line, for example, can be used to supply two 110 volt circuits consisting of three wires, one of which is a common intermediate wire The voltage between the intermediate wire and either of the outside ones is 110 volts If the loads on the two 110 volt circuits are unequal, the voltage can be balanced by an adjustment of the central tap point at the balance coil A balance coil is frequently an auto-**transformer** having only one coil, a certain portion of which is used for both a high and low tension winding The auto-transformer has connections at the ends of the coil, and an intermediate connection Auto-transformers are more efficient and have less copper and

iron for equivalent rating than a two-coil transformer, but should never be applied where it is desired to keep dangerous primary voltages from the secondary. (F.T.M.)

BALANOGLOSSIDA. Enteropneusta.

BALANOGLOSSUS. A genus of worm-like marine animals belonging to the lower **chordates.** The name is also commonly applied to any of the similar animals of several genera. **Enteropneusta.** (A.W.L.)

BALAS RUBY. Spinel.

BALATA. Gutta percha.

BALDNESS. Alopecia.

BALDPATE. Aves. 1. A North American **duck** *Mareca americana.* 2. A **dove** found in the West Indies. Both species are ineptly named from the white crown feathers. (A.W.L.)

BALLAST. Any material used for the purpose of providing stability is called ballast. Ballast is used in ships to bring the **center of gravity** of the vessel below a point called the **metacenter,** when there is a lack of cargo which would produce the same effect. **Balloons** and **airships** carry ballast which acts as a stabilizer and provides a means of controlling the rate of gain of rise as well as the altitude. Light vehicles which move at high speeds are often provided with ballast to lower the center of gravity and prevent overturning. Sand or water are very useful for ballast. Crushed stone which is placed under and between railroad ties to absorb impact and provide smooth riding conditions is also called ballast. (C.W.C., F.T.M.)

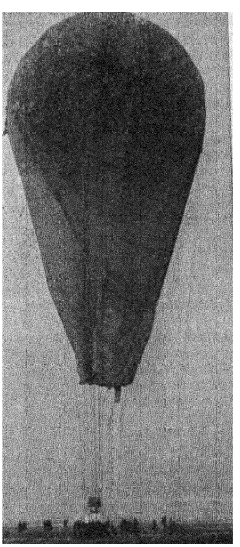
BALLISTICS. This is the science which treats of the motion of masses projected into space, especially as associated with the motion of projectiles from guns and cannon. The complete path of a projectile is comprised of three separate and distinct phases. The first occurs in the bore of the gun, and the study of projectile motion here is that of **interior ballistics.** Secondly, there is the study of the path taken by the projectile as it flies through space from the gun to the target. This is **exterior ballistics.** Then, thirdly, there is the study of the penetration and the penetrating power of a projectile, which, for want of a better term, might be called penetration ballistics.

Interior ballistics is largely interwoven with the study of **thermodynamics**—the pressure, volume, and temperature of an expanding gas during travel of the projectile in the bore. It is concerned with the amount and combustion characteristics of gunpowder. The maximum pressures, and location of the same, stresses in the barrel, and the design of the barrel to resist these stresses, may also be said to be interior ballistics. The science of exterior ballistics might be said to have been rationally developed by Newton as a by-product of his study in **gravitation.** If the effect of air on the motion of a projectile is omitted, then the trajectory is **parabolic,** since as soon as the bullet or shell leaves the muzzle of the gun, force of gravity begins to pull it towards the earth. It is therefore impossible for a bullet to travel in a straight line, and if it is to return to a target at the same elevation as the muzzle, it must have an initial upward component given by aiming the barrel somewhat above the target. If the muzzle velocity is V, and the inclination of the barrel to the horizon is i, its upward component is $V \sin i$. If the action of gravity is wholly unresisted, the time it will take to reach the top of trajectory (at which point the upward component has been reduced to zero), is the same as that required by a freely falling body to attain a velocity equal to that of the vertical component at the muzzle. Assuming a simple case where the target is at the same level above the earth's surface as the gun, it would take another equal interval of time for the projectile to move from the top of its trajectory to the target. The distance to the target would be that covered by the horizontal component $V \cos i$ in the period of time taken by the projectile in reaching the top of its trajectory, and then returning to its original level.

But the effect of air forces can not be neglected, practically speaking, and the simple equations derived from the mechanics of a freely falling body are not applicable without considerable modification. The retarding effect of air, and the effect of winds, as well as other matters, are factors which must be taken into account in modern ballastics.

There is but little known in respect to penetration ballistics, and laws which relate to the depth and character of penetration of bullets and shells into armor are not well understood. Empirical formulae are relied upon greatly at the present time in the field of ballistics. (F.T.M.)

BALLOON. The balloon is a lighter-than-air craft receiving its sustension from the **buoyancy** of the gas it contains. It is non-rigid. The shape, usually spherical, is formed by the internal pressure of the lifting gas. The lifting medium first used was air which was expanded and made lighter than the atmosphere by heat. The hot air balloon was first devised by the Montgolfiers in 1783. At the present time **hydrogen** is the principal lifting gas. Balloons may be thought of as free or captive. The captive balloon has some military use for observation, or fire control, but until recently the free balloon had little or no value other than sporting. The national and international balloon races gave impetus to this use of the free balloon, and many amazing records were hung up by sportsmen balloonists. The balloon drifts with the wind, and may be sent aloft by releasing **ballast,** or brought down by valving off the gas from the balloon. A knowledge of the science of meteorology is important in racing balloons, and there is a great deal of highly specialized knowledge required in connection with the operation of the balloon. Happy combinations of skill and weather conditions have enabled flights of more than a thousand miles to be made.



Balloon.

In recent times a new and scientific use of the free balloon has appeared. Several flights to the **stratosphere** have been made by specially built balloons. The flights of these balloons to high levels may serve to advance scientific knowledge of cosmic rays and to study atmospheric conditions in the stratosphere. To this end they may achieve some useful commercial result. The problems of stratosphere ballooning are highly specialized, and the equipment quite expensive; consequently, stratosphere ballooning is undertaken largely by societies or governmental departments. Professor Picard of Belgium was one of the pioneers in this field, and as-

cended to over 60,000 feet Whereas a racing balloon has a volume of some 80,000 cubic feet, the stratosphere balloons contain, when fully inflated, over ten times this volume This extremely large volume is necessary in order to obtain sufficient buoyancy to lift the useful load to the stratosphere, where the atmosphere itself is very thin Stratosphere ballooning is exciting, dramatic, and dangerous It has already taken its toll of human life, but has written one of the most thrilling modern chapters of the history of science

In the winter of 1933 three Russians ascended to an unofficial height of 72,000 feet Unfortunately, these intrepid men were killed during the descent, and no official mark was set In the fall of 1934 Captains Stevens and Anderson and Major Kepner, of the United States, had a narrow escape from death Having ascended to nearly 60,000 feet, they were in the process of a normal descent when their balloon split at 5000 feet Fortunately, all men parachuted safely to the ground, although the last man to leave was perilously low before clearing the gondola, which plummeted to the ground, destroying most of the scientific instruments carried However, in November, 1935, Captains Stevens and Anderson again ascended, and this time to a new world's record Leaving the ground at 7 A M , they climbed to 73,000 feet in four hours, and obtained a great deal of scientific information on stratosphere photography, radio transmission, spore distribution, and air composition Cosmic rays and the spectral distribution of sunlight were also studied during the hour or more that the stratosphere balloon (now being called stratostat) remained at the record height During much of the remainder of the day the crew was busy governing the descent until the balloon was once again safely on the ground In this case all instruments were intact and records were safely preserved To give an idea of the construction of a stratostat, the Explorer II used by Captains Stevens and Anderson had a volume of 3,700,000 cubic feet fully extended, and this was used to lift a tiny globe-shaped gondola made of monel metal, just large enough to contain the two observers and their equipment The globular shape is used because it must be sealed and made air-tight so that life will be possible in the stratosphere where the normal atmosphere would be almost instantly fatal The globe is the best shape for resisting the bursting pressure of the air contained within At the start of the ascent some 250,000 cubic feet of **helium** were put into the Explorer II, and as it ascended the bag filled out as the air pressure outside grew less (F T M)

BALSA WOOD. *Ochroma Lagopus* Bombacaceae Balsa wood is obtained from a South American tree, *Ochroma Lagopus* This wood is composed largely of wood **parenchyma**, a tissue characterized by thin-walled cells Balsa wood is almost colorless and very light, having a specific gravity of 0 2, which is less than that of cork The light porous nature of this wood leads to its use in life-preservers and floats, as an **insulating** material, and in the construction of special furniture (R M W)

BALSAM. Resins.

BAMBOO. Gramineae The tribe *Bambusae* comprises grasses which are particularly important in Oriental countries The plants included in this group are of extremely variable nature, ranging from small inconspicuous species to the largest species of grass known, some having slender erect stems approaching a hundred feet in height. Many are clambering vines which form dense impenetrable masses All these grasses are characterized by jointed hollow stems having solid nodes, familiar to western people in the common bamboo fish pole or the fairly rare broomstick Among the Eastern peoples, bamboo is much more commonly used The hollow stems may serve as pipes for conducting water, or as containers for storing water and other substances. Split stems may be flattened and used in constructing shelters, or boats, or furniture Some species yield a fibrous material which is used to manufacture a kind of paper The young stalks of certain species become an important foodstuff Indeed, in some regions the people have come to depend almost entirely on bamboo, so numerous are its uses (R M W)

BAMBOO RAT. Mammalia, Rodentia Any member of several species of burrowing **rodents** of the Oriental and Malayan region, related to the mole rats but with the small eyes exposed and with a short tail (A W L)

BANANA. *Musa paradisiaca* Musaceae The banana plant is a striking tropical plant found wild in the Old World tropics About thirty species are known The plant has a thick underground **rhizome** from which rises what seems to be a thick erect stem Actually this false stem is formed by the leaf bases which grow wrapped together to a height of ten feet From the upper portion, the large leaf blades spread out conspicuously, sometimes to a length of ten feet Up through the center of the tube formed by the leaf bases the flower stem pushes its way and bears bunches of inconspicuous small tubular flowers in the axes of large showy **bracts** After fertilization of the flowers, the bracts fall off, and the whole cluster gradually hangs over due to the weight of the developing fruit When green the banana fruit contains an abundance of starch, which changes to sugar as the fruit ripens The banana was introduced at an early period into the New World tropics, where it has now become one of the most valuable crops The banana is related to the **plantain.** (R M W)

BANANA-QUIT Honey creeper.

BAND OF FREQUENCIES A radio signal sent out as a wave of a certain frequency can be distorted by interference with another wave of a slightly different frequency For this reason it is necessary to assign a band of frequencies, or a channel of a certain band width, to specific transmitting service Wireless **telegraphy** can be sent on a very narrow band of frequencies Program broadcasting requires a fairly broad band, while **television** is said to require quite a wide band of frequencies The band of frequencies included in a channel must be sufficient to guard against the mutual interference of two stations and allow for the tolerance that is permitted in frequency stability Since there is an upper and lower limit of usable frequencies, there must be some control over channeling, because there are so many program broadcasting stations in addition to the wireless telephone, and telegraph services In the United States the Federal Radio Commission has the authority to allocate frequency and has worked out the system of broadcast channels which is in present use (F T M)

BAND SPECTRUM. Molecular Spectrum.

BANDED ANTEATER. Dasyure.

BANDICOOT. Mammalia, Marsupialia Medium or small burrowing animals of the Australian region, related to the kangaroos but stoutly built and quadrupedal There are several species of the genus *Perameles.* (A W L)

BANKET. A Dutch term originally applied to the gold-bearing **conglomerates** of the Witwatersrand, South Africa (R M F)

BANTAM. Aves, Galliformes A small variety of the domestic fowl Sebright bantams, the best-known breed, are characterized by the similarity of the sexes (A W.L)

BANTING. Mammalia, Artiodactyla The Javan **ox,** *Bibos sondaicus,* a species which also occurs in other East Indian islands and in India and the Malay Peninsula.

Domesticated herds are kept in part of its range (A W L)

BANYAN. *Ficus benghalensis* Moraceae The banyan trees of India, sacred to the natives of that country, are of interest because of their habit of sending down from the spreading branches aerial roots, which enter the ground and increase in size until they resemble trunks A single tree may have scores or, exceptionally, even hundreds, of these trunks, which enable it to spread out over a tremendous area It has been stated that Alexander and his army of men took shelter under a single extensive banyan tree (R M W)

BARABOO. A baraboo is a hill, mountain or other eminence which was once buried by the deposition of **sedimentary** material about it and has since been exposed by the erosion of the younger beds It is named from Baraboo, Wisconsin (E S C S)

BARB. One of the divisions of a **feather** which branch from the shaft to form the vane (A W L)

BARBASTELLE. Mammalia, Chiroptera A small European **bat** related to the California cave bat and to a few African and Asiatic species Only one of the related species, the Himalayan barbastelle, receives the same name (A W L)

BARBEL. 1 Pisces, Teleostei *Barbus* Any of numerous species of fishes (**Pisces**) of the Old World, related to the carps 2 A form of slender appendage found on the head in certain fishes and turtles, well illustrated by the **catfishes** (A W I)

BARBERRY. Berberidacae The barberries are shrubby plants growing wild in the northern hemisphere, and also in South America Many of them are spiny plants which are often cultivated as hedge plants Examination shows that the leaves may vary from entire spiny-toothed structures to those reduced entirely to spines, only their position on the stem revealing the fact that they are leaves The plants bear **racemes** of yellow flowers and later small red, yellow or black berries which make them very attractive **Pollination** in barberries is rather interesting Each of the six stamens (See **Flower**) has a spot at the base of the filament sensitive to touch When an insect, pushing about the base of the flower in search of nectar, touches this spot, the stamen moves violently, so that the sides of the insect's head are powdered with pollen When the insect visits another flower some of this pollen may be caught by the stigma, pollination then being completed

Considerable importance attaches to barberries because of the connection they have with the disease caused by wheat **rust**, *Puccinia graminis* (R M W)

BARBET. Aves, Piciformes Birds (**Aves**) of several species intermediate between the **woodpeckers** and **toucans** They occur in the tropical regions of both Old and New Worlds and some species are brilliantly colored The name was formerly applied to other members of the order found in tropical South America which are now known as puff-birds (A W L)

BARCHAN. **Dune.**

BARITE. The mineral barite is **barium sulfate**, $BaSO_4$, crystallizing in the **orthorhombic system** May occur as tabular crystals, in groups, or lamellar, fibrous and massive Barite has two perfect cleavages, basal and prismatic, hardness, 2 5–3 5, specific gravity, 4 3 to 4 6, which has led to the term heavy spar, occasionally used for this mineral Its luster is vitreous, streak, white, color, white to gray, yellowish, blue, red and brown, transparent to opaque Sometimes yields a fetid odor when broken or when pieces are rubbed together, due probably to the inclusion of carbonaceous matter Barite is a frequently occurring gangue mineral and is found also in large masses in **sedimentary** rocks Its name, barite, is derived from the Greek word meaning heavy It is used as a source of barium compounds

Barite localities are widespread, including many European occurrences, Czechoslovakia, Germany, France, Spain and England In the United States barite is found in New York, Connecticut, Pennsylvania, Virginia, Michigan, Missouri, New Mexico, Oklahoma, Utah, Colorado and South Dakota In Canada it occurs in Ontario and in Nova Scotia (E S C S)

BARIUM. Symbol Ba Atomic number 56 Atomic weight 137 36 Density 3 5 Melting point· 850° C Boiling point 1140° C (**Isotopes:** page 238)

Barium is a silver-white metal, harder than lead, oxidizes rapidly in moist air, reacts with water yielding barium hydroxide and hydrogen gas, burns when heated in air emitting a brilliant light and forming barium peroxide Discovered by Scheele in 1774 and isolated by Davy in 1808

Barium occurs chiefly as sulfate (**barite**, barytes, heavy spar, $BaSO_4$), and, of less importance, carbonate (**witherite**, $BaCO_3$) Georgia and Missouri are the principal producing states The sulfate is transformed into chloride, and the electrolysis of the fused chloride yields barium metal Barium metal has been recently used as a "getter" in radio tubes, and as a nickel-barium alloy in automobile ignition systems

Acetate barium acetate ($Ba(C_2H_3O_2)_2$), white crystals, soluble, by reaction of barium carbonate or hydroxide and **acetic acid**, and then crystallizing

Carbide barium carbide (BaC_2), black solid, by reaction of barium oxide and **carbon** at **electric furnace** temperatures, decomposes water yielding **acetylene** gas and barium hydroxide

Carbonates barium carbonate ($BaCO_3$), white solid, insoluble, (1) by reaction of barium salt solution and **sodium** carbonate or bicarbonate solution, (2) by reaction of barium hydroxide solution and **carbon dioxide**, decomposes at about 1300° C to form barium bicarbonate ($Ba(HCO_3)_2$), solution, by excess carbon dioxide and barium hydroxide solution

Chloride barium chloride ($BaCl_2\ 2H_2O$), white crystals, soluble, by reaction of barium carbonate or hydroxide and **hydrochloric acid**, and then crystallizing

Chromate barium chromate ($BaCrO_4$), yellow precipitate, by reaction of barium salt solution and **potassium** chromate solution

Cyanamide barium cyanamide ($BaCN_2$) mixed with **cyanide** ($Ba(CN)_2$), by heating barium carbide at 800° C with nitrogen gas Fusion of this cyanamide-cyanide mixture with sodium carbonate converts entirely to cyanide

Hydride barium hydride (BaH_2), white solid, by heating barium metal or amalgam in **hydrogen** gas at 1170° C, reactive with water yielding barium hydroxide and hydrogen gas

Hydroxide barium hydroxide ($Ba(OH)_2$), white solid, (1) by reaction of barium oxide and water, (2) by precipitation of barium salt solution with **sodium** hydroxide solution, yields ($Ba(OH)_2\ 8H_2O$) on crystallizing, decomposes upon heating at about 850° C to form oxide (BaO) and water

Nitrate barium nitrate ($Ba(NO_3)_2$), white crystals, soluble, by reaction of barium carbonate or hydroxide and **nitric acid**, and then crystallizing, used in pyrotechnics for the production of green light

Oxides barium oxide (BaO), white solid, melting point about 1900° C, reactive with water to form barium hydroxide, barium peroxide ($BaO_2\ 8H_2O$), white precipitate, by reaction of barium salt solution and hydrogen or sodium peroxide, yields anhydrous barium peroxide (BaO_2) upon heating at 100° C in a current of dry air Anhydrous barium peroxide is also formed by heating barium oxide in air or **oxygen** under pressure (at somewhat over one atmosphere pressure) and temperature of

400° C. there is transformed into peroxide with air 70%, with oxygen 95%, of the total barium oxide taken. This reaction was applied in the Brin process for separation of oxygen from air, first forming the peroxide, and later heating the same to a higher temperature when oxygen was evolved and barium oxide remained for use again.

Oxalate: barium oxalate (BaC_2O_4), white precipitate, by reaction of barium salt solution and ammonium **oxalate** solution.

Sulfate: barium sulfate ($BaSO_4$), white precipitate, by reaction of barium salt solution and **sulfuric acid** or **sodium** sulfate solution, insoluble in acids, by heating with carbon yields barium carbonate. Present in a mixture with zinc sulfide, known as lithopone, a paint pigment, formed by the reaction of barium sulfide and zinc sulfate in water, followed by filtration and drying. The mineral barite when powdered is used as a paint pigment, as a filler for rubber goods, paper, and linoleum, only source of all barium containing substances.

Sulfides: barium sulfide (BaS), grayish-white solid, by heating barium sulfate and **carbon**, reactive with water to form barium hydrosulfide solution; barium hydrosulfide ($Ba(SH)_2$), solution, (1) by reaction of barium sulfide and water, (2) by saturation of barium by hydroxide solution with **hydrogen sulfide**; barium polysulfides are formed by boiling barium hydrosulfide with **sulfur**.

Volatile compounds of barium, such as the chloride, color the bunsen flame green. (R.K.S.)

BARK. All tissues of stem or root which occur outside the **cambium** are collectively known as bark. In the earliest stages of its development, the **stem** is covered by a layer of thin epidermal cells, which may persist for some time. With increased age and growth, however, this epidermal layer is lost, and a new tissue is formed, either from the epidermal cells or from those cortical **cells** just beneath the epidermis. The cells which form this new protective layer are the periderm cells. The tissue which is formed by them is often called the outer bark. If the divisions of the periderm cells occur fast enough the bark will remain smooth for some time. In most cases, however, an internal periderm forms in the deeper cortical tissues, and by its development in isolated patches leads to the development of scales or patches of bark, with ever deepening fissures as growth continues. In a few cases, as in the beech tree, the smooth condition persists throughout the life of the tree. In all young stems the continuity of the surface is broken by patches of loose cells, the lenticels, which permit an exchange of gases through the bark. (R.M.W.)

BARK BEETLE. Insecta, Coleoptera. A small **beetle** of cylindrical form which burrows in the sapwood and inner bark of trees and logs, forming characteristic patterns. This habit also gives the name engraver beetle to these insects. Most of the numerous species infest forest trees but a few attack fruit trees. Together with the timber beetles and a few species which attack herbaceous plants they make up the family Scolytidae. (A.W.L.)

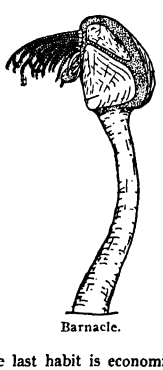
BARK LOUSE. Insecta, Homoptera. A scale **insect.** These insects are minute creatures with sucking mouths. They spend most of their lives attached to the leaves, stems, or roots of plants. The name scale insect is due to the common secretion of a scale which conceals the body of the insect. There are many species, of which some, like the oyster-shell bark louse, *Lepidosaphes ulmi*, and the San Jose scale, *Comstockaspis perniciosa*, are important enemies of fruit trees. Spraying with lime-sulphur and kerosene emulsion is a common method of control and fumigation with hydrocyanic acid gas is extensively practiced in the citrus groves of California. Sprays can be used more effectively when trees are dormant in winter.

Some scale insects produce substances of commercial value, notably cochineal and shellac. (A.W.L.)

BARKHAUSEN EFFECT. A series of minute "jumps" in the magnetization of iron or other ferromagnetic substance as the magnetizing force is continuously increased or decreased; discovered by H. Barkhausen in 1919. The effect may be observed by winding on the specimen, along with the magnetizing coil, a secondary coil connected to some delicate detector of current fluctuations, such as an **oscillograph** or a telephone receiver. As the magnetizing current is steadily increased, the current in the secondary circuit, instead of being constant, exhibits a succession of small, sharp peaks or maxima, which the telephone reveals by a faint clicking or snapping sound. These discontinuities in magnetization are interpreted as indicating the existence in the ferromagnetic material of elementary magnets, called "domains," which are much larger than atoms, but not large enough to be identified with individual crystals. Another possible interpretation is that the discontinuities are caused by the accidental coincidence of orientations in elementary magnets of much smaller size, somewhat as the **Brownian movement** of a particle is caused by the accidental impact of many molecules upon it simultaneously. (L.D.W.)

BARLEY. *Hordeum vulgare* and *H. distichon.* Gramineae. Barley is a cereal **grass** with stalks up to three feet in height, and with the inflorescence a close spike. Many varieties are grown in cultivation, all probably derived from plants growing native in Asia. In the older varieties the flower possessed stout barbed **awns**, which were very disagreeable to those who handled the grain, and often the cause of serious trouble when the grain was fed to livestock. In the newer varieties, originating in Russia and widely cultivated and improved in the United States, these awns have been lost, leaving a smooth-fruited variety. In the mature barley grain the **aleurone** layer is usually three cells in thickness; the **embryo** is very small; and there is no **gluten.**

Primitive man in Europe used barley for food, as do many modern races. However, lacking gluten, it is impossible to make light bread from barley, a fact which prevents it from being popular with cultured races. It is frequently used in soups, and in the manufacture of breakfast cereals. Large quantities of the smooth grain are used as stock food. Its principal use, however, is in the manufacture of malt. For this purpose the grain is first soaked in water for two days or more at a temperature of about 55° F., with frequent changes of water to prevent excessive development of **bacteria.** The soaked grain is then spread out on the floor for twelve days, during which time **fermentation** occurs and germination starts. **Enzyme** action causes the starch (See **Carbohydrates**) of the grain to change to sugar. Before germination has led to a well-developed **coleoptile,** the grain is heated to stop growth and to drive off excessive moisture, which is reduced to about 2%. The sprouts are then removed and the malt, a pasty mass rich in starch and the enzyme diastase, is ready for use, principally in the manufacture of beer. (R.M.W.)


Barnacle.

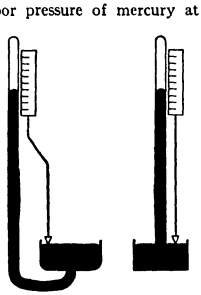
BARNACLE. Crustacea, Cirripedia. **Sessile** marine animals wholly unlike the more common **crustaceans** in appearance. Some are parasitic, some burrow in the shells of marine animals, and some attach themselves to submerged objects. The last habit is economically important since it results in the fouling of

ships' bottoms and entails the expense of periodical cleaning (A W L)

BARNETT EFFECT. In 1915, S J Barnett discovered that a relatively long iron cylinder, when rotated at high speed about its longitudinal axis, developed a slight magnetization, the value of which was proportional to the angular speed He found the magnetization to be about 1.5×10^{-9} c g s electromagnetic unit per revolution per second for a cylinder about 7 centimeters in diameter and 50 centimeters long The effect was attributed to the influence of the impressed rotation upon the revolving electronic systems within the atoms The suggestion has been made that the magnetic moment of the earth and of the sun may be due in part to the rotation of these bodies An inverse effect was discovered about the same time by Einstein and de Haas, viz, an iron cylinder, suspended vertically, was observed to rotate slightly when suddenly magnetized (L D W)

BAROGRAPH. A recording **barometer**, commonly of the aneroid type The pressure-sensitive unit consists of a pile of several elastic-walled evacuated boxes, connected through a suitable linkage to the stylus-arm, which carries the pen up and down on a slowly revolving drum The variations of atmospheric pressure are thus traced on the paper, usually ruled in days and hours for the period of one week Such instruments are extensively used by the U S Weather Bureau at its many observation stations (L D W)

BAROMETER The barometer owes its origin to Torricelli, who, in 1643, first utilized a column of water to measure the atmospheric pressure and its variations The obvious disadvantages of a barometer tube 34 feet long, with water vapor pressure above the liquid, soon brought about the substitution of mercury This reduces the necessary length of the instrument to about 3 feet over all, and the vapor pressure of mercury at ordinary temperatures is negligible To set up a mercurial barometer, one needs only to fill a clean glass tube, closed at one end, with pure mercury, heat it to boiling to expel air, and invert it in a small cup of freshly boiled mercury At normal pressures the column will sink to about 76 centimeters, leaving a "Torricellian vacuum" above it The scale must be made adjustable so that its zero may always coincide with the surface of the mercury in the cup In some barometers the mercury is contained in a leather bag tied to the lower end of a short glass cylinder, making it possible to raise or lower the mercury level by a screw compressing the bag The readings must of course be corrected for variations of temperature



Two types of mercurial barometer (diagrammatic)

The aneroid barometer is merely a delicate pressure gauge, consisting essentially of a round, flat, air-tight, evacuated metal box, with elastic bases which respond to variations in pressure by springing in and out, and the movements of which are communicated to a pointer on a graduated dial Such barometers are portable and quite sensitive, and are much used on shipboard, in airplanes, by engineers, etc (L D W)

BARRACUDA. Pisces, Teleostei Vicious marine fishes (**Pisces**) of several species, found in coastal waters of temperate and tropical seas They are said to be a more probable source of danger to bathers than the **sharks**; since many of them attain a length of six or more feet they are undoubtedly capable of inflicting severe injury

The flesh is excellent and the fishes are caught both for sport and for the market

The name barracuda is also applied to a New Zealand fish of the same order but of a different family (A W L)

BARRIER BEACH A recently emerged coast (like the present Atlantic Coastal Plain) with shallow water extending for some distance from the shore will lend itself to the formation of barrier beaches Waves tend to stir up the bottom materials of sand and gravel to be redistributed which gradually build up a low ridge parallel to the coast Such barrier beaches are also known as offshore bars and the quiet body of shallow water between the bar and the mainland is called a lagoon (E S C S)

BARYCENTRIC PARALLAX. Barycentric parallax is a term given to a slight oscillatory motion of the **earth** The **center of gravity** of the earth-moon system revolves about the sun in an orbit that is usually referred to as the orbit of the earth Both the earth and **moon** are revolving about this center of gravity of the system as it in turn revolves about the sun At the time of **conjunction** of the moon with the sun the moon is inside of the orbit of the system about the sun and the center of the earth is outside At opposition this condition is reversed and the center of the earth is on the inside Hence, the center of the earth oscillates slightly back and forth across the orbit with a period of one **synodic** month This slight oscillatory motion of the earth is known as barycentric parallax

Accurate measurements of barycentric parallax provide a method for the determination of the relative masses of the earth and the moon In accordance with the principles of mechanical equilibrium the distances of the center of gravity of the earth-moon system from the centers of mass of the two individual objects are inversely proportional to the masses of the objects Hence, if we can determine the distance of this center of mass of the system from the centers of the earth and moon we can at once determine the relative masses of the two objects Accurate measurements of barycentric parallax determine the position of the center of mass of the earth-moon system as 2880 miles from the center of the earth Since this is about 1/82 5 of the distance of the moon from the earth, we find that the mass of the moon should be 1/81 5 the mass of the earth (W K G)

BARYE The barye, or bar as sometimes written, is the c g s absolute unit of pressure, equal to one dyne per square centimeter It is of course a very small unit, one atmosphere (760 millimeters of mercury) being equal to about 1,013,200 baryes Hence the megabarye or megabar, i e, 1,000,000 baryes, is often more convenient Some confusion exists in the use of these terms, some authors using "barye" to designate 1,000,000 dynes per square centimeter and "microbarye" as synonymous with the barye above defined Still more unfortunate is the term "barie," defined as 750 millimeters of mercury, and hence very nearly equal to 1,000,000 dynes per square centimeter, though fixed on an altogether different basis (L D W)

BARYSPHERE. Lithosphere.

BARYTES. Barite.

BARYTOCALCITE. This mineral is a **carbonate** of **barium** and **calcium** which crystallizes in the **monoclinic system** but occurs massive as well It has a perfect cleavage parallel to the prism and one, less perfect, parallel to the base, fracture, sub-conchoidal, brittle, hardness, 4, specific gravity, 3 64–3 66, luster, vitreous, color, white or gray or may be greenish or yellowish; transparent to translucent Barytocalcite is found in Cum-

berland, England, associated with **barite** and **fluorite.** (E.S.C.S.)

BASAL CONGLOMERATE. A conglomerate that lies on, or occurs just above, a plane of erosion or **unconformity.** Such a conglomerate constitutes the first **sedimentary** stage in a normal cycle of sedimentation. (R.M.F.)

BASAL METABOLISM. Metabolism.

BASALT. A fine-grained to dense, sometimes **porphyritic,** intrusive extrusive **igneous rock,** black or greenish black in color, characterized by a preponderance of calcic **plagioclase feldspars** and **pyroxene** together with minor amounts of accessory minerals such as **olivine.** Glass may be present. Amygdaloidal structure is common in such cavities are frequently found beautifully crystallized species of **zeolites, quartz** or **calcite.**

The lava flows of the Plateau of the Deccan in India, the Columbia Plateau of Washington and Oregon States, as well as the Triassic lavas of eastern North America are basalts. Perhaps the most famous basalt flow in the world is the Giants Causeway on the northern coast of Ireland, in which the vertical joints give the impression of having been artificially constructed. Pliny used the word basalt and it is said to have had an Ethiopian origin, meaning a black stone. (E.S.C.S.)

BASANITE. Tephrite.

BASE. See individual bases under each metal; also **Acids, Bases and Salts.**

BASE LEVEL. The ultimate physiographic feature of the processes of **denudation** is the reduction of the land surface to sea level, because it is at this level that the processes of river **erosion** are completely checked. As sea level is the datum plane below which stream erosion is impossible this may be taken as the theoretical lower limit of stream erosion and the level to which all the land surfaces must be brought if no other forces intervene. Actually, however, base level seems to be a limit which, however closely approached, may not in reality ever be reached. Therefore a broader use of the term base level is frequently made, base level being the lowest level to which a given stream can cut. A stream flowing into a body of water at an elevation above the ultimate datum, sea level, is said to be at a temporary base level. In any case when a stream has cut its channel to such a degree that it has just enough velocity to carry its load without further erosion being possible, it is then said to be at grade. Local or temporary base levels of relatively small area may be developed without reference to sea level. In this sense the term base level is not entirely comparable to the term **peneplain.** (E.S.C.S.)

BASE LINE. Base line is a **surveying** term employed to describe an accurately measured horizontal distance which is obtained by the use of a graduated steel or invar tape (See **Chain**). The purpose of this measurement is to establish definitely the distance between two points called stations, from which to proceed with the instrument surveying. The base line should, if possible, be located where the terrain intervening between its ends is fairly level so that the measurements may be simply yet accurately made. The purpose of a base line determines the degree of precision which is to be used in the measurements of this line. The base line, laid out along the bank of a river in order to determine the width of the river by instrument sights taken from each end to a fixed point on the other bank, would not need to be as accurate as that for first order **triangulation** of the character needed in Coast and Geodetic surveying. The latter requires the use of a special tape standardized under certain conditions and made of invar, which has a very low coefficient of temperature expansion. When used in base line measurements for first order work the tape must be supported at intervals so as to eliminate, as far as possible, the effect of sag. Spring balances are required to reproduce the tension under which the tape was standardized. Thermometers are employed to record the temperature so that correction may be made for the thermal changes.

Another meaning of base line is connected with the methods of public **land subdivision** used principally in the western part of the United States. The primary unit of subdivision is the township, which is subdivided into sections. These units are referred to a pair of principal axes which have their origin at the intersection of a true **meridian** called the principal meridian, and the true parallel of **latitude** called the base line. (F.T.M.)

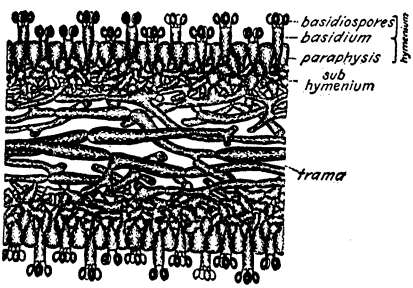
BASEDOW'S DISEASE. Thyroid Gland.

BASEMENT MEMBRANE. Epithelium.

BASIC ROCK. A term applied to **igneous rocks** whose content of silica is less than about 52%. It is not an exact term and is gradually going out of use. It may be convenient for field use. (E.S.C.S.)

BASIDIOMYCETES. Nearly all the **fungi** commonly observed belong to this group, which includes toadstools, mushrooms, puff-balls, and many other forms. The characteristic feature which distinguishes them from other fungi is the basidium, typically a club-shaped structure bearing four **spores** at its apex. Members of this group are found wherever plant life can exist. The majority of them are **saprophytes,** living on dead wood and soil rich in humus; a few are parasites. The life-history of the common mushroom, one of the best known and most important, is fairly typical of the group.

The vegetative phase consists of a mycelium. This is a mass of slender much-branched threads, called hyphae, which grow throughout the substratum. The mycelium



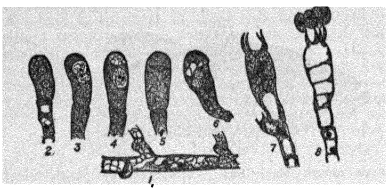
A section through the gill of a mushroom. *Coprinus Comatus.* Section cut perpendicular to the surface of the gill. (From Buller's *Researches on Fungi,* Longmans Green & Co.)

is perennial. Each hypha is a long filament composed of many segments, each containing two nuclei. The hyphae absorb from the substrate the organic materials which the fungus needs in order to live, and convert it into other forms. Much of this food substance accumulates within the mycelium.

When sufficient material has been stored and conditions are suitable the fungus fruits. The fruit body first appears as a small round object rising from the substratum. At first a thin membrane completely envelops the fruit body. When the latter elongates, the membrane is broken, revealing the elongating stalk bearing at its tip an umbrella-shaped cap or pileus. Remnants of the broken membrane sometimes remain on the surface of the pileus or around its edge. Part of the membrane often remains at the base of the stalk, forming a cup-like volva. In some species of mushrooms the membrane is double. The inner portion, when broken, forms

a ring, called the annulus, around the stalk. Both volva and annulus are found in many mushrooms; others have only one of them; in many no trace of either structure appears.

On the lower surface of the pileus there are numerous thin radiating plates called gills. The lateral surfaces of the gills are formed by hyphal tips which grow perpendicular to the surface and form a compact layer called the hymenium. The hyphal tips composing the hymenium are the basidia, the reproductive structures which



Development of basidium and formation of spores in mushroom. 1, Septate mycelius with binucleate cells; 2, Young basidium containing two unrelated nuclei; 3, 4, Fusion of nuclei in basidium; 5, 7, Development of fournucleate condition in basidium; 8, Formation of basidiospores that receive the four nuclei. (Redrawn from Harper.)

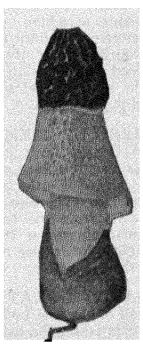
distinguish this group of fungi from all others. Each basidium is a cylindrical binucleate (See **Nucleus**) body cut off from the tip of a hypha. The two nuclei fuse and immediately divide, usually twice, so that the basidium contains four nuclei. From the outer end of the basidium four slender pegs called sterigmata develop. A small **spore** forms at the tip of each sterigma. Into each spore one of the nuclei of the basidium migrates. The spore is discharged from the sterigma and falls down between the gills and into the air. It is carried about by air currents and eventually falls to the ground. There the spore germinates, giving rise to a slender branching mycelium composed of uninucleate segments. This is the primary mycelium. Branches of two primary mycelia unite to form a secondary mycelium. The two nuclei present in each segment of a secondary mycelium have come from different spores. The manner in which they continue their identity during division is interesting. The two nuclei divide simultaneously. When division is about to occur a small bulge forms on the side of the hypha. One of the two nuclei enters this bulge, the other remains in the hypha. After division a cross wall forms, separating the two nuclei in the hypha. The protuberance containing the other nucleus continues to grow and forms an elbow-shaped structure, which joins the two cells of the hypha. It is called a clamp connection. One of the nuclei formed in this clamp returns to the original cell, the other passes through the clamp and into the other cell. By this means the two cells each receive a nucleus derived from one of the original nuclei. Nuclear fusion occurs only in the basidium. So there is in the mushroom an **alternation of generations** differing from that in most plants. The haploid or gametophyte phase consists of the primary mycelia. Following this a prolonged binucleate or dicaryon phase exists. Only in the basidium does nuclear fusion occur and reduction immediately follows. So the diploid phase or sporophyte is represented only by the basidium. There are no sex organs in this group of plants. The differences between the edible mushroom and other basidiomycetes is mainly in the structure of the fruit body, the location of the hymenium and the nature of the basidia.

The nature of the hymenium is the basis for classifying basidiomycetes. The Hymenomycetes are those in which the hymenium is exposed; in the Gasteromycetes it is formed within the fruit body. The principal order of Hymenomycetes is the Agaricales or **agarics**, or the gill fungi. These are commonly described as mushrooms and toadstools. While popular conception gives to these two terms very exact meanings, actually the terms are confusing and of little value. A common distinction is that a mushroom is edible and a toadstool poisonous. The question is then how to distinguish a harmless fungus from one that is poisonous. To eat them is perhaps a certain but not a safe way. There are many definitions which aim to establish ways of distinguishing the noxious forms, based on the presence of volva and annulus, and other features. These do not always hold true. The only safe way is to learn to identify with certainty any fungus to be eaten and to reject all that are not known.

Another well-known order of basidiomycetes is the Polyporales; of these the polypores or Polyporaceae are best known. The distinguishing feature of these are the pits or tubes on the lower surface of the fruit body. The hymenium lines these pits. The fruit bodies of the polypores usually do not have a stalk and pileus, but form a layer spreading over the surface of rotting wood or grow out from the wood like a shelf. This shelf-like habit has given to these plants the name bracket-fungi. The fruit bodies of bracket-fungi live for many years and often show distinct growth layers. In some species these are a foot or more across and several inches thick.

The other large group of basidiomycetes is the Gasteromycetes, distinguished by having the hymenium lining irregular cavities in the fruit body. Until these are fully mature, the spore-bearing parts are completely enclosed by sterile tissue. There are many different kinds of Gasteromycetes. One of the best known is the puffballs, or Lycoperdiales. The outer wall or peridium of the puff-ball surrounds the gleba or spore-bearing tissues. When the spores are mature the peridium breaks. In some genera the wall breaks up into irregular fragments and leaves the spore-mass exposed; in others a pore is formed at the apex of the fruit body. The slightest pressure against the peridium will cause clouds of spores to puff from the pore. The number of spores formed in a single puff-ball is tremendous; 7,000,000 has been given as the number from a good-sized sporophore. Some of the puff-balls are the largest fungi known, reaching a diameter of a foot or more. If gathered before the spores are formed, most of the puff-balls are edible. None are poisonous.

Geasters or earth-stars develop very much as puff-balls do. But when they are mature the outer peridium splits into sectors which bend outward, revealing the spore-bearing part within. These fungi are frequently found growing on dry sandy soil.



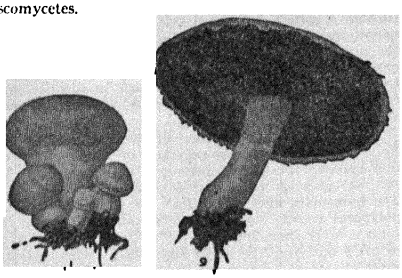
Dictyophora duplicata, Stinkhorn, a fleshy Basidiomycetes.

Another group of Gasteromycetes includes the Bird's-nest fungi. The spore-bearing structures here are the "eggs," small oval bodies resting in the bottom of an open cup of sterile tissue. A last and curious group of Gasteromycetes is the stinkhorns, vile-smelling fungi whose spores are included in a mass of sticky stinking tissue, formed by the disintegrated glebal substance. This attracts carrion flies and other insects, which carry the spores about.

Other important families of basidiomycetes are the **Rusts** and the **Smuts.**

There are several theories as to the origin of the basidiomycetes. Some maintain that they have evolved directly from certain primitive **flagellates**. Others derive them from the red **algae**. Many consider them to have descended from the **ascomycetes**. Adherents to this theory observe the dicaryon phase of the ascogenous hypha of the ascomycete and note that if this phase were prolonged for some time it would be very similar

to the secondary mycelium of the basidiomycete. They also note that asexual reproduction by conidia occurs in the basidiomycetes very much as it does in the ascomycetes.



Agaricus campestris. The first figure shows the cultivated variety; the second, the wild form (From Farlow's Icones Farlow Herbarium, Harvard University).

The basidiomycetes include many important plants. Many are much sought as food. A few, and especially the field mushroom, *Agaricus campestris,* are extensively cultivated. This cultivation is commonly carried on in caves or cellars, where the requisite moisture conditions may be maintained and where sudden fluctuations in temperature are not so apt to occur. The mushrooms are grown in beds. A mushroom bed is composed of a mixture of well-rotted manure, straw and other vegetable matter and earth. This mixture is allowed to stand for some time until heating has ceased and the temperature is constant. Then bits of mushroom spawn are buried in the mass. Mushroom spawn is a dense mass of healthy mycelium growing in a suitable substrate. The spawn grows rapidly and penetrates all parts of the bed. After about three weeks, fruiting begins, the young sporophores pushing up from the surface of the bed. They are gathered in the early stages of their development and kept in cool airy rooms until marketed.

Many basidiomycetes are serious disease-producing plants, attacking trees particularly. Often their presence is unnoticed until too late; the mycelium has permeated the tissues of the host. Other basidiomycetes attack dead plants, reducing them to simpler forms. These are the basidiomycetes which cause decay. They are saprophytes. (R.M.W.)

BASILAR MEMBRANE. A membranous partition in the auditory chamber (cochlea) of the inner **ear** forming the floor of the cochlear duct. Upon it lies the organ of Corti, which contains the sensory cells for hearing. The basilar membrane increases in width as it passes from the base of the cochlea towards the apex, thus influencing the character of the vibrations with which the basilar membrane responds to sounds of different frequency. (A.W.L.)

BASILAR PLATE. A plate derived from the ventral wall of the first body segment in millipedes (**Xiphosura**) which forms the most posterior component of the mouth parts. (A.W.L.)

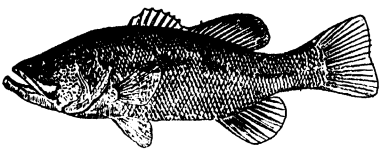
BASILISK. Reptilia, Sauria. *Basiliscus.* A large tropical American **lizard** with crests on the back and tail which resemble the fins of fishes. Four species are known. (A.W.L.)

BASIN. In structural geology, a special type of folded structure in which the strata **dip** in toward a central point from all directions. As exposed at the surface the ground plan of a basin may be roughly circular or elliptical. Type locality, the Paris Basin, France. (R.M.F.)

BASIPODITE. Biramous appendage.

BASOMMATOPHORA. An order of fresh water **snails** with eyes located at the bases of the **tentacles.** (A.W.L.)

BASS. Pisces, Teleostei. A term so loosely applied that no specific definition can be given. The small-mouthed and large-mouthed black bass, Kentucky bass, and warmouth bass are highly valued North American fresh water game and pan fishes. The white bass and yellow bass, also found in fresh water in North America, are members of another family which includes mostly



Large mouth black bass. *(Courtesy of Slingerland-Comstock Publishing Co.)*

marine species known as sea bass. These are also valuable for food and some species are excellent game fishes. Among the marine species the striped bass is important as a game fish on the Atlantic coast and the black sea-bass or jewfish of the Pacific coast is among the largest of marine game fishes, attaining a weight of 500 pounds or more. (A.W.L.)

BAST. As commonly used, the term bast is synonymous with **phloem.** (R.M.W.)

BAST FIBERS. In the secondary **phloem** of many plants there occur long slender thick-walled cells with tapering ends. These cells, often occurring in groups of considerable size, are called bast fibers, or better phloem fibers. They give to the stem of the plant considerable strength. Many bast fibers are useful to man, especially in the manufacture of cloth and cordage. Linen is made from the bast fibers of **flax,** while **hemp, jute** and ramie are coarser **fibers** used in making coarse sacking and cordage. (R.M.W.)

BAT. Mammalia, Chiroptera. A flying **mammal** whose wings are formed of folds of skin, the patagia, stretching between greatly elongated digits of the fore limbs, the sides of the body and hind limbs, and thence to the tail. Since the wings are living tissue they form extensive radiating surfaces, a fact correlated with the much greater development of the group in warmer regions. Most species found in the temperate zones hibernate, although migration has been reported, and few species invade more northern limits of these zones.

The habits of bats vary greatly. The flying foxes or fruit bats of the Old World are fruit-eating species exclusively, the horseshoe and leaf-nosed bats are insectivorous, and some species of vampire and false vampire bats are blood-suckers. Among the bats with distinctive names are the barbastelle, pipistrelle, noctule and serotine, all found in Europe and other parts of the Old World. (A.W.L.)

BATAGUR. Reptilia, Chelonia. Large fresh-water **tortoises** of several genera found in India and the Malayan region. (A.W.L.)

BATHOLITH. Batholith, by some writers spelled bathylith, is derived from the Greek meaning deep, and stone. It is a very large intrusive **igneous** mass with steeply inclined contacts, enlarging downward to undetermined depths. Typical batholithic rocks have a relatively coarse and even texture, such as **granites** and **diorites.** Batholiths occur as the roots or cores of folded and faulted mountain ranges and are therefore closely associated with mountain-building, although prob-

ably not the cause of the deformation but rather consequent to it. The mode of emplacement of such large cross-cutting and relatively uniform igneous rock bodies has not yet been definitely determined. The term was proposed by Zuess in 1888. (R.M.F.)

BATHYSPHERE. A closed and air-tight chamber arranged to contain observers, and to be lowered at the end of a cable to great depths of water, is a bathysphere. It is principally used for scientific study of animal life and other conditions in the depths of the ocean. The bathysphere is spherical in shape. It has a small observation window and a telephone, the lead of which is unwound along with the supporting cable. The observer keeps in communication with the mother vessel and possibly dictates notes by means of his telephone. Suffocation is forestalled by the slow release of compressed oxygen from tanks. Depths of 3028 feet have been reached by the bathysphere, and this, of course, is far beyond the maximum depth achieved by divers or submarines. (F.T.M.)

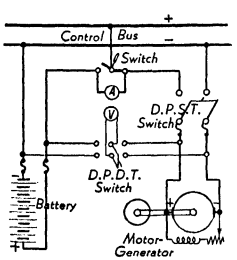
BATONETTE. Cell.

BATRACHIA. The frogs and toads.

BAT TICK. Insecta, Diptera. Highly specialized flies which live as ectoparasites on bats. Like other parasitic flies, their habits are accompanied by some structural resemblance to the true ticks, hence the inaccuracy of the common name. The bat ticks belong to two families, Streblidae and Nycteribiidae. All species of the latter are wingless. (A.W.L.)

BATTERY. The term battery refers to any group of duplicate units which are contributing individually to a common effect. A common usage of battery is in reference to a group of cannon forming, with the personnel, a military offensive unit. The word is also frequently applied to engineering usage, such as battery of boilers, which consists of a number of individual boilers on a common header supplying steam to a common service, or a battery of mixers, etc.

But by far the most common usage of the word is in reference to a collection of electrical cells for the production or storage of electrical energy. As such, the battery may be of the primary type, of which the individual unit is the primary cell, or it may be the ordinary storage battery, which is, strictly speaking, an electrical accumulator. The lead and sulfuric acid storage battery is the one most frequently found. A single cell of this type of battery has an e.m.f. of between 2 and 2½ volts when fully charged, and an ampere-hour capacity which is dependent upon the exposed area of the plates to which the electrolyte has access, as well as upon the quality of construction.



Battery and motor-generator parallel on control bus.

The electric system of the automobile is based upon the three-cell, six-volt, storage battery. Farm lighting plants are frequently thirty-two volt, and require sixteen cells. A sixty-cell battery is standard for 110-volt service. To obtain these voltages, the cells must be connected in series. When a storage battery is used, the accumulated energy is withdrawn through the conversion of chemical energy into electrical energy. Without some means of recharging, the battery will become completely discharged, and cease to deliver current. Automotive batteries are charged from a generator which is driven by the engine. Farm lighting batteries are recharged periodically by a special stationary engine-driven generator. Larger batteries, such, for instance, as those on 110-volt control buses, are usually kept charged by a motor generator set which converts some available source of alternating current into direct current. The accompanying figure shows a connection frequently employed where the direct current bus can be energized either by a motor generator or a battery, and the same motor generator used to recharge the battery. (F.T.M.)

BAUXITE. The term applied, by Dufrenoy in 1847, to the amorphous mineral aluminum oxide dihydrate ($Al_2O_3 \cdot 2H_2O$), an important ore of **aluminum**. The term is also applied to aluminous **laterites** which contain commercial amounts of aluminum hydroxide. (R.M.F.)

BAYBERRY. *Myrica cerifera.* Myricaceae. This is a shrub which is found in marshy places in the United States. The simple leaves are very fragrant, especially when crushed, and are sometimes used in cooking. The fruit, a blackish drupe (See **Fruit**), is thickly coated with a mealy crust of wax. To obtain this wax, the fruits are boiled in water, causing the wax to melt and float to the top. The wax is pale green and very fragrant. It is used in making candles and also in scented soaps. The wax from this plant, and from other species of *Myrica*, has been used medicinally.

Sweet bay is the true laurel, *Laurus nobilis*, a small tree found in the Mediterranean region. The leaves are very fragrant and are used as a condiment. From the berries a fragrant oil is obtained which is used medicinally. (R.M.W.)

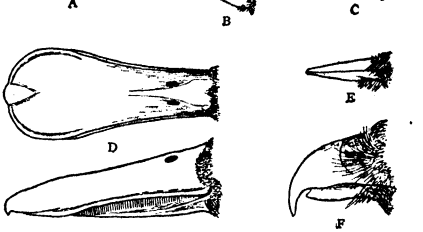
BAY OIL. Volatile oils.

BDELLOIDEA. An order of **rotifiers**, named for their fancied resemblance to leeches. (A.W.L.)

BDELLONEMERTEA. An order of **nemertine** worms of broad, flat form, named from their superficial resemblance to leeches. They live in the branchial chamber of **molluscs**. (A.W.L.)

BEAK. 1. A pointed protuberance. 2. The snout or rostrum of an animal, such as the beaked whale. 3. The horn-covered jaws of turtles and birds. The beak of birds is also called the bill. 4. The jaws of **cephalopod** molluscs.

Beaks of birds show a wide range of specialization for various uses, especially related to different types of food. Slender and elongate beaks are found in many wading species which must reach below the water for food and in the **hummingbirds** which visit deep-throated flowers. The broad beak of the **duck** has sieve-like structures at the sides and serves effectively to collect and strain out



The beaks of birds. A, yellow-legs, a wader; B, cardinal, a seed-eater; C, flycatcher, an insect eater; D, the shoveler duck, dorsal surface above and side view showing the lateral sieve below; E, a woodpecker's chisel-tipped beak; F, hawk, a bird of prey.

small particles from the water The hooked beaks of birds of prey, small and slender beaks of insectivorous birds, and thick, strong beaks of seed-eating species are other examples

The cephalopod molluscs, including the **squids, octopus** and related species, have two sharp jaws associated with the mouth which work together and resemble the beak of a bird (A W L)

BEAKED FISH. Pisces, Teleostei A member of a group of African fishes (**Pisces**), some of which have the snout sharply elongated Beaked members of other groups also occur, including the beaked salmon, which ranges from Japan to Australia This fish is not a true salmon but constitutes a separate family (A W L.)

BEAN. The fruits of many different plants and in many cases the plants themselves are called beans Nearly all of them are members of the **Leguminoseae** In Europe and America, beans are principally plants of the genus *Phaseolus*, with *Phaseolus vulgaris*, the common Garden Bean, a most important species, with many varieties in cultivation This plant is a tender annual, probably originally native in South America, and grows either as a low bush or as a twiner Many of the varieties grown have been selected to yield a thick, rather fleshy pod with small seeds, these are string or snap beans In some varieties chlorophyll (See **Pigments in Plants**) is either entirely or largely lacking in the pods, giving the Wax or butter bean Many other varieties are grown primarily for the dried seeds, which have a very high food value and keep exceedingly well if dried and protected from insects. Common varieties used as dry beans are Pea, Yellow Eye and Red Kidney beans Shell beans are those in which the nearly mature but green seed is eaten

Related to the Garden Bean is *Phaseolus multiflorus*, the Scarlet Runner Bean, which is often grown as an ornamental plant because of its showy scarlet flowers Another species, widely grown in warmer climates, is *Phaseolus lunatus*, the Lima Bean, another plant from South America The large flat pods of this plant contain a few large flat seeds Varieties have been developed which can successfully mature in regions having a short growing season

In Europe a common bean is the Broad Bean, also called Windsor or Horse Bean, *Vicia faba* Its seeds are rich in nitrogenous compounds and rather hard to digest These seeds are extensively used for horse food, as well as for human consumption

In the Orient, the bean crop is almost entirely *Glycine Max*, the Soy Bean The plant is an erect bushy annual with trifoliate leaves and bears fruit (pods) in great abundance Tremendous quantities are grown in Manchuria The plant has been introduced into the United States, where it is becoming increasingly popular, for several reasons One is the fact that it will grow well on poor soils and, being a legume, will build up the fertility of the soil, because of its associated nitrogen-fixing **bacteria** It is also an important forage crop The seeds are rich in oil and have received much attention from chemists, with the result that large quantities are now used in the preparation of enamels, linoleum, inks, paints, soaps, etc The cake remaining after the oil is pressed out is used as a stock food Unquestionably, soy bean culture will increase in the United States in the future.

In Africa, species of *Dolichos* are used as food

All the plants so far treated are legumes having "bean-" like fruit But in the Vanilla bean one deals with an entirely different plant Vanilla beans are the fruits of a climbing **orchid** growing wild in Central America and Mexico Since prehistoric times these fruits have been used to flavor chocolate At the present time (and with some difficulty) the plant is cultivated in several tropical countries, both in America and in the Orient Like many other orchids, the flowers are pollinated only by certain specially adapted bees and perhaps the **Hummingbirds** When introduced into regions where the necessary insects are lacking, **pollination** must be done by hand The fruits, or pods, are slender elongate structures containing innumerable minute seeds These seeds are germinated with difficulty, so new plants are usually obtained by cuttings of the old stem Three years are required before the rooted cuttings will begin to bear fruit In preparing the pods for market, they are first gathered and partially dried After this they are stored in tight boxes during the night This process is repeated daily throughout the period of "sweating" As a result of this treatment, the pods become deep chocolate brown, somewhat wrinkled objects, having a rich aromatic odor The cured pods are packed in tight containers and shipped to the manufacturers of the extract Vanilla is used mainly as a flavoring

Many other plants contain vanillin, or similar substances, and so are often used in the manufacture of artificial vanilla Among these are the seeds of a tropical South American plant, Coumarouna, which yield a product coumarin, used in **perfumery** The seeds from which this coumarin is obtained are called Tonka Beans (R M W)

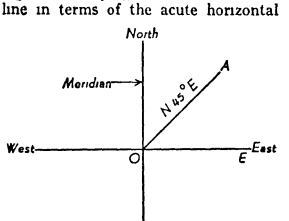
BEAN WEEVIL. Insecta, Coleoptera The common bean weevil is a small **beetle,** *Mylabris obtectus*, which attacks growing beans and cowpeas in the pod Methods of control are the same as for the **pea weevil** The four-spotted bean weevil is a related species which attacks beans and peas both in the field and in storage Control as above (A W L)

BEAR. Mammalia, Carnivora Large heavily built animals with rudimentary tail and plantigrade feet In North America the polar bear, *Thallasarctus maritimus*, black bear, *Ursus americanus*, grizzly, *U horribilis*, and Kadiak bear are recognized species and several less familiar names apply to species of brown bears of Alaska The term brown bear itself does not designate a single species Numerous varieties of the black and grizzly bears also occur

Bears are found in every continent except Australia, although Africa and South America have only one species each The African species, known as Crowther's bear, is found in the Atlas mountains and is related to the European brown bear The South American spectacled bear, named from the light-colored rings around the eyes, lives in the Peruvian Andes Among the more striking bears of Eurasia are the Himalayan bear, a black bear of moderate size with a white chevron on its breast, and the peculiar sloth-bear, *Melursus labiatus*, of India, which has unusually large curved claws

The term bear is also applied to the **koala**, which is known in Australia as the native bear for wholly superficial reasons (A W L)

BEARING. Bearing is a surveying term used to define the direction of a line in terms of the acute horizontal angle which it makes with a given line, called a meridian The meridian may be an assumed line, a geographical north and south line, or the magnetic north and south, depending upon the purpose of the bearing Bearings taken in reference to the magnetic north and south are called magnetic bearings, while those referred to the geographical north and south are called true bearings As shown in the accompanying figure the value of the angle varies



Bearing (Directional)

from 0° to 90° while the direction is governed by the quadrant in which the line is located If line *OA* makes an angle of 45° with the meridian the bearing will be N45°E (North 45° East) The bearing of *OE* which makes an angle of 90° with this meridian will be termed "Due East" Surveys (See **Surveying**) are referred to the magnetic north and south by observing the magnetic bearing of one line and calculating the bearings of the remainder A magnetic bearing may be changed to a true bearing by means of the angle of **declination**

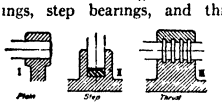
Bearing is a mechanical term used to denote that part of a machine which bears the friction occasioned when parts are in contact and have relative motion Bearings are to be found in a variety of forms, for example, lubricated and unlubricated, rotating and sliding, weight-carrying and thrust-carrying, etc See also **Anti-friction Bearings, Bearing Friction,** and **Bearings**

Bearing is a structural term denoting that part of a structure which transmits the loads to the supports Rolled steel plates, known as bedplates, are used for bearings for roof trusses, short plate girder bridges and wall bearing beams Cast steel pedestals have been used in place of bedplates Bridges are usually supported on hinged pedestals called shoes which are made of cast steel or from rolled steel shapes riveted or welded together The hinge consists of a heat-treated steel pin through which the loads on the **truss** are transferred to the shoe A fixed shoe is one which is firmly connected to the support Shoes which allow a certain degree of movement in one direction are expansion shoes In one type of expansion shoes rollers are used to provide the necessary means for movement and another type employs the principle of the rocker Simply supported bridges require fixed shoes at one end and expansion shoes at the other end to take care of the movement due to temperature changes

The allowable pressure which may be exerted on a material is often called its bearing power The force exerted by a plate on a rivet or pin is known as a bearing pressure A compressive **stress** is frequently referred to as a bearing stress (C W C)

BEARINGS. A mechanical bearing has been defined under **bearing** One of the most common elements of machinery is the bearing, because most machinery is characterized by parts in relative motion to one another Where relative motion is controlled, as in a machine, there are, necessarily, bearings The designer of any successful bearing must take several facts into consideration There are many different bearing materials, most of which have their own definite limitations and must, therefore, be selected with reference to the application, i e , the load, the lubrication, the rubbing speed, the impact, etc Then, since bearing materials are often soft, the bearing may be a strong shell in which are anchored the bearing materials When in use, bearings often wear and become loose, consequently they must be made adjustable, so that the wear can be "taken up," or compensated for This adjustment also provides for maintaining the clearance needed between the shaft and its bearing so that it may be sufficiently lubricated Many bearings receive so much heat from friction that it is necessary to provide some positive means of cooling them

There are three general classes of bearings plain bearings, step bearings, and thrust bearings The plain bearing carries load radially, the step and thrust bearings loads axially, but whereas the step bearing carries gravity loads, the thrust bearing is designed to take up loads due usually to another cause Another classification of bearings is into sliding and rolling types The latter are often called **anti-friction** bearings



Bearings

Not all bearings support rotary motion, although it is true that most of them are for that service Some examples of reciprocating bearing surfaces are the crosshead guides of a steam engine, or the slides on the ways of a lathe or other machine tool having a reciprocating table

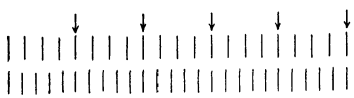
Still another important bearing classification is on the basis of lubrication Bearings may be continuously lubricated, intermittently lubricated, or initially lubricated A large percentage of the bearings in modern machines are the continuously lubricated type, especially in engines, motors, and the like This type of lubrication can be accomplished in a number of different ways, for example, by a pump forcing oil under pressure to the bearings, as in the automotive and aeronautical gasoline engine, or by a loose ring, or chain hung on the shaft and dipping into an oil reservoir under the journal—a common practice in electric motors Bearings which are not heavily loaded or are not in continuous motion, or are comparatively unimportant and easily replaced, may be periodically lubricated by grease or oil cups Initially lubricated bearings, often called oilless, are based on the incorporation of the lubricant into the surface of the bearing, or subdivided in the bearing metal itself While it is possible to impregnate a porous insert in the bearing with a liquid lubricant, the oilless bearing is mostly frequently lubricated by graphite inserted in the bearing or mixed with the bearing material If a bearing is lubricated for some time with an oil containing a special and finely suspended graphite, the surface of the bearing will often receive sufficient graphite to permit the bearing to run long periods of time without lubrication of any sort

The load that a bearing may safely carry is a matter on which the final word has not yet been written There is a lack of correlation of bearing pressures allowable on sliding bearings surfaces It is probable that a large number of the sliding bearings now in existence are unduly conservative, and have bearing areas much larger than could be justified if more accurate and generally accepted information on bearing pressures were available The safe bearing loads by rolling types of bearings can be more definitely stated, and ball and roller bearing manufacturers are able to quote very definitely the bearing loads which their different lines should carry The bearing pressure on sliding bearings is the load carried divided by the projected area of the bearing, this area being the bearing diameter multiplied by its length The **coefficient of friction,** when multiplied by the load, gives the friction force acting at the bearing surface The energy consumed in friction is the friction force multiplied by the rubbing speed of the bearing This energy is converted into heat and becomes the heat that must be dissipated from the bearing surface either naturally to the atmosphere, or artificially Machine elements attached to a rotating shaft often produce an end thrust on that shaft Examples of this are beveled gearing, steam turbine blades, air propellers, and the propeller of a steamship At other times the shaft may be vertical and attached to very massive and heavy parts, for example, the rotor of a hydraulic turbogenerator The aforementioned cases are instances where thrust bearings are necessary For very light thrusts a simple thrust washer or collar, with continuous or intermittent lubrication, does very well For somewhat larger thrusts, the ball or roller thrust bearing, or a multiple groove sliding bearing, or the step bearing, is suitable The heaviest thrusts are carried by sliding thrust bearings of specialized design An example is the Kingsbury thrust bearing, in which the shaft is mounted on a collar, while the stationary part of the bearing consists of a number of pivoted segments pressing against the collar The rotation of the collar carries a wedge of oil between the segment and the collar, so that in reality the shaft is floated on a film of oil Due to the pivoting of the segments, the wedge of oil is positively maintained, and

this bearing can be built to carry extremely large thrusts with a very low coefficient of friction

In the field of anti-friction bearings, the ball bearing is a smaller, more compact unit than the roller bearing, but is more limited in the load it can carry While it is possible to operate anti-friction bearings without a lubricant, they are generally lubricated Frequently they are initially lubricated by being packed with grease and having placed over the bearing a tight-fitting cover to retain the lubricant and keep out dust The accompanying illustration shows both the radial and the thrust types of anti-friction bearings The bearing will be seen to consist of three main parts, an inner race, which is a press or shrink fit on the shaft, a set of balls or rollers, sometimes mounted in a spacer cage, and an outer race which is a press fit in the bearing housing The balls revolve in the races in grooves of a radius slightly larger than the ball (F T M)

BEATS A series of alternate maxima and minima in **vibration** amplitude, produced by the **interference** of



Five coincidences in unit time between wave trains of frequencies 20 and 25

two **wave** trains of different frequency A familiar example arises in the case of musical **sounds** If two musical pipes or strings of slightly different pitch are sounded together, the result is a more or less distinct throbbing, often disagreeable to the ear The beat frequency is the difference of the two wave frequencies Thus, if the two tones are middle-c (256) and c-sharp (271 2), there will be 15 2 beats per second If the two tones are **ultrasonic**, but have a frequency difference within the audible range, the beats themselves may produce an audible "beat tone" A similar effect results from the simultaneous reception of two radio wave trains which are nearly, but not quite, synchronized Thus if two stations are sending on carrier waves of 1000 and 998 kilocycles, the receiver will emit a shrill whistle of frequency 2000 cycles This is the "heterodyne" effect, responsible for the annoying squeals and tremolos often heard in radio reception One type of radio "fading" may be regarded as a beat phenomenon of long period (L D W)

BEAVER. Mammalia, Rodentia An aquatic species with webbed hind feet and a broad flat tail The largest of the **rodents**, reaching a length of three and one-half feet and a weight of sixty pounds

The beavers are noted for their extensive building operations They construct dams of logs, branches and mud in order to form ponds in which their lodges are built The lodge, like the dam, is a disorderly heap of sticks and mud rising above the water It contains chambers with entrances below the surface of the water and may be occupied by one animal or by an entire family

Beavers fell trees for construction and for food by gnawing round and round, although some observers have claimed that they gnaw deeper on the side toward which the tree is to be felled They store up a supply of logs in their ponds from which the bark is eaten during the winter, although in the warm season they eat other green food

The fur of the beaver has been among the most valuable on the market and has been the chief reason for a slaughter which threatened to destroy the species With rigid protection they have become numerous in some parts of North America during the present century so the threatened extinction has apparently been averted

The European beaver, *Castor fiber*, is similar to the North American species, *Castor canadensis*, whether the two are separate species has been a matter of dispute. (A W L)

BECARD. Chatterer.

BECCAFICO Aves, Passeriformes A bird (**Aves**). This is an Italian name translated fig-eater or fig-pecker, said to apply to the European garden warbler, *Sylvia hortensis* (A W L)

BÊCHE-DE-MER Sea cucumber.

BECKE METHOD. Index of Refraction.

BECKMANN THERMOMETER. Liquid Expansion Thermometers.

BEDBUG. Insecta, Hemiptera A wingless, blood-sucking **bug** which hides during daylight in the crevices of beds and other furniture and about the woodwork of houses and seeks its victims at night It has been found also about chicken roosts

Corrosive sublimate (mercuric chloride) dissolved in alcohol and applied to the hiding places of the insects is one method of control Severe infestations are usually handled by fumigation of the entire building with **hydrocyanic acid** gas, a procedure which demands the services of an expert since the gas is deadly

This species, *Cimex lectularius*, gives the name bedbug family to the family Cimicidae which also contains a few species that attack bats and birds

Still another member of this order, the large bedbug, is sometimes found in beds It is almost an inch long and is capable of inflicting a painful wound This species is one of the **assassin bugs** (family Reduviidae) (A W L)

BEDDING A term used by geologists to designate the natural layering or stratification usually characteristic of **sediments** and sedimentary rocks Bedding is the result of the unequal rates of settling of particles of different sizes and specific gravities In the case of very fine grained sediments, or **shales**, the bedding may be shown by color bands The thickness of a bed or stratum may vary from several feet to a fraction of an inch Extremely thin beds are called laminae (R M F)

BEDEN. Ibex.

BEE. Insecta, Hymenoptera **Insects** which gather nectar and pollen to provision their nests, they are provided with structural adaptations associated with this habit The term means, to most persons, the **honey-bee**, of the genus *Apis*, unless it is further qualified, but there are many other kinds of bees and a large number of species Among the solitary bees are the carpenter bees, the leaf-cutting bees, and a number of mining or burrowing species, while the social bees include the honey-bees, the bumblebees, and the stingless honey-bees of the tropical zone Some species are parasitic in the nests of other bees

In connection with the social life of bees they show structural specialization into castes and reproduction is restricted to a few individuals of the colony, as in other social insects In the honey-bee colony three castes are recognized, the workers, drones, and queens The first are abortive females, the second males, and the last functional females Under normal conditions only a single queen is found in a colony

Bees illustrate a complete transition from solitary habits to permanent social groups Some are strictly solitary, some of the burrowing species build their nests independently but in groups, some form a common tunnel with which their individual nests connect; the bumblebees are social during the summer but hibernate as individuals, and the honey-bee colony is permanent.

Their association with flowers makes the bees important in the **cross-fertilization** of many plants. Red

clover, for example, is cross-fertilized by the bumblebees and for the production of a good crop of seed these insects are necessary (A W L)

BEE-EATER. Aves, Piciformes Brightly colored birds (**Aves**) of the Old World They have a long curved **beak** and are adept at catching insects in flight The several species make up the family Meropidae (A W L)

BEE FLY. Insecta, Diptera **Flies** whose habit of visiting flowers for pollen and nectar is like that of the bees They make up the family Bombyliidae (A W L)

BEE LOUSE. Insecta, Diptera A minute wingless parasitic **fly** found attached to the queen and drones in honey-bee colonies The few known species constitute the family Braulidae, containing the genus *Braula* (A W L)

BEE-MARTIN. Aves, Passeriformes *Tyrannus* The common **kingbird** of North America The name is undeserved, since scientific investigation has disclosed that he eats very few bees (A W L)

BEE-MOTH. Insecta, Lepidoptera A **moth** whose **larva** eats the wax and debris in old honeycombs, spinning a silken tunnel as it goes These insects are found chiefly in weak colonies of bees and in stored combs They may attack beeswax products, such as comb foundation in the supplies of the apiarist, but they cannot develop on a diet of pure wax, the organic waste in old brood combs provides the necessary nitrogenous material and furnishes a favorable breeding place The best known form is *Galleria mellonella*

In well-kept apiaries the bee-moth is rarely a serious pest The maintenance of strong colonies of bees prevents its entrance and the protection of stored supplies against the entry of the adult moths safeguards them against damage Fumigation of supplies is sometimes necessary It may be effectively carried out with **carbon disulfide** but since this compound is highly explosive it must be used with due precautions (A W L)

BEESWAX. A tough wax formed of a mixture of several compounds, secreted by honey-bees in the form of thin scales from glands on the ventral surface of the abdomen and used in building the combs in which the young are raised and honey and pollen are stored Commercially it is a compact mass varying from yellowish-white to brownish in color according to its purity It has a high melting point, near 140° F

Beeswax is used commercially to make fine candles, in polishing materials, as a component of modeling waxes, and in a variety of other products (A W L)

BEET. *Beta vulgaris* Chenopodiaceae The many varieties of beets now in cultivation are perhaps all derived from the native *Beta maritima* of southern Europe

The most important variety is the sugar beet, which in recent years has become an important rival of the sugar cane As a source of sugar, beets were first utilized in Germany and in France about 1800 In the United States they became important commercially only after the World War Their culture is still largely restricted to a few states, notably Colorado, Wisconsin, and California

The sugar beet is a biennial plant which during its first year of growth forms a large tapering tap **root** and a rosette of leaves At the end of this first year the plant is gathered for sugar production If allowed to grow the second year, the plant forms a branching stem and an abundance of inconspicuous flowers, utilizing the sugar stored in the root to produce them

The plant has an elongated tap root which tapers into a long slender root This may penetrate four to six feet into the ground In size and shape the root is extremely variable. Cut transversely, the root is seen to be composed of from six to ten or even more concentric zones Each zone comprises a ring of conducting cells outside which is a ring of small cells in turn surrounded by a ring of large cells The small cells are rich in sugar, while the large cells are primarily water-storage cells The formation of these zones is a consequence of the formation of a succession of **cambium** rings, each of which persists for a few weeks

In preparing the beets for sugar manufacture, the roots are first lifted from the ground, the leaves cut off, and the roots hauled to the factory There they are washed thoroughly and cut into thin slices These slices are put into hot water, which extracts the sugar The sugar solution is next treated with lime, and then precipitated with carbon dioxide this removes many impurities which are filtered off The purified liquor is bleached with sulfur dioxide, and then concentrated by boiling and crystallized under a partial vacuum From this crude product the molasses is removed by centrifuging, leaving the sugar which is dried and granulated, after which it is ready for the market

Many of the waste products of beet sugar production are utilized The tops are used as a stock food either in the raw condition or after preserving as ensilage The beet pulp left after extraction of the sugar is also used as a stock food, as is the molasses from the sugar Often the pulp and molasses are mixed before feeding Any refuse from the factory may be used as a fertilizer

In addition to sugar beets, several other varieties of *Beta vulgaris* are known One of them is the common table beet, which is eaten either boiled or pickled When correctly grown it has a minimum of fibrous elements as well as a high sugar content Most varieties of table beet are deep red in color, in contrast to the white-fleshed sugar beet Another variety of beet is the Mangel-wurzel or Mangel, of which there are several varieties They are of large size, have a sugar content varying from 4–8% and are developed principally as a stock food (R M W)

BEETLE Insecta, Coleoptera Any member of this order of insects The term is often compounded with other words, as rove-beetle, click-beetle, and leaf-beetle See **Coleoptera** (A W L)

BEGGIATOA Filamentous forms of sulfur **bacteria** which are capable of converting **hydrogen sulfide** to **sulfuric acid. Sulfur** granules are stored in the cells, and may be oxidized to supply the cell with the necessary energy for life (R M W)

BEHEMOTH. A biblical name for a large animal, probably the **hippopotamus** (A W L)

BEISA. Mammalia, Artiodactyla An **antelope**, *Oryx beisa*, of northeastern Africa, characterized by long sharp horns, ringed at the base and almost straight With several other species it belongs to the genus *Oryx*, a name often used as a common name for any of the included animals (A W L)

BELEMNITE. Invertebrate paleontology.

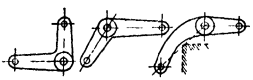
BELL AND SPIGOT. Pipe.

BELLADONNA. *Atropa Belladonna* Solanaceae The plant grows as a native in Europe and in parts of Asia It is commonly known as Deadly Nightshade It is about three feet tall, and has dull green leaves and purple flowers, which are followed by cherry-like red fruits Every part of the plant contains the poisonous substance for which it is known This drug, **atropine**, is a very poisonous **alkaloid** obtained principally from the roots and leaves Belladonna is used medicinally most often as the tincture Its action is that of atropine (R M W, R S M)

BELLADONNINE. Alkaloids.

BELL-BIRD. Aves A term applied to several species of birds (**Aves**) which produce bell-like tones, including a **chatterer** in the Guianas and a **honey-sucker** in New Zealand (A W L)

BELL CRANK. A means frequently used to transfer reciprocating motion at right angles is that of a rigid-angled arm pivoted to a fixed point at its vertex, and having hinge connections at its extremities The bell crank really is a type of **lever**, and the motions of its end are not those of reciprocation, but rather of rotation, but if comparatively long rods are hinged to it, the other ends of those rods will have similar motion The amplitude of the reciprocation transmitted by the bell crank is directly proportional to the radii from the pivot point to the joints (F T M)



Bell cranks

BELTS One way to transmit power from one point to another is to use flexible connecters which wrap around pulleys, sprockets, sheaves, etc, which are mounted on shafts The power is transmitted from one rotating shaft to another by means of pulls on these flexible connecters A belt is a flexible connecter which passes over a smooth-surfaced **pulley**, and whose surface it grips by friction alone The belt does not provide a drive of the same degree of positiveness as a chain and sprocket, since the belt may at times slip on the pulley This characteristic is often an advantage in favor of the belt, but sometimes is the reason for the use of a more positive drive Belting which passes over both driving and driven pulleys without slip provides a power transmission between two shafts with a speed ratio inversely proportional to the diameters of the pulleys Some slip is always present with leather belts because the stretch of the belt, passing over the pulley from the loose to the tight side, causes a "creep" which should not, however, exceed two or three per cent of the speed of the belt While a belt drive is simplest when the shafts are parallel, it is entirely possible to transmit power between two shafts having any relative position to each other, provided sufficient number of idler pulleys are used to turn the belt direction

A belt is able to transmit power by virtue of the difference in tension in the leather on the tight and slack side of the pulley When a belt is at rest, there is equal tension in the belt on both sides of the pulley When the driving pulley begins to revolve, a friction force is developed between the pulleys and the belt This decreases the tension in the belt on one side of the pulley, which therefore becomes slack, and increases it on the other side, the taut side In effect these tensions act the same as a force, equal to the difference between them, applied at the rim of the pulley and moving with the peripheral speed The horsepower of a belt, then, is

$$P = (T_1 - T_2)\frac{2\pi Nr}{33{,}000}.$$

T_1 = belt tension, in pounds, taut side
T_2 = belt tension, in pounds, slack side
N = revolutions per minute of the pulley.
r = radius of the pulley in feet

The coefficient of friction between the belt and the pulley, the initial tension, the power to be transmitted, and the belt speed are all factors entering into proper operation of belting When a belt runs over a pulley at high speed, the centrifugal force generated in the mass of the belt tends to decrease the pressure of the belt against a pulley face This affects the frictional force developed and the horsepower that can be transmitted; consequently, the weight of the belt material itself must be considered in determining the power that can be transmitted by belts operating at high speeds Another dimension of a belt drive that influences the power which can be transmitted is the arc of contact of the belt with the circumference of the pulley The simplest way to determine this is to make a scale drawing of the belt drive and measure the arc with a protractor

Belts are made of a number of different materials The oldest belt material, and still the most popular, is leather Leather belting varies in thickness, in different hides, but a belt of any desired thickness can be obtained by cementing a number of plies together Thus, two, three, and four ply belts are possible The cross-sectional area of a belt must be large enough to hold the tension on the taut side without exceeding the safe value of the material in tension The ultimate strength of leather belting varies with the way in which it is tanned, but common oak-tanned belting develops about 4000 pounds per square inch Canvas belts may be made to give the same ultimate strength as leather, but rubber and cotton belts are somewhat weaker Web belts, such as canvas, are cheaper than leather belts, but their coefficient of friction is lower The coefficient of friction of rubber belting is high, but its endurance and strength are less than for leather belting Leather weighs about 035 pounds per cubic inch, which is somewhat lighter than the cotton and rubber belts, and somewhat heavier than the canvas web belts. Belts can be made endless or jointed The endless belt of leather is made by overlapping the plies and cementing at the joints Web belts must be woven endless during process of manufacture Many different styles of metal belt joints as well as the older method of lacing with rawhide are available for the jointed belts Thin steel belts have been used, and while advantages of light weight, high speed, absence of creep, and maintenance of initial tension are claimed, their use is comparatively infrequent

In recent years, the V belt has been perfected to where it is available for all sorts of drives, especially those with short shaft centers, which are somewhat difficult to obtain in flat belting Fairly large amounts of power are transmittable by V belts through the use of multiple groove pulleys and multiple belts The V belts are made of rubber and cotton and do not require the large initial tension that would be necessary to transmit the same power under the same conditions with flat belting Small round leather belts are sometimes used to drive machines or parts of machines where the horsepower required to be transmitted is very small (F T M)

BELUGA. Mammalia, Odontoceti The white **whale**, *Delphinapterus leucas* A small arctic species which attains a length of sixteen or more feet The species has been captured for oil and for its flesh and the hide has been used for leather (A W L)

BENCH MARK. A definitely established point whose elevation is known in relation to some arbitrary plane is called a bench mark It is used in **surveying** as a vertical reference point when finding the elevation (with respect to the same arbitrary plane) of other points of a less permanent nature The point may be the head of a spike or bolt driven into a tree in such a manner that the top of the head is as nearly horizontal as possible, the highest point on the top of a hydrant, or the top of a flat, non-corrosive plate set securely in stone or **concrete** Bench marks may be temporary or permanent depending upon their use and should be located so that they are easily accessible for instrument work (C W C)

BENCH PHOTOMETERS. (See **Photometry**) The principle underlying the usual forms of bench photometer depends upon finding a point so located between the two light-sources under comparison that the flux

densities produced by them at that point are equal The luminous intensities of the two sources are then proportional to the squares of their distances from that point To this end, the two sources are mounted near the extremities of the scale of an optical bench, and on a movable carriage between them is some device, called the photometer "head," for receiving and comparing the illuminations from opposite directions

Among the many types of bench photometer head in use, only four can be mentioned here A crude form is the Joly "block" screen, composed of two blocks of opal glass or paraffin with an opaque partition between them When the sides of the blocks are equally illuminated, the two front faces are lighted up equally by diffusion from within One of the best known types utilizes the Bunsen screen, which is in effect a sheet of white paper with a grease spot at the middle When the two surfaces are equally illuminated, the grease spot becomes indistinguishable The Lummer-Brodhun "cube" screen somewhat resembles the Bunsen in principle, but with the paper and grease spot replaced by the interface between two right-angled prisms which are in optical contact only over a central area of some conventional shape This central area and the area surrounding it merge into a uniform field when the illuminations are equal

The distinctive feature of the "flicker photometer" head is that, by means of a rotating sector-disc, the two illuminations to be compared are presented to the observer in rapid alternation (but not too rapid), any difference between them being detected as a noticeable flicker This type of photometer is especially useful when the sources are not of exactly the same color (L D W)

BENDING MOMENT. The external bending moment at any section in a beam is equal to the algebraic sum of the moments, about the gravity axis of the section This definition assumes that all of the external forces are coplanar, that is, act in one plane An internal resisting moment at any section is equal to the sum of the moments of the internal **stresses** about the gravity axis of the section The external bending moment acting on any section is numerically equal to the internal resisting moment but acts in the opposite direction External moments are positive or negative depending upon the direction in which they tend to rotate the section of the beam under consideration This sign convention is entirely arbitrary although it is customary in beam analysis to assume that positive moments are those tending to shorten the top surface of the beam while negative moments are those which lengthen the top surface Bending moments have a very important part in beam action since they cause the flexural stresses (See **Flexure**) and are the chief cause of the **deflections** (C W C)

BENIGN Harmless, not malignant This term is usually applied to **tumors** of non-cancerous character (R S M)

BENT. A transverse frame which forms an integral part of a structural unit or supports another structural unit is called a bent Bents are designed to carry **lateral** as well as vertical **loads**, and are made of wood or structural **steel** They are used principally in connection with viaducts and mill buildings Viaduct bents consist of **columns** held firmly together by bracing in horizontal and vertical planes The mill building bent is composed of the roof **truss** and the supporting columns which are connected by inclined members called **knee braces** These knee braces stiffen the bent against the action of wind forces Transverse mill building bents are connected by members called purlins and girts in addition to the necessary longitudinal bracing The purlins rest on the top **chord** of the truss and support the roof while the girts which are connected to the columns are used to carry the siding (C W C, F T M)

BENTHOS. That part of the plant or animal world made up of individuals which rest on a solid support The term is also applicable to free or attached forms living on the ocean floor **Distribution** (A W I, R M F)

BENTONITE. The term applied to fine grained volcanic ashes which have been blown considerable distance from their origin and deposited in marine waters The resulting material is usually a white, but sometimes a colored, clay-like sediment which may contain bits of volcanic glass but is composed mainly of **colloidal silica** which will absorb large quantities of water Since bentonites are wind-blown deposits they are useful as definite datum planes in **stratigraphy**, especially in helping to determine the contemporaneity of the different **facies** of marine sediments (R M F)

BENZALDEHYDE. Benzaldehyde ("oil of bitter almonds," C_6H_5CHO) is a colorless liquid, boiling point 180° C, of characteristic odor, slightly soluble in water, miscible in all proportions with alcohol or ether, readily oxidized, even on standing in air, to **benzoic acid** Benzaldehyde reacts with many chemicals in a marked manner, (1) with ammonio-silver nitrate ("Tollen's solution") to form metallic silver, either as a black precipitate or as an adherent mirror film on glass, but does not reduce alkaline cupric solution ("Fehling's solution"), (2) with rosaniline (fuchsine, magenta), which has been decolorized by **sulfurous acid** ("Schiff's solution"), the pink color of rosaniline is restored, (3) with **sodium** hydroxide solution, yields benzyl alcohol and sodium benzoate, (4) with **ammonium** hydroxide, yields tribenzaldamine (hydrobenzamide, $(C_6H_5CH)_3N_2$), white solid, melting point 101° C, (5) with **aniline**, yields benzylideneaniline ("Schiff's base" ($C_6H_5CH\ N\ C_6H_5$)), (6) with **sodium** cyanide in alcohol, yields **benzoin** ($C_6H_5\ CHOHCOC_6H_5$), white solid, melting point 133° C, (7) with **hydroxylamine** hydrochloride, yields benzaldoximes ($C_6H_5CH\ NOH$), white solids, anti-oxime, melting point 35° C, syn-oxime, melting point 130° C, (8) with **phenylhydrazine**, yields benzaldehyde phenylhydrazone ($C_6H_5CH\ NNHC_6H_5$), pink solid, melting point 156° C, (9) with concentrated **nitric acid**, yields metanitrobenzaldehyde ($C_6H_4CHO(NO_2)$ (2)), white solid, melting point 58° C, (10) with concentrated **sulfuric acid**, yields metabenzaldehyde sulfonic acid ($C_6H_4CHO(SO_3H)$ (2)), (11) with anhydrous **sodium** acetate and **acetic anhydride** at 180° C, yields sodium cinnamate (C_6H_5COONa), (12) with **sodium** hydrogen sulfite, forms benzaldehyde sodium bisulfite ($C_6H_5CHOHSO_3Na$), white solid, from which benzaldehyde is readily recoverable by treatment with sodium carbonate solution, (13) with **acetaldehyde** made slightly alkaline with sodium hydroxide, yields cinnamic aldehyde ($C_6H_5CH\ CHCHO$), (14) with **phosphorus** pentachloride, yields benzylidine chloride ($C_6H_5CHCl_2$) Benzaldehyde is obtained (1) by boiling the glucoside amygdalin of bitter almonds with dilute acid, glucose plus hydrogen cyanide being formed simultaneously with benzaldehyde, (2) by heating benzal chloride with calcium hydroxide, (3) by heating a mixture of calcium benzoate and formate Benzaldehyde may be detected by the appearance of a blue color on treating with acenaphthene and sulfuric acid, followed by heating Benzaldehyde is used (1) as a flavoring essence, (2) in the production of cinnamic acid, (3) in the manufacture of malachite green **dye** (R K S)

BENZENE. Benzene "benzol" (C_6H_6 or) is a colorless, odorous liquid, melting point 5 5° C, boiling point 79 6° C, insoluble in water, miscible in all proportions with alcohol, ether, and many organic liquids,

dissolves iodine, sulfur, oils, fats, rubber, resins, burns, when ignited, with a smoky flame, the vapor forms with air an explosive mixture, used as a fuel in **internal combustion engines** Benzene reacts (1) with **chlorine**, to form (A) substitution products (one-half of the chlorine forms **hydrogen chloride**) such as chlorobenzene (C_6H_5Cl), dichlorobenzene ($C_6H_4Cl_2$(1, 4) and (1, 2), trichlorobenzene ($C_6H_3Cl_3$(1, 2, 4), tetrachlorobenzene (1, 2, 3, 5), and (B) addition products, such as benzene dichloride ($C_6H_6Cl_2$), benzene tetrachloride ($C_6H_6Cl_4$), benzene hexachloride ($C_6H_6Cl_6$) The formation of substitution products of the benzene nucleus, whether in benzene or its homologues is favored by the presence of a **catalyzer**, e g , **iodine**, **phosphorus**, **iron** (2) with concentrated **nitric acid**, to form nitrobenzene ($C_6H_5NO_2$), 1,3,-dinitrobenzene ($C_6H_4(NO_2)_2$(1,3), 1, 3, 5-trinitrobenzene ($C_6H_3(NO_2)_3$(1, 3, 5)), (3) with concentrated **sulfuric acid**, to form benzene sulfonic acid ($C_6H_5SO_3H$), benzene disulfonic acid ($C_6H_4(SO_3H)_2$ (1, 3)), benzene trisulfonic acid ($C_6H_3(SO_3H)_3$(1, 3, 5)), (4) with methyl **chloride** plus anhydrous **aluminum** chloride (Friedel-Crafts reaction) to form toluene, monomethyl benzene ($C_6H_5CH_3$), dimethyl benzene ($C_6H_4(CH_3)_2$), trimethyl benzene ($C_6H_3(CH_3)_3$), (5) with acetyl chloride plus anhydrous aluminum chloride (Friedel-Crafts reaction) to form acetophenone, methyl phenyl ketone ($C_6H_5COCH_3$), (6) with **hydrogen** in the presence of a catalyzer, e g , finely divided nickel, heated, to form dihydrobenzene, cyclohexadiene (1, 3)(C_6H_8), a cyclic diolefin hydrocarbon, tetrahydrobenzene, cyclohexene (C_6H_{10}), a cyclic mono-olefin, hexhydrobenzene, cyclohexane (C_6H_{12}), a cyclo paraffin, (7) with ozone, to form benzene triozonide ($C_6H_6(O_3)_3$)

Benzene is obtained from coal tar and coal gas Coal tar is distilled, the part of the distillate which is insoluble in water is collected up to about 210° C By fractional distillation of this portion, benzene, **toluene**, **xylene** are obtained From coal gas, benzene and toluene, in larger amounts than from coal tar, are obtained by "scrubbing," that is, passing the gas through a special non-volatile absorbing oil, and then distilling off the absorbed oil followed by fractional distillation of this portion "Ninety per cent benzol" is a commercial benzene product, 90% of which distils over before 100° C This product contains about 81% benzene, 15% toluene, 2% xylenes Pure benzene and toluene are obtained by further fractionation Benzene is used (1) as a **solvent** for many substances, such as oils, fats, resins for varnishes and lacquers, rubber, old paint, and in dry cleaning of fabrics, (2) as a motor fuel, (3) in the manufacture of nitrobenzene for **aniline**, of chlorobenzene for **phenol**, of benzene disulfonic acid for **resorcinol**, of azobenzene for **benzidine**, and of other organic chemicals, especially **dyes**

Homologues of benzene, e g , toluene, xylene, ethyl benzene, mesitylene, upon oxidation yield **carboxylic acids**, containing one carboxyl group (—COOH) for each side chain, and substituted side chains behave similarly (R K S)

BENZIDINE (4 4′ diaminodiphenyl) Benzidine is an important dye intermediate See **Dyes** and **Rearrangements**

BENZIL. Benzoin, Benzil, and Related Compounds

BENZOIC ACID AND BENZOATES. Benzoic acid (H $C_7H_5O_2$ or C_6H_5 COOH) is a white solid, melting point 122° C, boiling point 249° C, insoluble in cold water, soluble in hot water in alcohol, and in ether Forms benzoates, e g , **sodium** benzoate, **calcium** benzoate, which, when heated with calcium oxide, yields benzene and calcium carbonate, forms with **phosphorus** trichloride benzoyl chloride (C_6H_5COCl) an important reagent for transfer of the benzoyl (C_6H_5 CO—) group, forming meta-chlorobenzoic acid by reaction with **chlorine**, meta-nitro-benzoic acid by reaction with **nitric acid**. The following are esters of benzoic acid

			°C.
Methyl benzoate	$C_6H_5COOCH_3$	boil pt	200
Ethyl benzoate	$C_6H_5COOC_2H_5$	boil pt	211
Glycol dibenzoate	$C_2H_4(COOC_6H_5)_2$	melt pt	73
Glyceryl tribenzoate	$C_3H_5(COOC_6H_5)_3$	melt pt	76

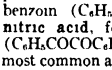
Benzoic acid may be obtained (1) from some natural products, e g , gum benzoin, **dragon's blood** resin, Peru and Tolu **balsams**, cranberries, urine of horses, (2) from benzotrichloride by reaction with water when heated, (3) as a by-product in the manufacture of benzaldehyde from benzol chloride or benzyl chloride Dilute solutions of benzoic acid give a violet coloration with hydrogen peroxide (drop) and ferric chloride, on heating (R K S)

BENZOIN *Styrax Benzoin* Styracaceae (For the chemical compound benzoin, see the article on **Benzoin, Benzil, and Related Compounds**) Benzoin is a fragrant resin obtained from the bark of a moderate-sized quick-growing tree which is native in Sumatra and Java The tree has alternate entire leaves, the lower surface of which is soft and hairy, the upper smooth The flowers are borne in compound axillary **racemes**; the fruit is a drupe (See **Fruit**) The **resin** is obtained by making incisions in the bark From these a thick white juice exudes and hardens This is scraped off It is a soft fragrant substance either white or of yellowish color It is used in medicine as a soothing inhalant and for application to the skin It contains about 25% **benzoic acid**

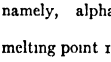
Frequently confused with this is the North American shrub *Benzoin aestivale*, often called Spice bush, which blossoms very early in the spring All parts of the shrub contain an aromatic substance which is very noticeable when the plant is bruised (R M W)

BENZOIN, BENZIL AND RELATED COMPOUNDS (For the resin, benzoin, see preceding article—**Benzoin**) When **benzaldehyde** (C_6H_5CHO) is warmed with **sodium** cyanide dissolved in alcohol, benzoin ($C_6H_5COCHOHC_6H_5$) white solid, melting point 137° C, is formed, and has the characteristics of a **ketone** and a secondary **alcohol** Benzoin, (1) upon reduction with sodium amalgam (sodium dissolved in mercury), forms hydrobenzoin ($C_6H_5CHOHCHOHC_6H_5$) white solid, melting point 134° C, mixed with isohydrobenzoin, melting point 110° C Hydrobenzoin yields an oxide of the formula (C_6H_5 CH — CH C_6H_5), which

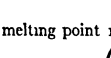
is known in two stereoisometric forms, symmetrical (inactive) and unsymmetrical (two optically active forms plus a racemic form), (2) upon reduction with zinc plus **acetic acid** or **hydrochloric acid**, forms desoxybenzoin ($C_6H_5COCH_2C_6H_5$), (3) upon oxidation with **nitric acid**, forms benzil, dibenzoyl, diphenyl glyoxal ($C_6H_5COCOC_6H_5$), yellow solid, melting point 95° C, most common alpha-diketone Two monoximes are known, namely, alpha-benzil monoxime (C_6H_5C—$CO\cdot C_6H_5$), HO—N (‖), melting point 140° C, beta-benzilmonoxime,



melting point 113° C; and three dioximes, namely anti-benzildioxime



, melting point 243° C; syn-benzildioxime



, melting

point 206° C.; amphi-benzildioxime

$$\left(\begin{array}{c} C_6H_5C\text{———}CC_6H_5 \\ \| \qquad\quad \| \\ N\text{—}OH\ N\text{—}OH \end{array}\right),$$

melting point 164° C. When benzil is heated with sodium hydroxide dissolved in alcohol, benzilic acid, diphenylglycollic acid $\left(\begin{array}{c} C_6H_5\ C\ C_6H_5 \\ \diagup\ \ \diagdown \\ HO\ COOH \end{array}\right)$, melting point 150° C, is formed

The related hydrocarbons are as follows

Symmetrical-diphenylethane (dibenzyl)	$C_6H_5CH_2\ CH_2C_6H_5$
Symmetrical-diphenylethylene (stilbene)	$C_6H_5CH \cdot CHC_6H_5$
Diphenylacetylene (tolane)	$C_6H_5C\ \ CC_6H_5$ (R K S)

BENZOPHENONE **Aldehydes, Ketones, and Related Compounds**

BENZOYL. **Radicals.**

BENZOYL CHLORIDE. **Chlorine.**

BENZYL. **Radicals.**

BERGAMOT OIL. An essential oil (See **Volatile Oils**) produced from the rind of the fruit of *Citrus bergamia*, a relative of the orange and lemon The small trees are cultivated in southern Europe and bear small yellow fruits From the skin of these the oil is expressed This oil is also used to some extent as a clearing agent in the preparation of material for microscopic examination (R M W)

BERGIUS PROCESS This is a process of catalytic **hydrogenation** of **coal** and **petroleum** under high pressure (R K S)

BERGSCHRUND. **Cirque.**

BERI-BERI A deficiency disease due to a lack of **vitamin** B in the diet This disease has been known for centuries in the Orient, and is especially liable to occur in jails, asylums and, formerly, on shipboard where diet was restricted In most cases of beri-beri in the Orient or in tropical countries it has resulted from an almost exclusive diet of polished rice If the external layers or husk portion of rice is not removed, beri-beri will not develop The main pathology that is found is degeneration of nerve tissue

Similar but milder pictures of this nerve degeneration are seen in vitamin B restriction in alcoholics who live for considerable periods on a restricted diet, obtaining the greater portion of their nourishment in a chemical liquid (alcoholic) form Nerve degeneration is also seen in pernicious **anemia**, and the symptoms are prevented and helped by liver extract injections, a potent source of vitamin B

The symptoms of beri-beri are multiple neuritis, with soreness and sensitiveness over nerves with numbness and tingling of the parts supplied by these nerves Later certain degrees of **paralysis** with muscular incoordination appears **Edema** or fluid-swelling in tissues may be marked There is listlessness, avoidance of exertion and severe heart weakness The disease untreated results in death

Treatment is merely eating of a regular normal diet More rapid improvement can be obtained by the administration of liver extract hypodermically and the administration of other less potent sources of vitamin B (R S M)

BERNOULLI'S LAW. An important law relating to the flow of **liquids**. Let the attention be fixed upon a small portion of the liquid, whose motion is traced along the line of flow. Then if, at any instant, the elevation of this particle above an arbitrary datum is denoted by e (centimeters), the pressure upon it by p (dynes per square centimeter), the speed at which it moves by v (centimeters per second), and the density of the liquid by ρ (grams per cubic centimeter, supposed constant), the total "head" of the liquid at this point is given by Bernoulli's equation as

$$e + \frac{p}{\rho g} + \frac{v^2}{2g} = H$$

g is the acceleration of gravity (centimeters per second per second) In hydraulics the three terms of the first member are commonly called respectively the "elevation head," the "pressure head," and the "velocity head" Bernoulli's law states that if the flow takes place without external interference, that is, without any work being done by or upon the liquid as it flows (an ideal condition, of course), then the total head H remains unchanged throughout the flow, a fact which follows from the principle of conservation of energy

Special cases arise when any one of the three terms is kept constant Thus if the flow is horizontal, so that e is constant, an increase in speed necessitates a decrease in pressure, a principle utilized in the **Venturi meter**. Many of the theorems of **hydrokinetics**, such as Torricelli's, may be derived from Bernoulli's law (L D W)

BERRY. A berry is a fruit in which the entire ovary wall becomes soft and fleshy, as in tomatoes and grapes Frequently, as in currants and gooseberries, the calyx tube grows around this ovary wall and forms the skin of the berry Strawberries, raspberries, mulberries, and so forth, are not berries in the botanical sense

Many other fruits are closely related to berries, but are distinguished by special names For example, melons, squashes and gourds are berries with a hard outer shell, and are called pepos, while a citrus fruit, such as an orange, lemon or grapefruit, etc, differs in having a tough leathery rind, and so is a modification of berry known as a hesperidium (R M W)

BERYL. The mineral beryl is a silicate of **beryllium** (glucinum) and **aluminum** corresponding to the formula $Be_3Al_2(SiO_3)_6$. Crystallizing in the **hexagonal system** the six-sided prisms of beryl may be very small or range up to several feet in length and a yard or so in diameter Terminated crystals are relatively rare Its fracture is **conchoidal**; hardness, 7 5–8, specific gravity, 2 63–2 80, colors, emerald green, green, blue green, blue, yellow, red, white and colorless, luster, vitreous, transparent to translucent The mineral beryl has long been used as a gem, the emeralds being a rich green variety, colored probably by minute amounts of some chromium compound A beautiful bluish sort is called aquamarine, morganite is pink, and the golden beryl is a clear bright yellow Other shades like honey yellow and yellowish green are common Beryl is found in granite rocks and especially in pegmatites, but it occurs also in mica schists in the Urals In addition to the many European localities as Austria, Germany, Ireland, etc, beryls of gem quality are found in Africa, Madagascar (especially for morganite), and Brazil The most famous place in the world for emeralds is at Muso, Colombia, South America, where they form a unique occurrence in limestones Emeralds are also obtained in the Transvaal and near Mursinsk, in Siberia In the United States, New England has furnished much beryl from its pegmatites and for a long time the huge crystals from Acworth and Grafton, New Hampshire, were the largest known Recently, however, giant crystals even larger than those from New Hampshire were discovered in Albany, Maine, the largest of which was 18 feet long, 4 feet through, and weighed about 18 tons Other localities are Paris and elsewhere in Oxford County, Maine; Royalston, Massachusetts, North Carolina, Colorado, South Dakota, and California. Metallic beryllium (glucinum) is ob-

tained from beryl Its lightness and strength make it very valuable for industrial purposes Alloyed with copper in small amount, it confers extraordinary properties on the copper The word beryl comes from the Greek meaning the gem beryl (E S C S)

BERYLLIUM OR GLUCINIUM. Symbol Be Atomic number 4 Atomic weight 9 02 Density 1 84 Melting point 1350°. No isotope, but single atomic form 9 (99 95%)

Beryllium is a silver-white, hard, malleable metal of markedly low density Beryllium is only slightly affected by water or cold **nitric acid**, but is readily dissolved by hot nitric acid, by **hydrochloric** or dilute sulfuric acid, and by **sodium** hydroxide solution, and when ignited in air forms beryllium oxide Chemically related to **magnesium** and **aluminum** Discovered by Vauquelin in 1797 On account of its lightness, strength, hardness and resistance to corrosion of alloys of beryllium extensive investigations have been undertaken with a view to its more common use

Beryllium occurs in beryl (11%–13% BeO) in the New England states, also in South Dakota and Colorado, in South Africa, Madagascar, Austria, and France The Copaux method of extraction consists in heating the beryllium aluminosilicate (beryl) with **sodium** silicofluoride, and later extracting with hot water, whereupon the beryllium salts are dissolved and thus separated from the other constituents **Electrolysis** of fused beryllium chloride at 700° C , a temperature below the melting point of beryllium metal, or of fused beryllium oxyfluoride mixed with barium fluoride at 1400° C , a temperature above the melting point of beryllium metal, are methods used to secure the metal

Hydroxide Beryllium hydroxide ($Be(OH)_2$), white, gelatinous precipitate by the reaction of **ammonium** hydroxide or sulfide with beryllium salt solutions This precipitate, while formed similarly to **aluminum** hydroxide, differs from the latter in being formed also by boiling a solution of beryllate, thus furnishing a separation from aluminum by boiling in sodium hydroxide (of 5 normal concentration)

Oxide Beryllium oxide (BeO), white solid, by ignition of the nitrate, hydroxide, or of the metal in air, an excellent refractory material, used in small amount in the mixture of oxides of **thorium** and **cerium** in the incandescent gas mantle

Beryllium dimethyl ($Be(CH_3)_2$), snow-white solid, sublimes at 200° C , and beryllium diethyl ($Be(C_2H_5)_2$), colorless liquid, of melting point 12° C and boiling point, at 15 mm pressure, 110° C , both compounds spontaneously inflammable in air, have recently (1927) been prepared by Gilman and Schulze. (R K S)

BERYLLONITE. A mineral composed of the rare **sodium beryllium phosphate**, which crystallizes in the **orthorhombic** system with short prismatic or tabular crystals Cleavage, perfect basal, hardness, 5–5 6, specific gravity, 2 8, luster is vitreous to somewhat pearly on the base, colorless to white or yellowish Attempts to make use of this mineral as a gem stone were unsuccessful owing to its relative softness Beryllonite is found at Stoneham and Newry, Oxford County, Maine (E S C S)

BESSEL, FREDERICK WILHELM (1784–1846). Frederick Wilhelm Bessel was born at Minden, Germany, on July 22, 1784 He showed promise of greatness as a mathematician very early in life, and at the age of twenty computed an accurate orbit of **Halley's comet**, using observations extending back to the **opposition** of 1607. As a result of the publication of this orbit **Bessel** was made assistant at an observatory in Lilienthal While at Lilienthal Bessel made a thorough investigation of the orbit of the comet of 1807 which attracted so much attention that he was summoned by the king of Prussia to erect the new observatory at Konigsberg At the completion of the observatory in 1813 **Bessel** was made the first director, a post which he held until his death

As director of the observatory at Konigsberg, Bessel began what may be called the modern era of practical astronomy His first task was to improve the star positions obtained by Bradley and from this list he published a catalogue of 3222 stars in which the positions were so accurate that they are still valuable for determination of **proper motions** and other reference purposes Having completed the reobservation of Bradley's Greenwich stars, Bessel set out to obtain accurate positions for all stars down to the ninth **magnitude** within the zone from −15° to +45° **declination** This task involved the observation of nearly 50,000 stars In connection with this problem he developed a system of application of corrections for **aberration**, **precession**, **nutation** and other minor effects which form the standard method of reduction of star positions at the present time

Besides his fundamental work on positions of stars Bessel was also active in a number of other astronomical measurements of precision He accurately determined the length of a **meridian** in East Prussia and from it made an accurate determination of the ellipticity of the earth He published the first known accurate value of **stellar parallax**, obtaining a value of 0″31 for the star 61 **Cygni** From a study of the proper motions of **Sirius** and **Procyon** he announced that these stars were *binaries* long before there was telescopic equipment of sufficient power to observe the companions

In addition to being worthy of being called the father of modern astronomy of precision Bessel was also a mathematician of note He is perhaps best known for his development of the so-called Bessel's Functions, which are a most valuable tool in modern analysis Bessel himself applied these functions to the solution of many complex problems in **celestial mechanics** In 1846, the year of his death, Bessel began a discussion of the **perturbations** of **Uranus** of the same type which later led to the discovery of the **planet Neptune** (W K G.)

BESSEL FUNCTIONS. The differential equation

$$x^2\frac{d^2y}{dx^2} + x\frac{dy}{dx} + (x^2 - n^2)y = 0$$

is called **Bessel's** equation It cannot be solved in terms of elementary functions It defines a new class of functions, the Bessel functions of the first kind, denoted by $J_n(x)$, and those of the second kind, denoted by $K_n(x)$ These functions are also sometimes called cylindrical functions

The functions $J_n(x)$ may be defined by the convergent series

$$J_n(x) = \sum_{k=0}^{\infty} \frac{(-1)^k x^{n+2k}}{2^{n+2k}\, k!\, \Gamma(n+k+1)},$$

and the functions $K_n(x)$ by the convergent series

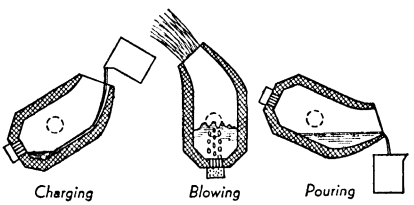
$$K_n(x) = J_n(x)\ \log x - \tfrac{1}{2}\sum_{k=0}^{n-1} \frac{(n-k-1)!\, x^{-n+2k}}{2^{-n+2k} k!} - \frac{1}{2}\sum_{k=0}^{\infty} \frac{(-1)^k x^{n+2k}}{2^{n+2k} k!\,(n+k)!}\ [H_k + H_{k+n}],$$

where $H_k = 1 + \frac{1}{2} + \frac{1}{3} + \cdots + \frac{1}{k}$ When n is an integer, the series for J_n may be written

$$J_n(x) = \frac{x^n}{2^n\, n!}\left[1 - \frac{x^2}{2(2n+2)} + \frac{x^4}{2\ 4(2n+2)(2n+4)} - \frac{x^6}{2\ 4\ 6(2n+2)(2n+4)(2n+6)} + \cdots\right]$$

When n is not an integer, the general solution of Bessel's differential equation is $y = c_1 J_n(x) + c_2 J_{-n}(x)$, where c_1 and c_2 are arbitrary constants When n is an integer, the general solution is $y = c_1 J_n(x) + c_2 K_n(x)$, where c_1 and c_2 are arbitrary constants (L.L.S)

BESSEMER PROCESS. The Bessemer process is one of four methods for making **steel,** the others being the crucible, the open hearth, and the electric processes. The pig iron (See **Blast Furnace**) used in the manufacture of steel must be refined to eliminate the impurities. The refining operation consists largely of oxidation of the impurities to effect their removal. In 1856 Sir Henry Bessemer gave the world his process for converting pig iron into steel. The Bessemer process is based on blowing compressed air through a mass of molten iron. On its way through the **iron,** the **oxygen** in the air combines with the **silicon, manganese,** and **carbon** in the iron, oxidizing them with the production of considerable heat. The "blow," as this oxidizing action is called, consumes only a short time, perhaps from ten to thirty minutes. After the blow, the liquid metal is recarburized to the desired point, and sometimes other alloying materials added, dependent on whether plain carbon steel or **alloy** steel is to be the final product. Spiegeleisen, a low grade ferro-manganese, high in carbon, is largely used in the manufacture of Bessemer steel.



Bessemer converter.

The Bessemer converter is often built in the form of a pear-shaped vessel having the top opening inclined towards the side. Tuyere openings for air are placed in or near the bottom of the converter, and the whole is mounted on trunnions so that it may be rotated into one or the other of three different positions, namely, inclined so that the opening is vertical for charging, upright during the blow, and horizontal for discharge of the finished product. The converter shell is made of steel plate and castings, and is lined with a **refractory** lining which may be either acid or basic, depending on the composition of the pig iron. Raw iron not containing phosphorus and sulfur is readily refined, by the blowing process just described, in a converter lined with a silicous material such as ganister. If the pig iron has considerable **phosphorus** and **sulfur** it is necessary to use a lining which has the proper fluxing characteristics, since phosphorus and sulfur are not readily removed by oxidation. Some of the materials for linings of the converter for the basic Bessemer process are mixtures containing limestone (**calcite**) and fire clay, **magnesite,** or calcined **dolomite.**

In the operation of the Bessemer converter it is necessary to have the whole charge and the converter intensely hot before beginning the blow. To this end the pig iron is either conveyed directly to the converter from the blast furnace, or is remelted in a cupola. The converter is prepared by firing with coal or oil until the lining it white hot. After the blow the iron is recarburized, and alloying elements are added and thoroughly mixed by stirring with a long iron bar and rocking the converter. (F.T.M.)

BETA FUNCTION. The beta function is a mathematical expression; it is one of the **transcendental functions** which occurs first in the advanced part of **Calculus.** It is also sometimes called an Eulerian integral of the first kind.

The **improper integral**

$$B(m, n) = \int_0^1 x^{m-1}(1 - x)^{n-1}dx \quad (m > 0, n > 0)$$

defines a **function of** m **and** n which is called the beta function. It can be expressed in terms of the **gamma function** by

$$B(m, n) = \frac{\Gamma(m)\Gamma(n)}{\Gamma(m + n)}.$$

(L.L.S.)

BETA PARTICLES, BETA RAYS. Radioactive Changes.

BETELGEUZE. Betelgeuze (α **Orionis**) is a contraction of an Arabic phrase indicating that this star is the "armpit of the central one," i.e., the armpit of Orion. Because of its rich reddish color the star has frequently been referred to as the "martial one," and in **Astrology** portends military or civic honors. Because it is the first star to rise of the brilliant and well known **constellation** of Orion, the title of "roarer" or "announcer" has been assigned to it by ancient writers.

Betelgeuze is of great interest astronomically. It is **an** irregular **variable** star. It is also one of the first stars to have its diameter measured with the stellar **interferometer.** The diameter is found to be variable between 260,000,000 and 180,000,000 miles. At maximum diameter the star would extend out beyond the **orbit** of **Mars** if put in the sun's place. (W.K.G.)

BETEL NUT. The fruit of the Areca palm, *Areca Catechu.* The Areca palm, a plant native to Malaya, is extensively cultivated in the southern Asiatic countries and in the East Indian Islands. It is a slender unbranched tree which reaches a height of 40 feet with a trunk diameter of 3 or 4 inches, and bears at its top a crown of six to ten large leaves. The fruit is slightly more than an inch in diameter and has a fibrous rind surrounding the very hard seed. This seed is extensively chewed in Asiatic countries. To prepare them for chewing, the fruits are gathered just before maturity, boiled, sliced and dried. A piece of this dried fruit, together with a bit of lime, is wrapped in a betel leaf and the whole placed in the mouth. Chewing this preparation causes an abundant flow of saliva which is colored brick-red and stains the mouth, as well as blackening the teeth. The betel leaves are obtained from an entirely different plant, the Black **Pepper,** *Piper betel.* (R.M.W.)

BEVELLED GEAR. Bevelled **gearing** is a means for transmitting rotation by toothed wheels from one shaft to another when the axes of the shaft intersect. The shafts may intersect at any angle, though, of course, the case of intersection at 90° is an important one. If the shafts do not intersect at 90°, the gearing is called skew bevel. Bevelled gearing to transmit rotation at constant speed between two shafts at 90° requires mating bevelled gears of the same size, called miter gearing. When the speed of the driven shaft is slower than that of the driving shaft, the driven gear is larger in diameter and is called the bevel gear, while the driving gear, the small one, is called the **pinion.**

Bevel gear and pinion.

Bevelled gears are made both with straight teeth and with spiral teeth. The gearing connecting the drive shaft of an automobile to the rear axle is one of the outstanding instances of the use of the spiral bevelled gear. While the cost of spiral bevelled gears is greater than for those with plain teeth, the quietness and strength, especially with pinions of small size having few teeth, are very definite advantages. However, spiral bevelled gears must be very accurately adjusted or they will tend to be noisy. If the **pinion** is moved toward the center of rotation

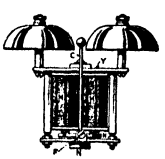
Spiral bevel gears.

of the large, or ring, gear, too far, the action which is known as "bottoming" of the gears, produces gear noise on the forward pull. Conversely, if the pinion is too far away from the center of the ring gear the noise occurs on the backward pull. If the ring gear is adjusted towards or away from the plane of the pinion shaft, the result is a moving of the line of contact between the teeth of the gears from the tip to the root of the tooth, or vice versa. By adjusting the pinion and the ring gear properly, cut spiral bevelled gearing may be made almost noiseless for both directions of rotation.

A blank for a bevel gear consists of a segment of a cone with a back surface also a segment of a cone. Theoretically, this back surface should be the surface of a sphere, but it is common practice to lay off the tooth profile on a back cone. Mating bevelled gears cause a thrust along their respective shafts, which must be allowed for in their design and operation. (F.T.M.)

BHARAL. Mammalia, Artiodactyla. The blue **sheep**, *Pseudois nayaur*, of Tibet. The species is closely related to the goats. (A.W.L.)

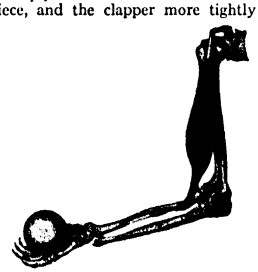
BIASED RINGER. The common telephone ringer, or bell, is operated by a clapper which is set in motion as follows: The clapper is attached to the middle of an **armature**, and together with that armature, is pivoted at F. Two **magnets**, one a permanent magnet, N, the other an electromagnet, M, are so arranged that when no current flows through the windings of the electromagnet, there is no net pull tending to displace the armature. But when an **alternating current** is passed through the windings, the flux from the electromagnet opposes that from the permanent magnet at one end of the armature, and adds it in the other, resulting in a motion of the armature around its pivot, carrying with it the clapper which taps the bell. In order to get a steady ring instead of a single stroke, there are two bells having the clapper between them, and alternating current of a frequency low enough to permit the armature system to follow it is used to cause the armature to oscillate in a vibratory fashion under the influence of the changing magnetic attractions of the combined permanent and electro-magnets. Where it is desired to have a multiple party line, a biased ringer is used, with pulsating instead of alternating current. A small spring holds the armature against one of the electro-magnetic cores, so that the clapper is against one bell. This biases the ringer. The pulsating current flowing in the direction needed for ringing will ring the bell, but in the opposite direction will simply hold the armature more tightly to the pole piece, and the clapper more tightly against the bell. If the armature is biased in the opposite direction by a spring on the other end of the armature, it will respond to a pulsating current of opposite polarity. (F.T.M.)



Telephone ringer.

BIAXIAL CRYSTALS. Double Refraction.

BICEPS. Any of several **muscles** with two heads. The principal examples are (1) the biceps femoris which, in man, lies in the back part of the thigh and flexes the lower leg, and (2) the biceps of the upper arm which flexes the lower arm. (A.W.L.)



Biceps muscle contracting forearm.

BICHIR. Pisces, Chondrostei. An air-breathing fish, *Polypterus*, found in the Nile, one of a few living representatives of a group which was once abundant and is supposed to have been ancestral to the bony fish. It was formerly thought that *Polypterus* belonged to the Crossopterygii, a group of fish (**Pisces**) ancestral to the terrestrial vertebrates. (A.W.L.)

Bichir.

BICUSPID. A tooth with two cusps, especially the premolars of man. (A.W.L.)

BIELIDS. Bielids or Andromedes are the names applied to a **meteor shower** which is observed about November 24th of each year. The **radiant point** of the shower is in the **constellation** of **Andromeda.**

The history of the Bielids and their connection with Biela's **Comet** is one of the interesting chapters in the development of meteoric astronomy. Biela's Comet was first discovered in 1772 but was not found to be periodic. In 1826 Biela discovered the comet again and it now bears his name. Its **orbit** is elliptical with a period of about six years. In 1832 the comet passed very close to the earth. In 1845 the comet was observed to break in two, and in 1852, at the time of the predicted return, it was found that the two parts of the comet were both very faint and separated by over a million miles. They were unfavorably located relative to the sun for observation in 1859, and at the time of the return in 1866 they were not to be found.

The first mention of a swarm of meteors located on the orbit of Biela's comet is found in the display of December 5, 1741, when a brilliant shower was observed in Russia. They were observed during December in 1798, 1830, and 1838. By this time calculations of the radiant point had been made and it was first located, apparently, in **Cassiopeia.** By 1867 the date of the shower had shifted to November and it has always been observed in that month since that year. Up to 1885, many brilliant meteors were associated with the radiant point with from two to four observers on November 27 of that year observing no less than 39,546 meteors in four hours and eight minutes. Since 1899, but very few members of the shower have been observed and it is evident that **perturbations** have shifted the orbit of the main swarm well outside the orbit of the earth. (W.K.G.)

BIENNIAL. Many plants, including some of the commonest cultivated ones, require two years of growth to complete their life-cycle. Such plants are called biennial. During the first year of growth they commonly form a close rosette of leaves growing from a very short stem, and spreading out close to the ground, and develop a thick tap root in which is accumulated a considerable amount for food reserves. During the second year of growth this reserve food is drawn upon to permit the development of a tall stem and flowers and fruit. **Beets** and **carrots** are examples of biennial plants in which the root rich in stored food reserves becomes an important source of food for man. (R.M.W.)

BIGHORN. Mammalia, Artiodactyla, *Ovis*. The mountain **sheep**, ranging from Alaska to Mexico and eastward into the bad lands of South Dakota. Several species and varieties are recognized in different parts of this range. (A.W.L.)

BILE. Bile is a secretion of the **liver,** alkaline in reaction, yellow, brown or green in color It consists of water, bile salts (sodium glycocholate and sodium taurocholate), inorganic salts, bilge pigments (See **Pyrrole and Related Compounds**), **cholesterin,** and lecithin (See **Aminoacids, Polypeptides, and Proteins**) About a quart of bile is secreted every twenty-four hours, the quantity depending on the amount and kind of food eaten.

The bile salts are important, they stimulate the liver and have other functions of which little is known After being secreted in the bile, the bile salts to a large extent are reabsorbed in the intestine and resecreted by the liver The amount of bile pigments present determines the color of the bile

The action of bile in the **digestion** of food is concerned with **fats.** Bile, plus the action of the **pancreatic** secretion, serves to break down the fats to **glycerin** and **fatty acids.** It is also supposed to have an antiseptic action in the intestine preventing putrefaction Other functions of bile are not definitely known

The bile is secreted by the liver into the biliary channels in the liver which enter the common bile duct The bile duct enters the **duodenum** where a muscular **sphincter** controls the amount of flow into the intestine Fatty foods and certain drugs cause the sphincter to open so that more bile escapes into the intestine

If the flow of bile is prevented through obstruction, by stone formation, or by swelling of the bile duct walls from infection, the bile backs up and is absorbed by the blood stream and carried throughout the system Such a condition results in **jaundice** The same results follow if sufficient number of the smaller bile channels in the liver are obstructed (R S M)

BILL. The **beak** of a bird (A W L)

BILLFISH. Pisces, Teleostei The garfish (**Pisces**), a marine species found from Massachusetts to Texas and ascending the rivers Not to be confused with the garpikes or gars (A W L)

BINARY GRANITE. **Granite.**

BINARY STARS The term binary star was apparently first introduced by Sir William Herschel in 1802 to designate "a real double star—the union of two stars that are formed together in one system, by the laws of attraction" At present, binary stars are classified under three headings **visual binaries, spectroscopic binaries,** and **eclipsing binaries** under which headings the characteristics of the different types will be found discussed elsewhere in this work

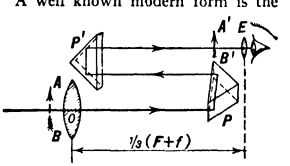
During the past one hundred and fifty years a large amount of research has been carried out on the binary systems leading to certain general conclusions It is believed that at least one-fourth of all stars are at least binary systems, with a considerable percentage, possibly as great as ten percent, of these systems multiple systems, i e, containing more than two stars There is a direct correlation between the period of revolution of a binary star and the eccentricity of its **orbit,** with the systems of short period having the smaller eccentricities There is a regular gradation from pairs with short period in which the stars are practically in contact up to pairs so widely separated that the physical connection is only indicated by their common **proper motion** through space Finally, in pairs in which the components are equal in brightness both stars have the same **spectral type,** while in systems where the brightnesses are different the fainter star is bluer if the brighter star is a **giant;** and redder if the brighter star belongs to the main sequence

Since mass can be determined only from **gravitational** attraction and the only stars (with the exception of the **sun**) for which gravitational attraction can be determined are the binary stars, these objects form the one group from which the masses of stars may be determined In the case of a visual binary star, after the orbit has been determined and the **stellar parallax** of the system obtained, the combined masses of the two stars may be obtained by a direct application of the **Keplerian Harmonic Law.** Unfortunately, it is impossible to obtain the complete orbit of a spectroscopic binary unless it is also a visual or an eclipsing binary, so from these objects a determination of mass is impossible except on the basis of a statistical discussion In the case of those eclipsing binaries which are also spectroscopic binaries it is possible to make a complete solution for the specifications (i e, masses, densities, sizes, luminosities, and approximate shapes) of both members of the system From such objects, and only from such objects, may the complete characteristics of individual stars be determined (W K G)

BINNACLE. The stand for supporting and protecting the steering **compass** on board a ship is known as the binnacle This stand is usually constructed of brass and is provided with a shaded light which illuminates the compass during the night, but does not shine in the eyes of the helmsman

In addition to protecting the compass from effects of weather the binnacle also contains a number of fixed and adjustable magnets and masses of soft iron for the purpose of partially compensating for the effects of the **magnetic field** of the ship The process of adjusting the various compensating devices is known as compass adjusting and is usually carried on by experts while a ship is in port (W K G)

BINOCULAR. An instrument composed of two similar **telescopes,** one for each eye, usually with **focusing** tubes controlled by a common screw adjustment The ordinary opera glass is a binocular utilizing Galilean telescopes The field glass employs erecting telescopes of the spy glass type A well known modern form is the "prism binocular" The special feature of this instrument is a pair of right-angled, total reflection **prisms** in each telescope, which contribute three advantages — (1) The prisms, by means of two double total reflections in planes at right angles, accomplish the erection of the image without additional lenses (2) The tube is rendered much shorter than in the ordinary field glass of equal power by the "doubling up" of the rays due to the reflections (3) The objectives are by the same means set farther apart than the eyepieces, thus increasing the "stereo power" of the instrument as a binocular, so that objects can be seen to have depth or solidity at a greater distance than with the ordinary type (See **Binocular Vision.**) (L D W)



Optical system of prism binocular
(Weld and Palmer, Textbook of Modern Physics, Blakiston)

BINOCULAR VISION. The possession of two **eyes** set at a distance apart, but with approximately parallel axes, enables us to obtain two views from slightly different angles, and thus to become sensible of the solidity of single objects and to get an idea of the actual distribution of different objects in space To become vividly conscious of this faculty, one has only to look about the room for a time with a hand cupped over one eye, and then suddenly to remove the hand If the vision is reasonably normal, it will be noticed that with one eye only the scene appears flat, like a photograph, but as soon as both eyes are used, objects spring into clear relief In some manner the brain is able, through long experience, to blend the two different sensory pictures

from the two different **retinal** images and to interpret the resulting sensation in terms of geometrical solidity There is, however, a limit to the distance at which this impression is perceptible, and for very distant objects other factors must be relied upon, such as the apparent size (as of buildings or trees), or the opacity of the atmosphere (as in viewing distant mountains) In the absence of such factors, no estimate of distance can be formed, thus the stars all appear to be at the same distance This limiting "stereoscopic radius" is for normal, unaided eyes, only a few hundred feet, but with a **binocular** telescope, and especially with a prism binocular, it is increased in a ratio called the "stereo power" of the instrument.

An interesting aspect of the subject is the use of binocular pictures and the stereoscope Two photographs or drawings are prepared of the same group of objects from viewpoints approximately the same distance apart as the human eyes (say about 2¾ inches) and mounted side by side on a card so that each is viewed separately by the eye to which it corresponds, the observer gets the sensation of viewing a three-dimensional scene The observation is facilitated by a pair of lenses so designed as to allow of focusing the eyes for distance, and with a diaphragm set up between them to avoid seeing both pictures with either eye This arrangement is the stereoscope (I D W)

BINOMIAL COEFFICIENTS. Binomial Formula.

BINOMIAL FORMULA. The binomial theorem gives a formula expressing any **power** of a binomial $a + x$ in terms of powers of a and x

Binomial Theorem If n is any positive integer, the expansion of $(a + x)^n$ is given by

$$(a+x)^n = a^n + na^{n-1}x + \frac{n(n-1)}{2!}a^{n-2}x^2 + \frac{n(n-1)(n-2)}{3!}a^{n-3}x^3 + \cdots + \frac{n(n-1)(n-2)\quad(n-r+1)}{r!}a^{n-r}x^r + \cdots + nax^{n-1} + x^n,$$

where there are $n + 1$ terms on the right If n is not a positive integer, the binomial expansion becomes an **infinite series:**

$$(a+x)^n = a^n + na^{n-1}x + \frac{n(n-1)}{2!}a^{n-2}x^2 + \cdots + \frac{n(n-1)(n-2)\quad(n-r+1)}{r!}a^{n-r}x^r + \cdots$$

which is convergent for $|x|<|a|$

The symbol $m!$, called factorial m, is the repeated product 1 2 3 m of all the positive integers from 1 to m inclusive, it is also sometimes denoted by $\underline{|m}$

The r^{th} term (general term) of the binomial expansion $(a + x)^n$ is

$$\frac{n(n-1)(n-2)\quad(n-r+2)}{(r-1)!}a^{n-r+1}x^{r-1},$$

sometimes the general term is taken as the $(r + 1)st$ term:

$$\frac{n(n-1)(n-2)\quad(n-r+1)}{r!}a^{n-r}x^r.$$

The coefficients in the binomial expansion are called binomial coefficients They are often denoted by the symbols 1, $\binom{n}{1}$, $\binom{n}{2}$, $\cdots$, $\binom{n}{r}$, $\cdots$, so that

$$\binom{n}{r} = \frac{n(n-1)(n-2)\quad\cdots(n-r+1)}{r!}.$$

By the formula for **combinations**, it follows that $\binom{n}{r} = {}_nC_r$

The binomial theorem is often written:

$$(1+x)^n = 1 + \binom{n}{1}x + \binom{n}{2}x^2 + \binom{n}{3}x^3 + \quad + \binom{n}{r}x^r + \cdots$$

in terms of the binomial coefficient notation

The binomial coefficients may be arranged in an interesting scheme called Pascal's triangle

```
                1
              1   1
            1   2   1
          1   3   3   1
        1   4   6   4   1
      1   5  10  10   5   1
    1   6  15  20  15   6   1
  1   7  21  35  35  21   7   1
1   8  28  56  70  56  28   8   1
```

where each row of numbers represents the binomial coefficients of a certain power of a binomial

The binomial formula gives the following important approximation

$$(1 + x)^n \approx 1 + nx$$

if x is sufficiently small, special cases are

$$(1+x)^2 \approx 1 + 2x, \qquad (1-x)^2 \approx 1 - 2x,$$
$$(1+x)^3 \approx 1 + 3x, \qquad (1-x)^3 \approx 1 - 3x,$$
$$\frac{1}{1+x} \approx 1 - x, \qquad \frac{1}{1-x} \approx 1 + x,$$
$$\sqrt{1+x} \approx 1 + \tfrac{1}{2}x, \qquad \sqrt{1-x} \approx 1 - \tfrac{1}{2}x,$$
$$\frac{1}{\sqrt{1+x}} \approx 1 - \tfrac{1}{2}x, \qquad \frac{1}{\sqrt{1-x}} \approx 1 + \tfrac{1}{2}x,$$

if x is sufficiently small (L L S)

BINOMIAL THEOREM Binomial Formula.

BINTURONG. Mammalia, Carnivora An Oriental species, *Arctictis binturong*, related to the civets It is cat-like in appearance with tufted ears and a long, slightly bushy tail (A W L)

BIOCENOLOGY. The division of biological science which considers the factors binding populations of animals together as units in relation to environmental conditions A subdivision of **ecology.** (A W L)

BIOCHEMISTRY Biochemistry is that branch of the science of chemistry which deals with the chemical processes and products of living organisms The fundamental biochemical process upon which living organisms are dependent is that of **photosynthesis** which takes place in the green leaf of the plant Under the influence of sunlight, the green leaves of plants, through the presence of **chlorophyll**—the green coloring matter of plants—and water, fix **carbon dioxide** of the atmosphere (about 0 03 percent carbon dioxide of the atmosphere) into **glucose**, and ultimately into **sucrose, starches, celluloses, carboxylic acids, tannins** and **fats.** By means of **nitrogen** supplied from the soil, certain plants synthesize **proteins** (in **legumes,** cereal grains, seeds) and many other nitrogen containing organic substances, such as the **alkaloids.** The sugars, starches, celluloses, fats and proteins are the diet of herbivorous animals These animals serve as food producers for their own and other kinds of animals, supplying these with protein and fat in the form of milk, eggs, and meat See **Foods; Carbohydrates; Fats; Aminoacids and Proteins; Photosynthesis.** Compounds of three carbon atoms form the common intermediary by which carbohydrates, fats and proteins are mutually interconvertible Such three carbon compounds are lactic acid ($CH_3CHOHCOOH$), pyruvic acid ($CH_3COCOOH$), glyceric aldehyde ($CH_2OHCHOHCHO$), and pyruvic aldehyde (CH_3COCHO)

Chemical reactions of a specific character take place throughout the lifetime of each animal in each organ of its body. In the **stomach** there occurs acid digestion of

foods, in the **intestines** alkaline digestion of foods, in the **lungs** absorption of oxygen into and liberation of carbon dioxide from the blood stream, in the **liver** production of glycogen and transformation of protein nitrogen into urea The **thyroid** gland contains ten times as much iodine as any other organ of the body, and the thyroid secretion stimulates carbohydrate and calcium **metabolism** and exercises an effect on body fats Over-secretion of the thyroid gland may result in **goiter,** whereas undersecretion may result in stunted growth or in great increase of weight from fat, accompanied by slow metabolism and retarded bone-growth

The composition of the vegetation of the earth is estimated to consist of the four elements, **carbon, oxygen, hydrogen, nitrogen** in total amount 95 percent, and of the nine elements, **potassium, sodium, calcium, magnesium, silicon, sulfur, phosphorus, chlorine, iron** in total amount nearly 5 percent These thirteen elements are stated above in the order of their decreasing abundance The first three, carbon, oxygen and hydrogen are derived from carbon dioxide of air and from water of air and soil These, along with soluble nitrate nitrogen and the small amounts of the second group of nine elements supplied from the soil, are manufactured by the plant into its component materials, largely carbohydrates, fats and proteins About 80 to 90 percent of the weight of the plant cell is water, and only in resting tissues, such as those of dried seeds, is the percentage of water small

The composition of the human body is estimated to consist of the four elements, oxygen, carbon, hydrogen, nitrogen in total amount 96 percent, and of the seven elements, calcium, phosphorus, potassium, sulfur, sodium, chlorine, magnesium, in total amount about 4 percent Traces of several other elements are also present in the body, **fluorine** 0 01%, **iron** 0 005%, **silicon, bromine, aluminum, manganese** about 0 001% each, and iodine still less Small percentages of certain elements play a determining role in the functioning of certain parts of the body, e g , iodine in the thyroid, and iron in the blood (R K S)

BIOECOLOGY. The division of biological science which treats the general relations of living things (A W L)

BIOGENESIS The established principle that all living things spring from previously existing living things. **Abiogenesis.** (A W L)

BIOHERM. A geologic term for beds or mounds of colonial and gregarious marine **fossils** with calcareous shells or skeletons Present day bioherms are usually referred to as **coral reefs.** (R M F)

BIOLOGICAL SURVEY A governmental agency which gathers data on the wild life of the country, makes this information available to the public through official publications, takes an active part in conservation, and aids in the control and eradication of harmful organisms

The United States Bureau of Biological Survey is a subsidiary of the Department of Agriculture which is primarily occupied with work on birds and mammals The insects are dealt with by the Bureau of Entomology and Plant Quarantine and the fishes and many marine invertebrates by the Bureau of Fisheries The Bureau has an extensive organization reaching to all parts of the national domain and is especially important in the establishment of game refuges, the protection of game by all available measures, the extension of assistance in the propagation of game species, and the control of predatory animals

The work of the United States Bureau is supplemented by that of state biological surveys The latter, however, are limited chiefly to the study of wild life and the publication of records Conservation activities in the states are usually in the hands of special bureaus with greater power and resources than the biological surveys. (A W L)

BIONOMICS. The division of biological science which treats the relations of living things to each other and to the environment (A W L)

BIOPSY. A diagnostic procedure by means of examination of a piece of tissue removed from a living patient The tissue is usually examined under a microscope after sectioning and staining In this way an accurate diagnosis can be made, especially in cases of cancer and tuberculosis (R S M)

BIOSTROME A geologic term for layers, beds, or strata composed of calcareous fossil shells which form **coquina,** or shell-limestone The term biostrome is primarily intended to distinguish shell-limestone from **bioherms,** or typical coral reefs (R M F)

BIOTHERM The principal factor determining the geographical distribution of a plant in a north-south direction and also the maximum height at which a plant may grow on a mountain is temperature Using this as a basis, C H Merriam determined the life zones in North America Each zone is marked off on the basis of the total heat above 43° F available for growth in a single season, these are the biotherms There are three main belts in North America—the Boreal, covering much of Canada and extending to the far north, with arms projecting southward to include high mountains, the Austral, which includes most of the United States and Mexico, except for the high mountains, and the Tropical belt, which covers the southern tip of Florida, the coastal regions of Mexico and the Central American countries These principal belts are subdivided into narrower zones according to the flora present (R M W)

BIOTIC AREA. A geographical division characterized by certain environmental factors which determine the nature of its population (A W L)

BIOTIC FACTOR. Plants are profoundly affected by various environmental factors Among these are the effects of other plants and various animals The living forces are the biotic factors, which severally affect every part of a plant In the soil are countless numbers of **bacteria,** including the nitrogen-fixing group, which are of tremendous importance to the plant Here also are earthworms and various soil-inhabiting animals Above ground are the many animals which feed on the plant and also the numerous parasites which attack it Large numbers of these parasites gain entrance to the plant tissues, where their presence may cause very great changes Again, there is the effect which any plant may have on its neighbors in the constant struggle for existence Many plants are much more aggressive than others, and so able to invade new regions, where they crowd out native plants already present Plants of this type include many of the common **weeds** Finally a very important biotic factor is man He is constantly disturbing the established balance by his activities, often with serious consequences to himself Wittingly or otherwise he introduces many new plants into regions where their presence is not desirable He cuts off forests, and so leads to the destruction of shade-loving or shade-tolerant plants which grew under the trees Many indeed are the **fungous** pests which he has carried to new regions, where the fungus has found new hosts which had not developed resistance and so readily succumbed to the parasite (R M W)

BIOTIC POTENTIAL. A quantitative expression of the dynamic significance of various inherent vital properties of living things as a factor in the establishment of external relationships It summarizes the reproductive and survival potentialities of the organism (A W L)

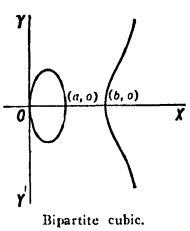
BIOTIC RESISTANCE. The living factors in the environment of an organism which tend to hinder its normal increase. Parasitic and predacious enemies and organic food supply are outstanding examples. (A.W.L.)

BIOTITE. A common **silicate** mineral containing **potassium, magnesium, iron** and **aluminum,** sometimes called "iron mica," is found in granitic rocks, **gneisses, schists,** etc. Although actually **monoclinic,** it often assumes a pseudo-**hexagonal** form. Like the others of the **mica** group biotite shows a highly perfect basal cleavage. It has a hardness of 2.5 to 3.; specific gravity, 2.7–3.1; luster, pearly to vitreous or sometimes submetallic when very black in color; cleavage sheets are elastic; color, greenish to brown or black; transparent to opaque.

Biotite is occasionally found in large sheets, especially in **pegmatite** veins and also occurs as a contact metamorphic mineral or the product of the alteration of **hornblende, augite, wernerite** and similar minerals.

Biotite occurs in the lavas of Vesuvius, at Monzoni, and many other European localities. In the United States and it is found especially in the pegmatites of New England and of Virginia and North Carolina and the granite of Pike's Peak, Colorado. Biotite was named in honor of the French physicist, J. B. Biot. (E.S.C.S.)

BIOT-SAVART LAW. A law expressing the intensity of the **magnetic field** in the neighborhood of a long, straight wire carrying a steady **current.** If a permanent **magnet** is rigidly attached to a rod or frame which is capable of rotation about such a wire as an axis, with both of its poles on one side of the wire, and in general at different distances therefrom, it is found that there is no resultant **torque** about the wire. From this it is readily shown that the field intensity varies inversely as the distance from the wire. If the current is i (abamperes) and the distance r (centimeters), the intensity is given by the Biot-Savart law as $H = 2i/r$ (*oersteds*). **Ampère's law** is sometimes called by this name, since either of the two laws may be deduced from the other. (L.D.W.)



Bipartite cubic.

BIOTYPE. A group of individuals of similar hereditary organization. (A.W.L.)

BIPARTITE CUBIC. This name is given to the curve whose equation in **rectangular coordinates** is

$$y^2 = x(x-a)(x-b) \qquad (o < a < b).$$

Its shape is shown by the accompanying figure (L.L.S.)

BIPINNARIA. The form of **dipleurula** larva found in the starfishes (**Asteroidea**). It is bilaterally symmetrical and has a ciliated band. (A.W.L.)

BIPRISM. Young's Interference Experiment.

BIQUADRATIC EQUATIONS. Quartic Equations.

BIRAMOUS APPENDAGE. The primitive jointed appendage of the **arthropods,** still found in various form in the **crustaceans.**

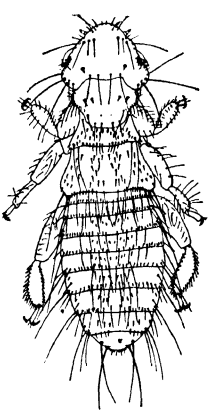
The appendage consists of a single basal portion called the protopodite which is usually divided into a proximal coxopodite and a distal basipodite. It may bear on its outer margin one or several lobes called epipodites. From the protopodite two branches arise, an inner endopodite and an outer exopodite; this characteristic of the appendage is responsible for the name biramous. The endopodite is divided into five or less segments, named in order from the base the ischiopodite, meropodite, carpopodite, propodite, and dactylopodite. The exopodite is much less uniform and is often lacking.

These appendages have become modified and specialized for many functions in the existing crustaceans, as is nicely demonstrated by the appendages of the **crayfish** and **lobster.** In these animals they form sensory organs (antennae), mouth parts (jaws and accessory appendages), walking legs, swimmerets, accessory reproductive organs, and broad, flat swimming appendages. They are also regarded as the form from which the simpler jointed appendages of insects and other arthropods have been evolved. (A.W.L.)

BIRD. A warm-blooded feathered vertebrate. See **Aves.** (A.W.L.)

BIRD OF PARADISE. Aves, Passeriformes. Any bird (**Aves**) of numerous beautiful species which make up the family Paradiseidae. They are characterized by the gorgeous colors and bizarre forms of the plumage and are unsurpassed in splendor by any other group of birds, although they are fairly near to the crows in classification. Most of the species are found in New Guinea. (A.W.L.)

BIRD-LOUSE. Insecta, Mallophaga. A wingless ectoparasitic insect with biting mouth parts. Most species of bird lice live among the feathers of birds and eat bits of feather and other debris. Although a few species are found on mammals the prevailing type of host has given its name to the entire order; the name biting lice is also distinctive.


Bird-louse

The bird-lice which affect poultry are economically important. Even though they do not suck blood like other parasites the irritation resulting from their presence in large numbers is serious to the birds. Various measures of control have been devised, among them whitewashing roosts, oiling perches with kerosene, and the use of various insect powders in nests and on the birds themselves. The maintenance of clean surroundings for the flock is of the utmost importance in preventing severe infestation. (A.W.L.)

BIRD'S NEST FUNGI. Basidiomycetes.

BISHOP-BIRD. Aves, Passeriformes. Any bird (**Aves**) of several brightly colored species of African weaverbirds which make up the genus *Pyromelana.* The name has also been applied in the past to some of the brightly colored birds of North America, especially by the early settlers in Louisiana. (A.W.L.)

BISMUTH. Symbol: Bi. Atomic number: 83. Atomic weight: 209.00. Density: 9.8. Hardness: 2.5. Melting point: 271° C. Boiling point: 1450° C.

Bismuth is a white metal having a reddish tinge, lustrous, brittle, not very hard, somewhat malleable, not very ductile, when bent at 100° C. emits a creaking sound due to friction of the crystals; permanent in air or ordinary temperatures, burns to the trioxide upon heating to high temperature; insoluble in **hydrochloric**

or dilute **sulfuric acid,** soluble in **nitric acid** to form nitrate; heated with **chlorine** yields chloride. Discovered by Valentine in 1450. Bismuth metal is used in alloys, for bearing or anti-friction metals, and for fusible metals. The salts of bismuth are frequently used in medicine, principally in (1) digestive disorders as a soothing protective to irritated mucous membranes, (2) in **X-ray** diagnostic examination where the opacity of bismuth makes simple the production of contrast pictures of the entire gastro-intestinal tract, (3) in the treatment of **syphilis** where it is given intramuscularly by hypodermic injection.

Bismuth occurs as native bismuth in Bolivia and Saxony and frequently is associated with lead, copper, and tin ores—the sulfide (**bismuthinite,** bismuth glance, Bi_2S_3) is also found in nature. Separation of bismuth from lead takes place during the **electrolytic** refining of the latter with bismuth remaining in the anode mud.

Chlorides: bismuth chloride ($BiCl_3$), white crystals by reaction of (1) bismuth metal heated with **chlorine,** (2) bismuth oxide and **hydrochloric acid,** and then crystallizing, reactive with water to form oxychloride; bismuth oxychloride, bismuth subchloride (BiOCl), white solid, soluble in hydrochloric acid.

Hydroxide: bismuth hydroxide ($Bi(OH)_3$), white precipitate, by reaction of bismuth salt solutions and alkalis, soluble in hydrochloric, sulfuric, or nitric acid.

Nitrates: bismuth nitrate ($Bi(NO_3)_3 \cdot 5H_2O$), white crystals, by reaction of (1) bismuth metal or oxide and **nitric acid,** and then crystallizing, reactive with water to form oxynitrate; bismuth oxynitrate, bismuth subnitrate ($BiONO_3$), white solid, soluble in nitric acid, used in cosmetics, in pharmacy, in producing luster on metals, in enamels on ceramic ware.

Oxides: bismuth oxide, bismuth trioxide (Bi_2O_3), pale yellow to brownish solid (1) by heating bismuth hydroxide or nitrate, (2) by burning bismuth at a high temperature in air, soluble in hydrochloric, sulfuric, or nitric acid; bismuth textroxide (Bi_2O_4), yellow to brown solid by reaction of bismuth trioxide and sodium hypochlorite solution; bismuth pentoxide (probably $Bi_2O_5 \cdot H_2O$ or $HBiO_3$), scarlet red, by electrolytic oxidation of bismuth trioxide in alkali, decomposes when heated at 150° C. yielding trioxide and oxygen.

Sulfates: bismuth sulfate ($Bi_2(SO_4)_3$), white crystals, by reaction of bismuth trioxide and sulfuric acid, and then crystallizing, reactive with water to form bismuth oxysulfate; bismuth oxysulfate, bismuth subsulfate ($(BiO)_2SO_4$), white solid, soluble in sulfuric acid.

Sulfide: bismuth sulfide (Bi_2S_3), dark brown precipitate, by reaction of bismuth salt solution and **hydrogen sulfide,** soluble in hot dilute nitric acid, insoluble in **sodium** or **ammonium** sulfide. (R.K.S.)

BISMUTHINITE (Bismuth glance). A mineral containing a **sulfide** of **bismuth** and sometimes **copper** and **iron;** a variety from Mexico contains about 8% **antimony.** Bismuthinite is **orthorhombic** although its thin needle like crystals are rare as it usually occurs in foliated or fibrous masses. It has one good cleavage parallel to the prism; hardness, 2.; specific gravity, 6.4–6.5; metallic luster; streak, lead gray; color, similar but often with iridescent tarnish; opaque.

Bismuthinite is a rather rare mineral although somewhat widely distributed. European localities are in Norway, Sweden, Saxony, Rumania, and England. It is found also in Bolivia, Australia, and in the United States in Utah. It is used as an ore of bismuth. (E.S.C.S.)

BISON. Mammalia, Artiodactyla. A large hoofed animal with a prominent hump, short curved horns, and in the male sex a heavy mane. Two species occur, the European *Bison bonasus,* and American, *B. americanus.* The former is a browsing forest species of northern Europe and the latter a grazing species, formerly very abundant on the plains of North America but now restricted to a few protected herds.

The romantic—and tragic—story of the American bison is known to everyone. A mainstay of the plains Indians for food, hides for the construction of shelters, and fuel in the form of buffalo chips, it served the same purposes for early settlers, but the greater destructiveness of firearms and the availability of an eastern market for hides soon threatened its extinction.

The European bison also goes by the names wisent and zubr but the name aurochs, sometimes applied to it, is not correctly used here. (A.W.L.)

BITING LOUSE. Bird louse.

BITTERLING. Pisces, Teleostei. Fishes (**Pisces**) of several species allied to the carp. One, *Rhodeus amarus,* lives in Europe and the others in Eastern Asia. (A.W.L.)

BITTERN. Aves, Ciconiiformes. Wading birds (**Aves**) allied to the herons and egrets. They have moderately long legs and a straight beak which is strong and sharp. Two species, the American, *Botaurus lentiginosus,* and least, *Ixobrychus exilis,* bitterns, occur in North America, and several others are found on other continents. (A.W.L.)

BITUMEN. A general term for petroliferous substances ranging from true **petroleum** through the so-called mineral tars to **asphalt.** (R.M.F.)

BITUMINOUS COAL. Coal.

BIURET. Amines and Amides.

BIVALVE. A shell composed of two distinct parts or valves. Such shells are secreted by **brachiopods,** in which the valves are dorsal and ventral, and by certain **crustaceans** (Ostracoda) and **molluscs** (Pelecypoda) in which the valves are lateral. The most common examples of bivalves are among the edible molluscs, including **clams, oysters,** and **scallops.** (A.W.L.)

BLACK APE. Mammalia, Primates. A **monkey,** *Cynopithecus niger,* of Celebes whose rudimentary tail gives it some superficial likeness to the apes. It has an elongate muzzle and is related to the **macaques** and **baboons.** (A.W.L.)

BLACKBIRD. Aves, Passeriformes. 1. The ouzel of Europe. 2. Several species of North American birds of the genus *Agelaius* related to the orioles and grackles, and sometimes applied to the grackles as well. 3. In the West Indies applied to the ani, a member of the order Cuculiformes. (A.W.L.)

A North American red-winged blackbird. Glossy black, shoulders scarlet, edged with yellowish. Female streaked with no red.

BLACKBERRY. Rose family.

BLACK BODY. This term denotes an ideal body which would, if it existed, absorb all and reflect none of the **radiation** falling upon it; its reflectivity would be zero and its absorptivity would be one hundred per cent. Such a body would, when illuminated, appear perfectly black, and would be invisible except as its outline might be revealed by the obscuring of objects beyond. The chief interest attached to such a body lies in the character of the radiation emitted by it when heated and the laws which govern the relations of the

flux density and the **spectral energy distribution of** that radiation to the temperature.

The total emission of radiant energy from a black body takes place at a rate expressed by the **Stefan-Boltzmann** (fourth-power) **law;** while its spectral energy distribution is described by **Wien's laws,** or more accurately by **Planck's equation;** as well as by a number of other empirical laws and formulae. (See **Thermal Radiation.**)

The nearest approach to the ideal black body, experimentally, is not a sooty surface, as might be supposed, but an almost completely closed cavity in an opaque body, such as a jug. When such an enclosure (called a *Hohlraum* in German) is heated, the radiation escaping through the opening closely resembles the ideal black-body radiation; while light or other radiation entering by the opening is almost completely trapped by multiple reflection from the walls, so that the opening usually appears intensely black. For this reason, black-body or "Planckian" radiation is often called also "cavity radiation." (L.D.W.)

BLACK BUCK. Mammalia, Artiodactyla. The Indian **antelope,** *Antilope cervicapra.* (A.W.L.)

BLACKCOCK. Aves, Galliformes. The male of the Eurasian black **grouse,** *Lyrurus,* of which there are two species, one limited to the Caucasus. (A.W.L.)

BLACK COLOB. Mammalia, Primates. A species of thumbless **monkey,** *Colobus satanus,* found in western Africa. (A.W.L.)

BLACK DEATH. The great pandemic of plague which swept Europe in 1348. (R.S.M.)

BLACKFIN. Pisces, Teleostei. A small fish **(Pisces),** *Lythrurus atripes,* of southern Illinois and Iowa with black-marked dorsal and anal fins. Related to the shiners. (A.W.L.)

BLACKFISH. 1. Pisces, Teleostei. The black sea **bass,** *Centropristis striatus.* 2. Mammalia, Odontoceti. A black **whale** of moderate size, up to twenty feet long. It is found in both the Atlantic and Pacific Oceans and is widely distributed from north to south. Also called the pilot whale. *Globicephalus melas.* (A.W.L.)

BLACK-FLY. Insecta, Diptera. A minute **fly** whose small head and large **thorax** give it hump-backed appearance. They are also called buffalo-gnats and the Indian name no-see-'em is sometimes used for the very small species. They constitute the family Simuliidae.

While some of these insects are harmless, others are among the most troublesome of our blood-sucking insects. Their bite is extremely irritating, considering its size, and the swarms are sometimes so numerous that their attack is serious to man and may cause the death of smaller animals, such as chicks. They are especially abundant in the woods, where campers and outdoor workers sometimes find it necessary to use oil of citronella, or one of the preparations containing tar, on exposed portions of the skin to prevent attack. (A.W.L.)

BLACK-GAME. Aves, Galliformes. The Eurasian black **grouse.** (A.W.L.)

BLACKHORSE. Pisces, Teleostei. A fish **(Pisces)** *Cycleptus elongatus,* of the Mississippi River system, also called the Missouri sucker. It attains a length of thirty inches and its flesh is excellent. (A.W.L.)

BLACKWATER FEVER. **Malaria.**

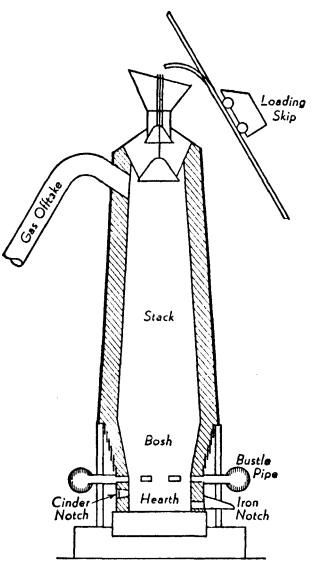
BLADDER. A thin-walled reservoir in animals, such as the gas-filled swim bladder of fishes. Bladders often serve as reservoirs for body secretions. The term usually applies to the urinary bladder situated in the anterior portion of the pelvic cavity. This serves as a reservoir for the **urine** secreted by the **kidneys.** (See also **Gallbladder** and **Excretory System.**) (R.S.M. and A.W.L.)

BLADDER WORM. Platyhelminthes, Cestoda. An immature resting stage of **tapeworms** consisting of a bladder-like **cyst** in which one or more heads are inverted. Also known as the cysticercus stage. (A.W.L.)

BLADDERWORTS. **Insectivorous plants.**

BLADE. **Leaf.**

BLAST FURNACE. The blast furnace is the chief means of reducing iron ore to pig iron. The reduction process is carried out at high temperature, and in the presence of a fluxing substance. A cross-section of a blast furnace is shown in the accompanying figure. The furnace may be ninety to a hundred feet high, and of



Blast furnace.

varying diameters. It may be thought of as being composed of three sections: the lower section, called the hearth, in which the molten iron is accumulated; a short section above the hearth, called the bosh; and the stack, which is above the bosh. The hearth portion is constructed of fire brick of the best quality with thick walls. The tapping hole is situated at some convenient point in the hearth, as is also the slag hole. Near the top of the hearth section tuyeres are spaced around the circumference for the admission of air for combustion. Each tuyere receives a supply of air from the tuyere stock which is connected to a header called a bustle pipe. The latter is a large pipe which encircles the furnace and distributes heated air to the tuyeres. The bosh, being just above the air admission point, encloses the hottest portion of the furnace. In order to keep the bricks from burning out, water cooled plates are built into the brickwork of the bosh, and much heat is carried away by the circulating water. Extending upward from the bosh to the top of the furnace is the stack, made of plate steel and lined with fire brick. At the top of the furnace is a double bell, which forms

a sort of airlock for the admission of materials during continuous operation of the furnace

When in use, the blast furnace is first charged in the proper manner with alternate layers of **coke**, ore, and **limestone**. The coke is ignited at the bottom and is rapidly burned under the influence of a forced draft of air blown in through the tuyeres As the coke is burned away, the material moves downward in the furnace towards the hearth, but the stack is kept full by fresh charges admitted through the bells The process of reduction is rather complicated chemically, but the net effect is the conversion of the ore, which may consist chiefly of **hematite** (Fe_2O_3), into liquid iron in the hearth, with slag, consisting of the limestone flux and the ash from the coke, together with compounds formed by reaction of the flux with substances present in the ore, floating in a molten state on the iron This molten slag, or cinder, may be tapped off through the cinder notch, which is a slag opening The iron is tapped at intervals through the iron notch As the hot gases from the combustion region pass upward from the furnace they heat the fresh charges and pass out of the furnace through ducts which carry them to the purifying equipment Since a reducing atmosphere is maintained in the blast furnace, the gases leaving it have some fuel value, due to their **carbon monoxide** content These gases are passed through dust catchers and scrubbers until they are comparatively free from dust, after which part of the gas is used in gas engines which operate the blowers, and part of it is used in stoves or regenerative heaters, which preheat the air going to the bustle pipe (F T M)

BLASTING Blasting is the rending or loosening of a hard or closely packed material by **explosives** Blasting action can be one of shattering percussion or heaving, depending upon the type of explosive used, and the method by which it is placed The principal field of blasting is in connection with earth or rock, although many other uses are found for it For example, it may be used to loosen coal from the seam, to fell a large obsolete chimney, or to break up foundations which are to be replaced, etc Blasting is very frequently used in preparing the right of way for a new road Rocks must be shattered, boulders loosened and broken up, tree stumps blown out, and earth loosened and rendered suitable for rapid excavation Quarry work offers a considerable opportunity for skilful removal of stone from the native mass by means of judiciously placed explosives Ditches may be dug with explosives by transmitted blasting, and material of all sorts may be loosened so that loading by power shovel is rapid and economical

The explosives used for blasting constitute one very definite branch of all explosives Dynamite and powder are chiefly used While a great many high-powered explosives of different sorts are used in shells for offensive weapons, these are not suitable for general blasting service Nitroglycerin dynamite and ammonia dynamite are the principal explosives for commercial blasting work Blasting powders are also used where a permissible explosive is not required A permissible explosive is a short flame explosive which is considered safe for use in mines where the atmosphere may contain some combustible gas. This feature is not important, naturally, for blasting in stone, slate, and granite quarries, where blasting powder is in use Dynamite is available in cartridges, in granular form, and powder form Some dynamite, such as gelatine dynamite, is distinguished by plasticity, high density, and imperviousness to water Other dynamites can not be used in wet locations In cold weather special low freezing formulas are required The dynamite cartridges are made in strength varying from fifteen to sixty percent dynamite so that the explosive power of a blast may be regulated Dynamite and blasting powder are set off by means of blasting caps containing picric acid, tetryl and mercury fulminate, or lead azide The blasting caps are ignited to produce an initial detonation, either by the heat of a fuse or by an electric current A blasting machine is a hand operated apparatus for generating current used in firing electric blasting caps

There are several ways of using an explosive in blasting A hole may be drilled in the earth or rock, and the dynamite cartridges placed at the bottom of the hole The blasting cap, with fuse or wires attached, is placed on the top of the charge, and the hole is then "stemmed" Stemming consists of carefully tamping the hole above the explosive full of a material such as moist clay or earth, so that the explosive force of the dynamite will be confined and will produce the maximum shattering or loosening effect Another way of using dynamite is to place it on top of the boulder or rock to be shattered, and cap it thoroughly with a layer of mud or clay well packed The effectiveness of this kind of blasting is the result of the intensely fast action of dynamite, so rapid that the mud and atmospheric reactions are sufficient to give a shattering blow to rock or boulders having a brittle structure This method of blasting tends to be wasteful of explosive, and is not used unless other methods, such as boring of holes, are impracticable Considerable skill in the use of multiple charges in excavation or break-up of rock or coal is attained by those dealing regularly with dynamite There are two methods of detonating multiple charges With one, the charges are exploded simultaneously, with the other, one charge explodes the next one, and so on For simultaneous explosion, electrical firing is a necessity, but where electrical firing is not used, multiple charges can be set off without difficulty if the ground is so thoroughly wet that the shock of an initial charge is transmitted through the ground to the adjacent one with sufficient intensity to detonate it Blasting is comparatively safe in the hands of those trained and skilled in the use of explosives as long as they remain careful and cognizant of the hazards involved, but is not to be recommended for the inexperienced or casual user of explosives (F T M)

BLASTOCOELE. The first cavity formed during the embryonic development of animals In many species the cleavage of the fertilized **ovum** gives rise to a hollow **blastula** of spheroidal form, the cavity of this structure is the blastocoele (A W L)

BLASTOMERE Any of the **cells** resulting from the subdivision of the fertilized **ovum** during early embryonic development (A W L)

BLASTOMYCOSIS. A chronic infection caused by the **fungi** of the blastomycetes group It is characterized by multiple abscesses in the skin and at times internally The disease is not common but more cases are seen in the Middle West than elsewhere in the United States The disease is chronic and prolonged with remissions The systemic form is usually fatal (R S M)

BLASTOSTYLE. A **polyp** from which medusae arise by budding, in colonies of hydrozoan **coelenterates.** (A W L)

BLASTULA. The stage in embryonic development which results from cleavage of the fertilized **ovum** and precedes the establishment of the germ layers It is a hollow sphere in its primitive form but is modified in many animals, particularly in connection with the extensive storage of yolk in the egg, and in some of these modified forms the exact equivalent of the primitive blastula is difficult to determine (A W L)

BLAUBOK. Mammalia, Artiodactyla *Hippotragus* A south African **antelope** allied to the oryxes It is said to be extinct (A W L)

BLEACHING SUBSTANCES, BLEACHING AND DECOLORIZING. Bleaching and decolorizing treatments are applied to **textile** fibers, **paper** pulp, **wheat** flour, **petroleum** products, **oils** and **fats**, raw **sugar** solutions In some cases, the results are attained by chemical reaction of the reagent and material treated, and in other cases by adsorption of undesirable material by the reagent followed by separation, e g, by filtration, from the desired material

The following gases are used in bleaching flour **chlorine** 300 parts per million, chlorine (98%) plus nitrosyl chloride (2%) 300 parts per million, **nitrogen** tetroxide 4 parts per million, **nitrogen** trichloride 50 parts per million, and most commonly, **benzoyl peroxide** 120 parts per million

Chlorine, sodium **hypochlorite** and calcium hypochlorite are strongly oxidizing in their behavior, **hydrogen peroxide** and per- compounds mildly oxidizing, and **sulfur dioxide** reducing Hydrogen peroxide is specially adapted for use in bleaching hair, silk, feathers, straw, ivory, teeth, bones, gelatin Chlorine and hypochlorites are used in bleaching paper pulp

Chlorine and hypochlorites, when used in bleaching textile fibers and paper pulp, must be scrupulously removed upon completion of the bleaching operation to avoid deterioration by further action This is done by the use of antichlor, such as **sodium** thiosulfate solution

Various porous solids of high adsorptive power are used for decolorizing liquids and solutions See **Colloidal state, Adsorption** Bone charcoal is used to decolorize raw sugar solutions, various clays and gels for oils and fats (R K S)

BLEAK Pisces, Teleostei *Alburnus* Small fishes (**Pisces**) of several species found in Europe and western Asia, related to the **carps** (A W L)

BLEEDER. This term is used both in medicine and in engineering In medicine a bleeder is an individual whose blood does not clot normally (See **Hemophilia** and **Heredity**)

In engineering a bleeder is a pipe line or an extraction point from which part of the flow of a stream of fluid is diverted for some specific purpose A common usage of this term applies to the bleeding of steam from a turbine called a bleeder turbine (See **Steam Turbine**) (R S M, F T M)

BLEEDING IN PLANTS Often, particularly in spring, sap may be observed flowing from the broken ends of branches, from the fresh stumps left when stems are cut, or from cracks The phenomenon is called "bleeding" The force causing this flow of sap from stems is called root pressure, since it seems due to osmotic forces in the living cells of the root The flow of maple sap when the tree is tapped in the spring may be considered as a form of "bleeding" (R M W)

BLENDE **Sphalerite.**

BLENNY Pisces, Teleostei Marine and fresh-water fishes (**Pisces**) of wide distribution Some move about on the bottom by means of the paired fins and others are able to leave the water and move about on the shore About fifty species of blennies are known (A W L)

BLEPHAROPLAST. The basal body from which a **cilium** or **flagellum** grows forth In many cases synonymous with **centrosome** (A W L)

BLESSBOK Mammalia, Artiodactyla One of the smaller species of South African **antelopes**, *Damaliscus albifrans* (A W L)

BLIND-FISH. Pisces, Teleostei Small fishes (**Pisces**) of which certain cave-inhabiting species have rudimentary eyes Together with a few species whose eyes are normal they make up the family Amblyopsidae. (A W L)

BLIND FLIGHT. Ordinarily, piloting of aircraft is accomplished by visual orientation on the part of the pilot with respect to fixed references such as horizon, clouds, and sky Although some experimentation has been made with flying instruction starting with the hooded cockpit, this is still in its infancy, and piloting talent of the present time has been built up on the basis of visual orientation Now when the aforementioned references are blotted out from view by fog, clouds, snow, or rain, the pilot can not, by sense of gravity alone, maintain even keel and constant heading of the aircraft Under these circumstances he is faced with the necessity of blind flight, that is maintenance of direction and equilibrium by the use of instruments located in the cockpit, which are read by the pilot, and used by him to create a mental image of the attitude of his plane

When blind flight becomes necessary the only alternatives are to quit the airplane by parachute, or risk a crash The ordinary flight instruments are not sufficient for blind instrument flight because of errors they introduce when the airplane undergoes circling flight The ordinary bubble or bank indicator, pitch indicator, and compass may be sufficient for short stretches of blind flight if the air is comparatively calm, but are not to be thought of as blind flying instruments In this classification come the artificial horizon, the turn and bank indicator, the sensitive altimeter, and various radio apparatus The gyroscope possesses features which fit it admirably for incorporation into various types of flight instruments, particularly those which indicate the flight condition of the airplane The artificial horizon, for instance, has a vertical gyroscopic axis in a frame mounted on gimbals so that it can rotate freely in the casing The case is fixed to the airplane, and should the latter move out of the desired flight conditions, a small visible bar maintains a true horizontal position A small painted airplane on the dial moves with the frame and the airplane, and its position with respect to the true horizontal bar gives the pilot an easily assimilated image of the position of the real plane with respect to the actual horizon Thus he may instantly apply corrective measures to offset **rolls** or **pitches** caused by air conditions

Since, in blind flight, the lack of sight of the ground prevents the visual observation of drift or other methods of determining the effects of wind, the radio must be depended on for the maintenance of the airplane on a course which is being flown blind While meteorological information may be given by radio, a radio system designed for the specific purpose of indicating a given course has been devised and put into operation in the United States by the Department of Commerce This is known as the radio beacon, and forms the important element of the Federal airways

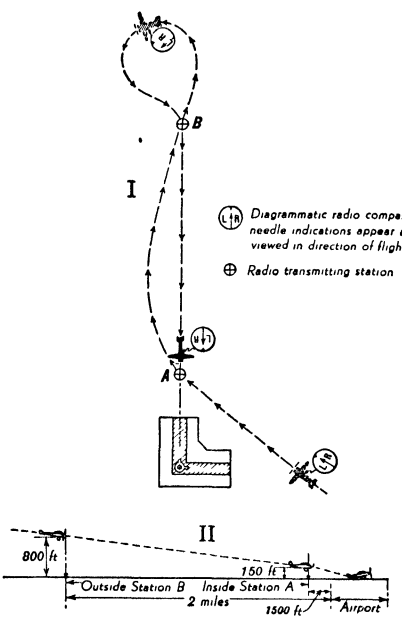
The radio beacon sends out signals directively along predetermined courses coinciding with the established airways Each radio range beacon provides four courses The standard offcourse signals of dash-dot and dot-dash are transmitted in groups separated by the station identifying signal "On-course" is indicated by the interlocking of "off-course" signals, thus forming a series of long dashes or continuous monotone signals which are also separated by the station signal The sending antenna consists of two loops at an angle to each other The signals sent out by these antennae form a pattern in a horizontal plane, whereby the course may be determined It will be noted that though there are apparently four courses, the inclination of the sending loops is set to produce a narrow beam on the desired course leaving that at right angles too wide to be of much use Reliable reception on aircraft in flight can normally be had up to distances approximately one

hundred miles from the station, and the width of the beam in which the dot-dash and dash-dot signals are completely interlocked is about ten miles at a point a hundred miles from the station As long as the pilot is on course, he hears in the ear phones a series of long dashes interspersed with a range beacon identifying signal Should the plane get off to one side of the marked course, the dashes would gradually break up and be replaced by the offcourse signal, either a dot-dash, or a dash-dot, depending on which side of the true course the deviation had been made (F T M)

BLIND LANDING A more humanly impossible task than the successful landing of an airplane blindly, that is, without any observation of the ground, sky, or horizon, would be difficult to imagine Yet if aircraft are to become reliable and accepted means for public transport, they must be able to maintain scheduled flights regardless of the state of the weather In the whole field of blind flight there is no problem more serious or difficult of solution than that of the blind landing The problem of the ground fog has been a serious one since the earliest days of aviation, and the lack of a suitable solution, until recently, has accounted for many air disasters, and loss of a great many lives This problem, however, bids fair to be successfully solved, perhaps not all in one step, but by a series of progressive steps extending over a development period As a Federal aid to flying, the Government of the United States, through the Department of Commerce, has undertaken to experiment with, and if possible, equip the Federal airways with means for successfully accomplishing blind landings

The Army Air Corps system, which involves the use of radio aids, apparently holds a great deal of promise for the successful solution of the blind landing The important components of this blind landing system are two radio stations transmitting on different frequencies One is located about 1500 feet from the airport, and the other some two miles away Each station has a non-directional radio beam, and, in addition, a vertical transmitter which acts as a radio marker to flash an indicating light in the cockpit whenever the plane passes over the transmitter In the airplane, in addition to this station marker light, which is really a radio receiver, there would be a radio compass, a sensitive altimeter, directional gyroscope, all in addition to the usual **blind flight** instruments When approaching a field equipped for blind landing, the pilot tunes in on one of the special landing transmitters with the radio compass receiver By means of a needle on a dial this receiver shows the heading of the plane towards the broadcasting station When correctly headed, the needle assumes a zero position Subsequent deviations of heading are indicated, right or left, as the case may be, by deflections of the needle By merely steering the airplane so as to keep the needle central, the pilot flies with certainty of exact heading towards the transmitting antenna The radio compass makes use of the loop **antenna.**

The operation of the loop compass should not be confused with a radio range beacon The radio compass is a homing device making no use of fixed radio beams, but operating on any transmitter or commercial broadcasting station It indicates heading rather than position with reference to a fixed predetermined path, in short, the radio loop compass tells the pilot directly, not where he is, but where he wants to go The pilot, having arrived at the predetermined point by means of the radio compass, is informed of his arrival over the transmitter by the light flash set up by the vertical marker beam Immediately the pilot passes the first station, he tunes in the frequency of the other, and flies to it with the radio compass One or more of these interstation trips serve accurately to line up the pilot with the runway, whose course is then set on the gyroscope compass In preparation for the final approach, the pilot has obtained, by radio, the barometer reading at the ground level and set his sensitive altimeter accordingly He then, on the final approach, lets down to approximately 800 feet over the field, and passes over the outer station at this altitude Immediately on passing this station, the engine is throttled, and the airplane, by instrument, is held in a glide of such angle as to enable it to pass over the inner station at an altitude of about 150 feet On passing the intermediate station the marker light flashes again, and then the pilot is through with the special blind landing equipment With his other instruments he maintains the glide angle and watches the altimeter and air speed indicator When just a few feet off the ground, the airplane is put in landing position and the plane settles to the ground An advantage of this system of landing is that it depends on a succession of logical steps which become progressively simpler as the more critical point of actual contact with the ground is approached A disadvantage is the necessity for long and unobstructed approach to the runway and the duplication of transmitters where more than one runway is to be used for blind landing Nevertheless, this system has been thoroughly tested and proven to be entirely feasible, and will doubtless do much to remedy the serious situation hitherto existing The accompanying figure represents the operation of this system of landing (F T M)



Air corps blind landing systems I, Plan view II, Side view

BLIND SPOT. That portion of the **retina** of the **eye** where the optic nerve enters and which is insensitive to sight (R S M)

BLIND WORM Amphibia, Gymnophiona Slender worm-like **amphibians** with no trace of legs and with the tail and eyes rudimentary They are also called caecilians (A W L)

BLISTER BEETLE. Insecta, Coleoptera Soft-bodied **beetles** of medium to large size They are

named from their blistering properties; when crushed on the skin even the common species are capable of raising a blister.

Blister beetles are of commercial importance as a source of a pharmaceutical preparation known as Spanish-fly, from the species of that name This material is composed of the dried pulverized bodies of the insects and is used for producing blisters Some of the North American species are also occasionally important enemies of plants, among them the old-fashioned potato beetle They can be checked by the application of sprays containing arsenical poisons

Several hundred species of blister beetles have been described They constitute the family Meloidae (A W L)

BLOCK SIGNAL. A block signal is the mechanism employed to show the engineman, operating a train over a railroad protected by the automatic block signal system, whether there are any trains in the block ahead In the operation of a railroad system the trackage is divided into blocks of from one to five miles' length, and the **railway signaling** system devised to prevent two trains occupying the block simultaneously The block signal itself is a semaphore mounted on a mast and placed alongside the track in clear view of the enginemen It is electrically energized from an alternating or direct current transmission line running along the right of way, and is actuated by electro-magnets properly connected across the "blocks" of track A standard system of signalling is the semaphore arm held vertical for "proceed" and horizontal for "stop" At night, red and green lights replace the semaphore as a means of indicating the condition of the block (F T M)

BLOCKING LAYER. Photovoltaic Effects.

BLOOD. A liquid tissue whose chief function is the ready transportation of materials through the animal body

All bloods consist of two principal parts the liquid intercellular material called the plasma, and the cells which float in it The plasma is a complex mixture containing absorbed products of digestion, waste products of the various tissues, special secretions, enzymes, and antibodies, and gases **oxygen, carbon dioxide,** and **nitrogen.** All bloods contain white cells or leucocytes and the blood of **vertebrates** also contains red cells whose function is the transportation of oxygen

The transportation of dissolved materials by blood depends upon selective **osmotic** interchange with the tissues with which it comes into contact The transportation of oxygen is, in some animals, of the same nature but in others complex proteins containing copper or iron enter into combination with the gas Haemocyanin (See **protein**) containing copper and haemoglobin (See **protein**) containing iron, are the two most common compounds known to act in this way The former is found in some **arthropods** and **mollusks** and the latter in some **nemertine** and **annelid** worms, a few arthropods, the phoronids, and the **vertebrates.** In the vertebrates it is contained in the red cells

More is known of human blood than of that of any other species because of its importance in medicine The average amount of blood in the human body is about 1/20 of the body weight or about four to seven quarts Arterial blood is bright red due to its contents of oxygen Venous blood is darker in color due to depletion of its oxygen by the tissues Blood is salty in taste, slightly heavier than water, has a peculiar odor and its normal temperature is about 100° F In addition to extensive knowledge of the chemistry of the plasma the normal characteristics of the cell content have been determined and the significance of deviations from the normal has become an important factor in clinical diagnosis The human red cells or erythrocytes are biconcave discs averaging 0075 millimeter in diameter The enucleate condition is characteristic of mammals but in other vertebrates the nucleus is present. The red cells are filled with hemoglobin, which has the power of combining with oxygen easily and giving up the oxygen readily when the body cells require it. The color of the blood depends on its content of oxygen—the more the oxygen content, the brighter the color of the blood

This is the principal function of the red cells—that of oxygen carriers, and this depends on their hemoglobin content and total number

The number of red cells varies In health the average number of cells is 4,500,000 to 5,000,000 per cubic millimeter The hemoglobin content normally varies between 75 to 100 percent Any percentage lower than this with a total count of less than four million cells is classed as **anemia.**

The red blood cells are manufactured by the narrow cells of the long bones of the body The average life of a red cell is estimated from 50 to 70 days They are destroyed, when useless, by the **liver, spleen** and **lymph** glands

The white cells are of two groups (1) agranulocytes, including lymphocytes and large mononuclear leucocytes, both with clear cytoplasm and a compact nucleus ranging from round to kidney-shaped, (2) granulocytes, which differ in the presence of granules of specific staining reaction in the cytoplasm and include neutrophils, acidophils or eosinophils, and basophils There may be from 5000 to 8000 white cells per cubic millimeter of blood under normal conditions Lymphocytes are cells 006 and 008 millimeter in diameter, with a large round nucleus and very little cytoplasm, they

EXPLANATION OF PLATE A

Figure 1 The cells of normal blood reproduced from actual cells Wright's stain × 1000 (1 mm = 1 μ)

1, Red corpuscles and blood platelets 2, Two lymphocytes 3, Lymphocyte with azurophilic granules This cell lay in a thin portion of a film and was exceptionally large 4, Three endothelial leucocytes, one with fine cytoplasmic granules The granules are rarely so distinct as here shown 5, Polymorphonuclear neutrophils 6, Eosinophils, one ruptured The cells selected for drawing contained fewer granules than are usual 7, Basophils

Figure 2. Leucocytes found in the blood in disease All reproduced from actual cells stained with Wright's stain, excepting No 15, which is copied from Pappenheim × 1000 (1 mm = 1 μ)

8, Two myeloblasts, showing nucleoli 9, Two promyelocytes Note the blue edge of one 10, Two mature neutrophilic myelocytes 11, Eosinophilic myelocyte 12, Basophilic myelocyte Some of the granules have dissolved, leaving vacuoles and staining the cytoplasm 13, Two lymphoblasts, one with lobulated nucleus (Rieder cell) 14, Turck's irritation leucocyte with vacuoles 15, Plasma cell 16, Degenerated nuclei, one a so called "basket cell" 17, Neutrophilic leucocyte with vacuoles (toxic change).

DESCRIPTION OF PLATE B

Abnormal red corpuscles All drawn from actual specimens and all stained with Wright's stain except where noted × 1000 (1 mm = 1 μ)

Figure 1 Variations in size, shape, and hemoglobin content, from cases of pernicious anemia and chlorosis

Figure 2 Polychromatophilia and basophilic granular degeneration, from cases of lead poisoning and pernicious anemia

Figure 3 Normoblasts, reticulated red cells, and one microblast The top row represents stages in the development of the normoblast The two reticulated red cells are stained with brilliant cresyl blue

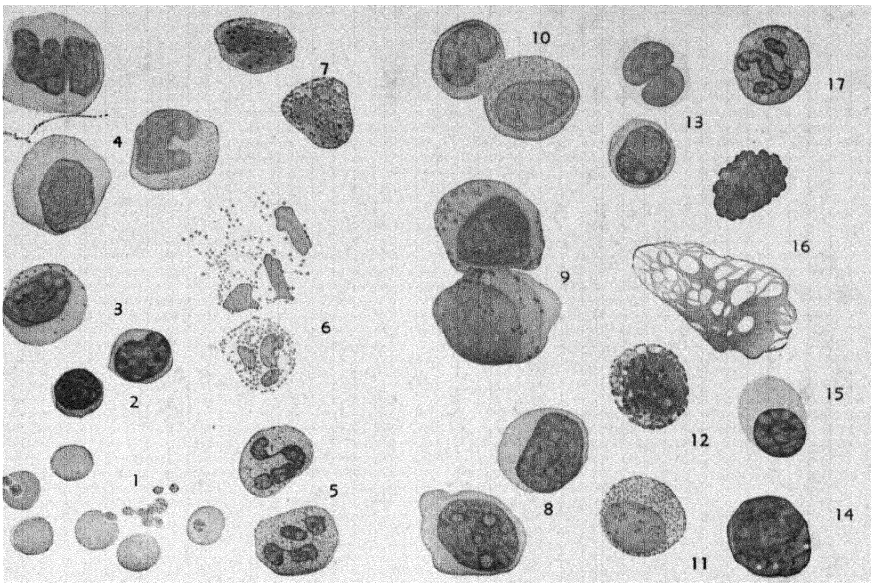
Figure 4 Megaloblasts from cases of pernicious anemia Two show polychromatophilia and fairly typical nuclei, two have condensed nuclei, and one of these has basophilic cytoplasmic granules

Figure 5 Nuclear particles or "Howell-Jolly bodies" One cell also shows basophilic granular degeneration

Figure 6 Mitotic figures, two from myelogenous leukemia, one with polychromatophilic cytoplasm, from von Jaksch's anemia. The last was stained with Leishman's stain.

Figure 7 Cabot's ring bodies, from a case of von Jaksch's anemia Two cells also contain nuclear particles and one shows basophilic granular degeneration. Leishman's stain

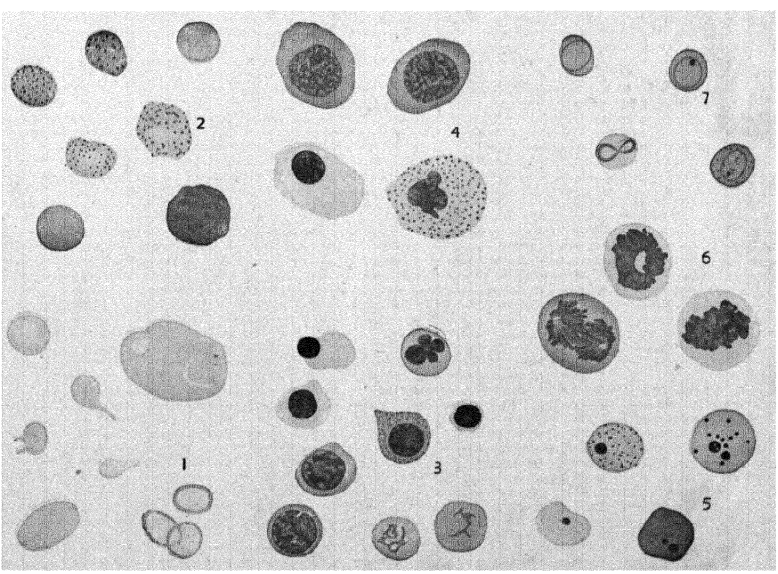
PLATE A



The cells of normal blood (scale: 1 mm. = 1 μ).

Leucocytes which appear in the blood in disease (scale: 1 mm. = 1 μ). (J. W. Rennel, pinx.)

PLATE B



See page 148 for detailed discussion of these Plates. Reproduced from Todd and Sanford, *Clinical Diagnosis by Laboratory Methods*, courtesy of W. B. Saunders Co.

PLATE C

Malarial Parasites.

Wright's stain. × 1000 (1 mm. = 1μ).

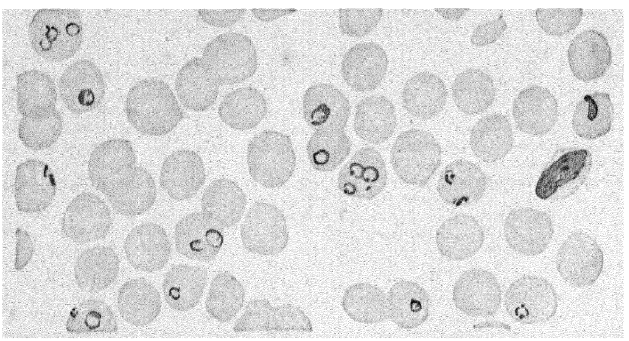


Fig. 1.—Estivo-autumnal malaria, exact reproduction of a portion of a field, showing an exceptionally large number of parasites.

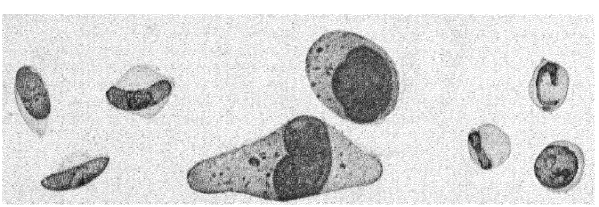


Fig. 2.—Estivo-autumnal gametocytes

Fig. 3. — Leucocytes with engulfed pigment.

Fig. 4.—Quartan parasites

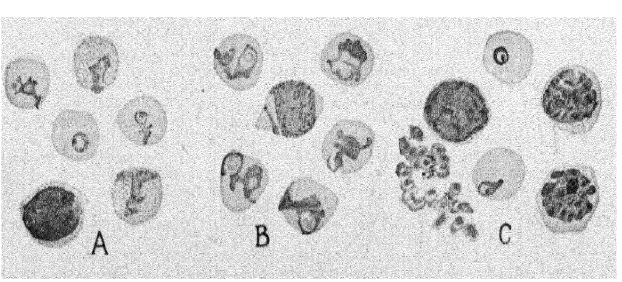


Fig. 5.—Tertian parasites. A, Eight hours after chill, showing malarial stippling, five young parasites, and one gametocyte, from two slides; B, twenty-four hours after chill, five half-grown parasites: one gametocyte; C, during chill, one presegmenter, two segmenters, a cluster of freshly liberated merozoites, and two very young parasites, from one slide. (J. W. Rennel, pinx.)

Reproduced from Todd and Sanford, *Clinical Diagnosis by Laboratory Methods*, courtesy of W. B. Saunders Co.

make up twenty to twenty-five percent of the white cells. Mononuclears range from .009 to .02 millimeter, with more abundant cytoplasm and a round to kidney-shaped nucleus, and make up three to eight per cent of the white cells The granulocytes are also called polymorphonuclear leucocytes because the nucleus elongates and become deeply constricted to take on a variety of forms as they mature. Neutrophils have very fine cytoplasmic granules, the cells are 006 to 008 millimeter in diameter and constitute sixty-five to seventy-five per cent of the total Eosinophils have coarse and numerous granules which stain red with eosin, they are about 009 millimeter in diameter and are only two to four per cent of the total Basophils have relatively few coarse granules, which stain dark blue with the usual blood stains, they are rare, amounting to only one-half to one per cent of the total Both eosinophils and basophils are slightly larger than neutrophils, averaging 009 to 01 millimeter In addition to these cells the blood contains minute cytoplasmic fragments called blood platelets

The ratio between non-granular and granular cells varies from the normal ratio when disease is present and this is of practical use in diagnosis of disease Certain of the white cells are called macrophage or scavenger cells They are wandering cells, either in the tissues or blood stream, whose purpose is to engulf and destroy disease organisms, dead or harmful cells, or other injurious matter Other similar but smaller leucocytes are called microphage cells Others are called phagocyte cells and the process of destroying bacteria or other harmful organisms is termed **phagocytosis.**

The function of the blood is complex

(1) It serves as a medium to provide nutriment to the **tissue** cells of the body and to remove waste from the tissue cells of the body

(2) It aids in controlling the temperature of the body, equalizing body temperature by passing from organs or tissue having a higher metabolism to organs or tissue having a lower metabolism

(3) The fluid content of tissues is maintained, there being a balance between tissue and blood fluids

(4) The **hormones** of the various glands of the body are distributed throughout the body by means of the blood stream

(5) The blood carries **oxygen** to the body cells and carries the waste products, **toxic** substances and **carbon dioxide** away from the cells

The functions of the white cells in general are protective, fighting infection, hastening tissue repair, removing debris, and aiding in tissue repair after injury Many of their functions are not known They are supposed to form certain substances and liberate certain extracts One of these substances plays a part in the clotting of blood **Pus** is partly formed by destroyed leucocytes An increase in number is termed leucocytosis and is seen when infection is present in the body The more severe the infection the greater number of white cells are present, indicating a proper response to acute infection This is not always true in some diseases, however In **leukemia** an abnormally large number of white cells is present Decrease in white cells is known as leucopenia and occurs in a few diseases. When present in the average acute infection it shows a lack of defensive power of the body and is a bad prognostic sign

The blood of some invertebrates, particularly that of the insects, is commonly called haemolymph (A W L, R.S.M.)

BLOOD GROUPS OR TYPES. There are four recognized groupings of human **blood.** The blood grouping of a person is hereditary, follows the principles of the Mendelian Law (See **Heredity**) and remains unchanged through life. The establishment of blood groups in the human race is due to congenital antigenic difference in individuals.

Landsteiner, in 1901, first accurately described three of the blood groups for the first time. In 1902 the fourth group was added by two of his pupils Jansky in 1907, in further work, called the groups by numbers, thus, group I, II, III, and IV In 1910, Moss classified the group IV, II, III, and I so that Jansky I became Moss IV and Jansky IV became Moss I. This caused considerable confusion so, that at present, an international grouping arrangement is by preference used naming the groups according to the antigen contained in the cells Thus the groupings are called Group O, A, B, and AB

Blood grouping is vital in transfusion of blood Not only must a donor of the same group be used, but his blood must be compatible with the patient's blood This latter is called cross-grouping and tests must always be done

Group O is called the universal donor group However, a group O donor is never used in transfusing patients of other groups unless as an emergency procedure, when there is no time to obtain a donor of the same group

Lately grouping has been used legally in establishing paternity In certain cases it can be proved that the suspected individual could not have been the father. It never can be proved that the individual *is* the father (R S M)

BLOODSTONE or **HELIOTROPE.** A massive variety of **quartz** of greenish color with small spots of red **jasper** somewhat resembling blood drops It is used as a semi-precious stone When placed in water in full sunlight bloodstone will frequently give a general reddish reflection, hence the term heliotrope derived from the Greek words meaning sun, and to turn (E S C S)

BLOOD WEAVER-FINCH. Aves, Passeriformes A group of **weaver-birds** of Arabia and Africa Named from the prevalence of scarlet in their plumage (A W L)

BLOOD WORM. 1 **Annelida.** Certain marine worms whose bright red blood gives color to the entire body 2 Insecta, **Diptera** The aquatic larvae of certain **midges** which have haemoglobin dissolved in the plasma of the **blood** and so are red in color (A W.L)

BLOW-FLY. Insecta, Diptera **Flies** which deposit their eggs on meat The name is applied to an entire family, however, containing other species which breed in dung, in wounds on living animals, and as blood-sucking parasites of nestling birds The commoner species are also known as **blue-bottle** flies (Family Calliphoridae) (A W L)

BLOW-HOLE. A blow-hole is a small irregular hole in a **casting** caused by passage of gases through the metal of the casting during the process of solidification Large numbers of blow-holes will materially weaken a casting Even a single blow-hole may be sufficient cause for rejection of castings which are used to contain liquids or gases The majority of blow-holes are due to the condition of the mold The use of molding sand which does not vent the gases freely, improper ramming of the sand, or errors in making or placing the cores, are prolific sources of blow-holes (F T M)

BLUE. Insecta, Lepidoptera **Butterflies** whose prevailing color is bright blue The females are usually less blue than the males and some few species are not blue With the coppers and hair-streaks they constitute the family Lycaenidae. (A W L)

BLUEBACK. Pisces, Teleostei A commercially important **salmon,** said to be second only to the king salmon in this respect It ranges from California to Alaska Also called the redfish Also a species of **trout** found in Maine and northward (A W L)

BLUEBERRY. Heath Family.

BLUEBIRD. Aves, Passeriformes. 1. Several species of North American **thrushes** whose prevailing color is blue. Of these the male mountain bluebird, *Sialia currucoides,* of the west is entirely blue while other species are marked with shades of reddish brown. 2. One of the **babblers** of the Oriental region. 3. Said to be applied to a South African **albatross** (Order Procellariiformes). (A.W.L.)

BLUEBOTTLE. Insecta, Diptera. Large **flies** of shining blue, green or purple color. They lay their eggs on meat and other foods and so are often seen in dwellings. (A.W.L.)

BLUEFIN. Pisces, Teleostei. A fish (**Pisces**) found in the Great Lakes and smaller lakes of the same region; one of the lake herrings, also called the blackfin. *Leucichthys nigripinnis.* (A.W.L.)

BLUEGILL. Pisces, Teleostei. A fish (**Pisces**) *Helioperca incisor,* related to the sunfishes and bass. Widely distributed east of the Rockies in lakes and the quieter parts of streams and esteemed as a pan fish. It attains a length of ten inches or more but in well-fished waters rarely attains this size. Although small, it rises readily to a fly and so ranks among desirable game fishes. (A.W.L.)

BLUE GROUND. Kimberlite.

BLUE MUD. A typical deep sea, fine grained sediment containing an appreciable amount of **calcium** carbonate. The bluish-gray color is caused by organic matter and finely divided **iron** sulfide. (R.M.F.)

BLUE PRINT. Paper coated with ammonium **ferric citrate** or **oxalate** and **potassium** ferricyanide. On exposure to light the ferric ion is reduced to ferrous, and on subsequent treatment with water the ferrous ion forms ferrous ferricyanide which is blue while the ferric ion forms the brown ferric ferricyanide which is washed off the paper. (R.K.S.)

BLUE RACER. Reptilia, Sauria. A variety of the **blacksnake** found in the prairie and plains states. Like many snakes, it has a bad reputation but is quite harmless. *Zamenis constrictor.* (A.W.L.)

BLUETHROAT. Aves, Passeriformes. A European bird (**Aves**) related to the warblers. *Luscinia suecica.* (A.W.L.)

BLUNT-NOSE. Pisces, Teleostei. A small fish (**Pisces**) *Hyborhynchus notatus,* found in streams west of the Alleghanies, related to the dace and chub. (A.W.L.)

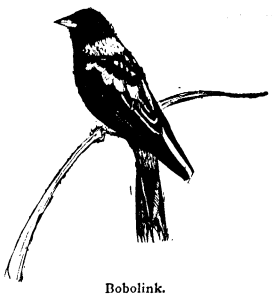
BOA. Reptilia, Sauria. Any **snake** of the family Boidae. The United States has only two small species of the western states; the bulk of the family is made up of large arboreal snakes such as the **boa-constrictors,** *Boa constrictor,* of South America and the **pythons,** *Python,* of the Old World. One of these species, the **anaconda,** *Eunectes murinus,* attains a length of over thirty feet and is the largest snake known. Boas are not poisonous. (A.W.L.)

BOAR. The male of any species of swine. (See **Pig**). The term wild boar is also applied generally to two species found respectively in India, *Sus cristatus,* and in Europe and the adjoining areas of Asia and Africa, *S. scrofa.* (A.W.L.)

BOBAC. Marmot.

BOBCAT. Wildcat.

BOBOLINK. Aves, Passeriformes. A widely distributed North American bird (**Aves**), *Dolichonyx oryzivorus,* of which the male, marked with black, white, and yellowish, is conspicuous in the prairies and meadows where the species breeds. The female is duller and plainer. The bobolink is noted for its cheerful song. (A.W.L.)



Bobolink.

BOB-WHITE. Quail.

BODE'S LAW. In the latter part of the eighteenth century an empirical relationship was noticed between the mean distances of the various **planets** from the sun. This relationship was first published by Bode in 1772 and has since become known as Bode's Law, in spite of the fact that there is certain evidence that it was known and used by Titus a number of years previous to the time of its announcement.

Bode's Law may be stated as follows: write down a series of 4's; to the first one add 0, to the second one add 3, to third one add $6 = 3 \times 2$, to the fourth one $12 = 6 \times 2$, to the fifth $24 = 12 \times 2$, etc.; the resulting numbers, divided by 10 will give the approximate mean distances of the planets from the sun in **astronomical units.** The sequence is as follows:

Planet	Bode Distance	Mean Distance
Mercury	4 + 0 = 4	0.39
Venus	4 + 3 = 7	0.72
Earth	4 + 6 = 10	1.00
Mars	4 + 12 = 16	1.52
	4 + 24 = 28	
Jupiter	4 + 48 = 52	5.20
Saturn	4 + 96 = 100	9.53
Uranus	4 + 192 = 196	19.19
Neptune	4 + 384 = 388	30.07
Pluto	4 + 768 = 772	39.5

The value in the last column is the actual mean distance of the planet from the sun in astronomical units.

At the time that the law was first proposed the gap between Mars and Jupiter was not filled and no planets were known outside of Saturn. The law predicted distances and when Uranus was discovered with mean distance so close to the predicted value, Bode's Law was believed to be established. The discovery of the **asteroid** Ceres with a mean distance of 2.77 gave further support to the validity of the law. It is interesting to note that, in making the computations which led to the discovery of **Neptune,** Adams used the predicted Bode distance for the then unknown object.

During the nineteenth century many unsuccessful attempts were made to place Bode's Law upon a theoretical foundation. The failure of the law in the cases of Neptune and Pluto has convinced most astronomers that the law is a purely empirical relationship, more in the realm of coincidence than an actual physical law. (W.K.G.)

BOEHMERIA NIVEA. Urticaceae. A perennial Asiatic plant growing up to seven feet in height and producing several crops of canes annually. Cultivation of the plant occurs principally in China, although smaller quantities are grown in other oriental countries. The plant is grown for its bast fibers, which are both long (up to 200 millimeters) and of unusual strength, though they do not stand twisting very well. In the

Orient these fibers are removed from the plant entirely by manual labor, the cortex is scraped off by drawing the stems over a coarse knife against which they are pressed The fibers obtained by this process are dried, and in this condition are known as "China Grass" Repeated washing and drying is next used to remove the gummy substance which surrounds the fibers and to separate them, a slow tiresome process Ramie fibers are considerably coarser than those of flax, and have great tensile strength, but are little used because of their lack of resistance to twisting Cultivation has been attempted in the United States, but without much success, because of the difficulty of preparing the fibers for manufacturing processes (R M W)

BOG IRON Limonite.

BOG MANGANESE Wad.

BOIL. Furuncle A localized pus infection of the skin and underlying tissues, usually caused by the **Stapylococcus** group of micro-organisms It is characterized by localized destruction of tissue in its center, (core) with softening and discharge of pus Treatment is surgical (R S M)

BOILERS A boiler is a pressure vessel designed to transmit heat developed by combustion of a fuel to water and steam contained in the boiler In some instances the liquid in a boiler has been something other than water, but the purpose of this article is to discuss the **steam** boiler The boiler should hold its contents safely and deliver the steam in the desired condition It is desirable, also, from the standpoint of economy that the heat be transmitted with minimum loss to the atmosphere

The steam boiler is an external combustion device, that is, the combustion takes place externally from the region of boiling water This fact, then, implies the existence of a surface separating the interior of the boiler from the combustion zone All of the heat which reaches the water must be transferred through this surface It is called the **heating surface** All but a very small portion of the surface enclosing the water and steam region of a boiler is heating surface Some boilers are built so that the heating surface encloses the furnace, while others have furnaces built as an auxiliary to the boiler In the latter the boiler and furnace are enclosed in a refractory, heat insulating casing called the setting

Heat generated by **combustion** is transferred to the heating surfaces in two ways The surfaces which might be said to "see" the incandescent region of combustion receive heat at a rapid rate by **radiation** Other portions may receive heat by **convection** from the products of combustion which have been heated in the furnace and act as vehicles for transportation of heat to the boiler surface The heat is transferred by **conduction** from the gas side of the heating surface through the metal to the water

Beginning with the simple cylindrical shell type boiler, heated with flames applied to the outer surface, many and varied types of boilers have been evolved Some have characteristics which fit them for marine service, others for land service, others for heating, etc For a comprehensive picture of the whole field, it is well to classify the group in logical order The following table illustrates various classifications

Classification of Boilers

I On the basis of the contents of the tubular heating surfaces
  - A Fire tube, having flame and products of combustion in the tubes
  - B Water tube, having the water and steam in the tubes, and the products of combustion outside

II On the basis of position of the furnace
  - A Internally fired
    The internally fired boiler has the furnace region completely surrounded by heating surface, as in the small portable vertical boilers, the Scotch boiler, or the locomotive boiler
  - B Externally fired
    All water tube boilers are externally fired, and one of the fire tube class, the horizontal return tubular, is externally fired

III On the basis of the shape and position of the tubular heating surface
  - A The inclination of the tubes, as horizontal, inclined, or vertical
  - B The form of the tubes—straight or bent

IV On the basis of the drums
  - A The number of drums, as single drum, two drum, or multiple drum
  - B The position of the drum with respect to the tubes, that is to say, across the tubes or parallel to the tubes, giving rise to the names cross-drum and long-drum

V On the basis of the type of headers employed to connect the tubes to the drums
  - A Sinuous, forged steel headers having a number of individual sections Each section serves the tubes in a single vertical row, and there are as many sections side by side as the tube bank is wide
  - B The box type riveted header, made of plate steel, and having sufficient area for the accommodation of all tube connections

A fire tube boiler consists of a plate steel shell, usually cylindrical since that shape best withstands internal bursting pressure Holes are bored in the tube sheets, which are the ends of the cylinder, in such a manner that tubes may be passed through the shell and fastened tightly in the holes These tubes are submerged in the water within the boiler, and hot gas passes through them In some boilers the surface of the tubes comprises the entire heating surface Figure 1 shows the construction of a fire tube type known as the horizontal return tubular boiler, an externally fired type which has been very popular as a source of steam for heating, industrial processes, and small amounts of steam power It consists of a plain cylindrical shell with flat ends between which are supported a great many 3-inch or 4-inch iron boiler tubes The tubes do not entirely fill the shell, as a space must be left above them for the accumulation and storage of steam The tube sheets above the tubes are braced against bulging by steel stay braces The boiler is completed by the addition of proper taps for instruments, steam leads, feed water pipe, and safety devices, and with the provision for some means of supporting it, such as brackets or loops The furnace is built below and external to the boiler shell, and both furnace and boiler are enclosed in a brick setting The flames and hot gases play against the bottom of the shell, pass from the front to the back, and return to the front of the boiler through the tubes The lower portion of the shell and the tubes form the heating surface

Slightly different is the arrangement of the locomotive fire tube boiler, shown in Figure 2, where the boiler is internally fired, and the flame and hot gases leaving the furnace region pass forward through the tubes They emerge from the tubes into the smoke box, from whence they are blown to the atmosphere through a short stack, under the influence of a steam jet which receives steam from the exhaust of the locomotive cylinders The heating surface consists of the tubes and the shell surrounding the furnace

A water tube boiler is composed of drums and tubes, the tubes always being external to the drums, and a means of joining the tubes to the drums The drums are used for storage of water and steam, and for connections of steam and water pipes As they are not required

to contain any tubular heating surface, they are much smaller in diameter than the shells of fire tube boilers, and can be built for higher boiler pressures than are possible in fire tube design. The heating surface is entirely in the tubes, the function of which is therefore simply to absorb the heat and generate the steam. The method of joining a tube to a boiler or header is to insert that tube into a hole having the same diameter as the outside of the tube (tubes are sized on their external diameter, whereas pipes are sized by the nominal internal diameter). The tube wall is forcibly expanded or rolled against the metal surrounding the hole, so as to make a tight joint. This process requires that the axis of the tube be perpendicular to the plane of the hole, or if the hole is bored in a curved surface, the axis of the tube must be radial to the curvature of the surface. If tubes are expanded directly into the drums, dispensing with an intervening header, the only row of tubes that may be absolutely straight is that row that lies in the surface which joins the center lines of two parallel drums. All other rows of tubes must be bent at their ends so as to enter the drum surface radially. Some headerless boilers are built entirely with straight tubes by connecting the tubes to the flat ends of cylindrical drums, but the more

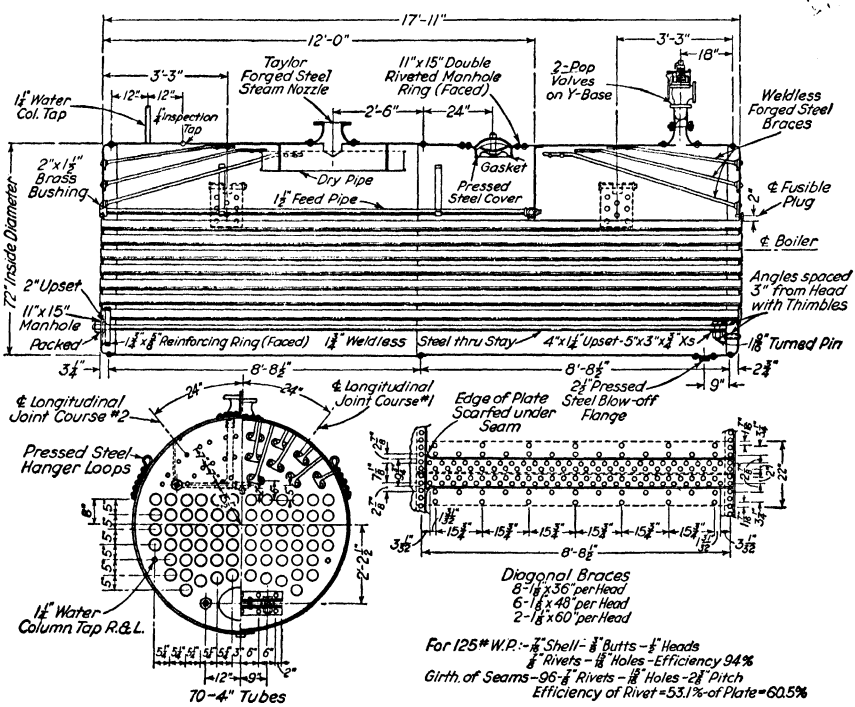


Figure 1. Longitudinal section and end view, Wickesfire tube boiler. (*Courtesy of Wickes Boiler Company*).

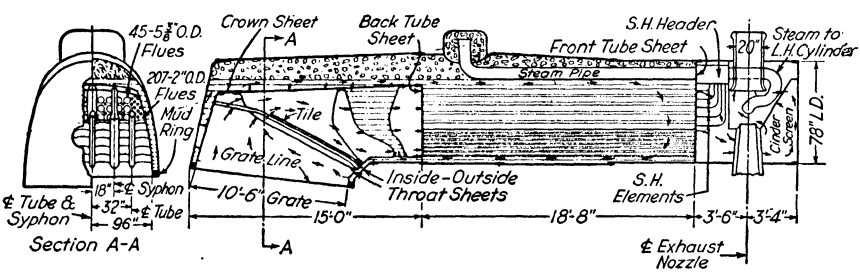


Figure 2. Pacific locomotive boiler.

common construction is that shown in Figure 3, where it can be clearly seen that the tubes are bent.

The common construction of a straight tube boiler involves the interposition between the tubes and the drum

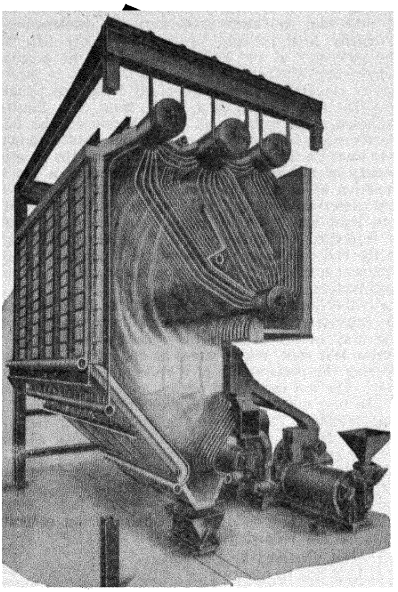


Figure 3. Boiler equipped with water walls and fired by pulverized coal.

of a header which will provide a flat surface for the connection of the tubes, and which is connected to the drum by means of circulation tubes or sheet steel saddles. Figure 4 shows the arrangement of surface in a straight

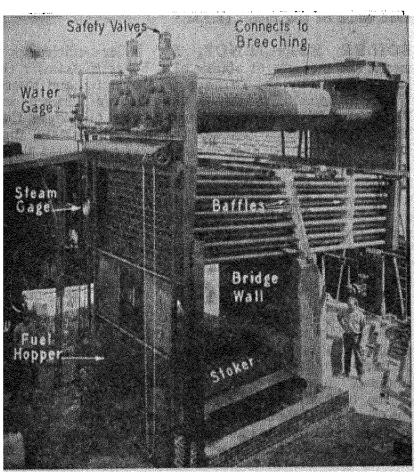


Figure 4. Arrangement of Longitudinal Drum Boiler. (*Courtesy of Edge Moor Iron Co.*)

tube box header boiler. As it is necessary to incline the tubes slightly to the horizontal in order to promote water circulation, the box type header must necessarily be inclined somewhat to the vertical, since the surface of the header must be perpendicular to the tubes. Sectional forged steel headers may be exactly vertical, since an inclined surface may be forged at the opening for each tube so that the hole will be perpendicular to the axis of the tube.

The materials from which boilers are constructed are steel and iron. The low pressure steam boilers so frequently employed in steam heating systems are generally made up of cast iron sections. This material is entirely too weak and heavy for pressure boilers and rolled sheet iron and steel are employed in its place. The tubes are generally seamless iron or steel, and the drums are made of rolled steel sheets which are fabricated by welding or riveting, or both.

In operation, a boiler is supplied with heat from the combustion of a fuel, and with water from a pump known as the boiler feed pump which is capable of overcoming the pressure existing in the boiler. Upon entrance to the boiler, the water absorbs heat until it reaches its boiling temperature, and is then boiled off to form steam, which collects in the highest part of the boiler drum because of the difference in density of steam and water. Fresh feed water must be introduced to take the place of all steam generated and withdrawn from the boiler, so that the water level will be maintained at the proper position—midway up the drum of a water tube boiler, and above the level of the tubes in a fire tube boiler. Safety devices to protect against low water and high pressure must be provided. In addition to these safety devices, however, boilers are equipped with other auxiliaries, such as dry pipes to filter the entrained droplets of water from the steam and deliver dry steam at the steam nozzle, water level gage, drain and blowdown connections, **superheaters**, soot blowers, **water walls**, and steam pressure gages. Operation of the whole steam generating unit may also involve combustion equipment, draft fans, chimney, boiler feed pump, breechings, **economizer**, and **air preheater**. Figure 5 shows a sectional drawing of a large power boiler in which many of these auxiliaries are pictured. An air preheater and economizer, fans, water wall, stoker, and superheater may be noted.

The capacity of a boiler is frequently given in terms of horsepower. A rated **boiler horsepower** is 10 square feet of heating surface for a water tube boiler, and 12 square feet for a fire tube boiler. The rated heat transfer capacity of 10 square feet of heating surface is 33,500 BTU passed to the water in an hour, but since modern boilers can exceed this figure steadily without being overloaded, actual capacity is more than rated capacity, a situation which makes necessary the use of the term "per cent rating."

The selection of a boiler is likely to be greatly influenced by personal prejudice or previous experience of the owner. Given service conditions can usually be met equally well by several boilers of different design. However, in spite of the wide variations in design, there are certain requirements which are fundamental to all water tube boilers. All boilers deserving consideration should meet these requirements, though, of course, not all the favorable points of different designs are covered. But it is nearly certain that if the boiler does not conform to them, operating difficulties will occur early in its life. First, there are the conditions governing the behavior of the water within the boiler. Most important of these is good water circulation. The process of evolution in boiler development has eliminated types with faulty circulation. The disengagement surface where the steam breaks through the surface of the water in the drum should be unrestricted. Priming of the steam with droplets of moisture may result from restricted disengagement surface. In order to control impurities which will be precipitated from the feedwater, it should dis-

charge into the drum at a point where the circulation will deposit the precipitate in a settling chamber called the mud drum. For example, on a boiler in which the mud drum is at the bottom of the rear header, the feedwater should be introduced where the precipitate will be swept out of the drum and into a downcomer leading to the header. Adequate storage space for steam is a requirement indirectly connected with water conditions. The volume of steam storage should conform to the demands of the load served. Insufficient storage space has

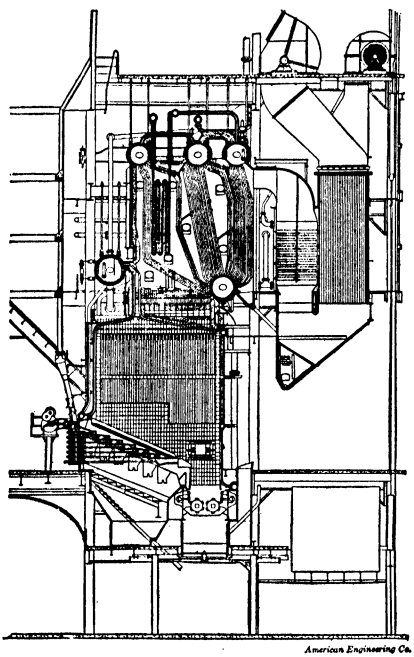


Figure 5. Cross-section of steam generating unit, Delray No. 3 Station, Detroit Edison.

a bad effect on steadiness of steam pressure under variable load, and has been known to cause pulsations in the boiler and steam piping.

The path of the gases through the boiler should be so baffled and directed over the tubes that they give up heat to the required degree. This required degree is less when auxiliary heat transfer surface in economizer or air preheater are provided than when they are absent. Certain features of a boiler may result in undetermined thermal stresses being set up, such as the discharge of cold feedwater against the boiler shell setting up contraction stresses. Joints and seams should be well protected from the flames, and burners should never be set so the flames play directly against tube surfaces. To provide for intelligent and safe operation of the boiler a full complement of leads, gages, and safety devices should be provided. These would include blow off, steam lead, feedwater lead, water gage, pressure gage, safety valve, and fusable plugs. By no means the least important requirement is the necessity of having an accessible boiler. This need is true of all boilers which are expected to be insured, in order that the insuring companies' inspectors may from time to time determine the state of the risk. Accessibility is also needed for maintenance, inspection, and repair by the regular boiler operating personnel. (F.T.M.)

BOILER CODE. Many years ago the need for a set of rules and regulations governing the construction of externally fired pressure vessels was keenly felt, since the purchaser of the **boiler** usually had no means of determining whether the boiler was adequate to meet its service conditions. The particularly hazardous situation was that failure often came in the form of a disastrous explosion, with little or no prior warning. The Boiler Construction Code was set up and has been maintained ever since by the Boiler Code Committee of the American Society of Mechanical Engineers. This code is the formulation of rules for the construction of boilers of safe and conservative design, and has frequently been written into legal and insurance regulations concerning boilers. It is revised continuously as new developments appear in the boiler field, and its committee attempts to answer pertinent questions regarding points and details of boiler construction.

Another form of boiler code, which is also a project of the American Society of Mechanical Engineers, but not in any way connected with the construction code, is the **boiler test** code, which serves as a standard way of expressing the performance of a boiler or steam generating unit. The test code is, in reality, an arithmetical balance of the heat entering a steam generating unit against the heat leaving. The heat in the coal or other fuel fired into the furnace must be accounted for either as useful heat or as one or the other of several different losses. A **boiler test** is performed to obtain the information necessary to account for the heat produced by combustion of the fuel.

The boiler test code for stationary steam generating units has the following items:

1. Heat absorbed by the boiler.
2. Loss due to moisture in coal.
3. Loss due to water formed by burning of hydrogen.
4. Loss due to hydroscopic moisture in air.
5. Loss due to heat carried away in dry chimney gas.
6. Loss due to incomplete combustion of carbon.
7. Loss due to unconsumed combustible in refuse.
8. Loss due to unconsumed hydrogen and hydrocarbons, radiation, and other losses.

The sum of these eight items is equal to the higher heat value of the fuel. (F.T.M.)

BOILER EFFICIENCY. By boiler efficiency is meant the measure of ability of a boiler to transfer the heat given it by the **furnace** to the water and steam. This will sometimes include **superheater** performance. Boiler and furnace are so much a unit nowadays that "boiler and furnace" efficiency is more important than boiler efficiency. In fact, boiler efficiency is often taken with the meaning of boiler and furnace efficiency; that is the percentage of the higher heating value of the fuel which will be in the steam. Efficiency is also designated by "evaporation," which is simply the pounds of steam produced per pound of fuel fired. This evaporation may be either the actual evaporation or the equivalent evaporation that would be obtained with the same heat producing steam at 212° F. from feedwater at 212° F.

In the light of the second law of **thermodynamics**, it would hardly seem right to charge the boiler with being unable to absorb any of the heat that was at a lower thermal level than the boiler itself. The "true boiler efficiency" is an expression used to denote that portion of the heat above the saturation temperature which is absorbed by the boiler. It is obtained by dividing the heat absorbed by the boiler by the heat liberated in combustion, less the heat regained if the products of combustion were cooled from the boiler saturation temperature to atmospheric temperature. (F.T.M.)

BOILER HORSEPOWER. The term boiler horsepower was defined in 1876 At that time the average engine would operate on 30 pounds of steam per horsepower per hour, and a boiler horsepower was defined as the capacity to generate steam at that rate The average rate of evaporation, then, was 3 pounds of steam per square foot of heating surface per hour in a water tube boiler, so 10 square feet of heating surface was accepted as manufacturer's rating for a boiler horsepower The 10 30 ratio of heating surface to steam rate became obsolete when steam rates were reduced to less than 10 pounds per horsepower hour through improvements in steam turbines and engines, and evaporative rates were increased from 10 to 15 pounds per square foot per hour by improvements in boiler design and manufacture Yet the 10 square feet per boiler horsepower persisted, so that now capacity can be expressed in terms of the manufacturer's horsepower rating only by misuse of the term "per cent rating" For instance, an 8000 square foot boiler when producing 72,000 pounds of steam per hour would be said to be operating on 300% rating This might be construed to mean an overload of 200% on some equipment, but it would be the normal load for the boiler When the significance of the term "per cent rating" is understood, there is no disadvantage to the use of boiler horsepower actually developed, as 1 boiler horsepower = 33,500 B T U per hour transferred to the water (F T M)

BOILER TEST. The performance of a steam generating unit cannot be gauged by visual inspection of the equipment in operation Yet an understanding of where the heat units are going, what portion of them are usefully retained and what portion lost, and of those lost, how they are lost, and whether the losses are tending to increase, or whether they may be reduced, is highly desirable whenever there is an attempt to operate a boiler plant with the highest standards of technique and economy Furthermore, a breakdown of costs often requires definite numerical data as to the performance of the steam generating unit Then, too, there is always the natural curiosity of boiler operators as to the results they are getting from their equipment, and whether these results are the best that can possibly be obtained This information can be secured by a test upon a **boiler,** although a complete test is a job of no little magnitude

Most boiler tests are planned to obtain sufficient data to set forth the results in the form of the balance called for in the **boiler test code** The test information that must be obtained is as follows First, there is an analysis to determine the percentage of constituent gases present in the products of combustion These gases are some or all of the following **nitrogen, carbon dioxide, carbon monoxide,** and **oxygen** Their relative proportions are obtained by a gas analyzer known as the Orsat apparatus The temperature of the products of combustion (called flue gas) at the exit from the **boiler** must also be taken The ultimate chemical analysis of the **fuel** in the state as fired is determined for a representative sample of the fuel used during the test Then if there is refuse, such as the ash of a coal-fired furnace, that refuse must be analyzed for the presence of unburned combustible The atmospheric conditions of temperature and humidity are also needed, although frequently the effect of moisture in the air is neglected, and humidity readings are omitted The boiler test is made over an extended period of time to eliminate the effect of small irregularities of load, and no test of less than one hour's duration should be considered worth while Tests are more frequently run for a period of three to twelve hours The amount of steam produced during this period, as well as the weight of fuel fired, temperature of the feedwater, steam pressure and temperature complete the information required to determine the distribution of the total heat available in the fuel, between useful heat and the various losses The computations involved are quite beyond the scope of this article, but will be found adequately explained in any good book on heat engineering (F T M)

BOILING POINT. The normal boiling point of a **liquid** is the temperature at which its maximum or "saturated" **vapor pressure** is equal to the normal **atmospheric pressure,** 760 millimeters of mercury If the pressure on the liquid varies, the actual boiling point varies in accordance with the relation between the vapor pressure and the temperature for the liquid in question (See **Vapors**) Water, for example, with a normal boiling point of 100° C or 212° F, boils at ordinary room temperature when the pressure is reduced to about 17 millimeters, and inhabitants of elevated regions often find difficulty in cooking food by boiling, because of the low boiling point On the other hand, the boiling water and steam in a "pressure cooker" are so hot that such foods as meat and rice are cooked tender in a very short time If a solid is dissolved in the liquid, or if another less volatile liquid is mixed with it, the boiling point is raised to a degree expressed by the boiling point laws of Van't Hoff, Raoult, and others (See **Solutions**)

A liquid does not necessarily begin boiling when the temperature reaches the boiling point If kept perfectly quiet, and especially if covered with a film of oil, water may be raised several degrees above its normal boiling point, before it suddenly boils with explosive violence, it then returns to its true boiling point

Following is a brief table of normal boiling points

Substance	B P (°C)	Substance	B P (°C)
Alcohol	78 3	Glycerin	291
Benzene (C_6H_6)	80 0	Helium	−272
Bromine	58 8	Hydrogen	−259
Carbon disulfide	46 3	Mercury	357
Chloroform	61 2	Turpentine	150
Ether	34 6	Water	100

(I D W)

BOLE. A fine-grained, sticky, bright red, **laterite;** the decomposition product of **basic igneous** rocks, such as **basalt** (R M F)

BOLIDE. Bolide is the term applied to **meteors** which are observed to explode in the air, and break up into two or more fragments Such objects are frequently described as having the appearance of an exploding rocket Not infrequently following the explosion of a Bolide a sharp detonation is heard (W K G)

BOLL WEEVIL Insecta, Coleoptera A **snout-beetle** or **weevil,** *Anthonomus grandis,* averaging about one-fourth inch in length, which damages cotton The adult punctures the cotton squares to lay its eggs and thus prevents the formation of the boll, and later in the season deposits eggs in the bolls, where its larvae damage the seeds and lint

The species entered the United States from Mexico in the early nineties and is now an established pest in practically all cotton-growing areas, causing annual loss estimated at $200,000,000 The problem is met by various methods of keeping the insect in check The destruction of cotton plants after the crop is harvested kills many insects, and dusting the growing plants with **calcium arsenate** has been found effective The powder is applied by hand dusters in small fields or by larger power dusters where necessary Aeroplanes have been used in recent years for dusting on a large scale (A W L)

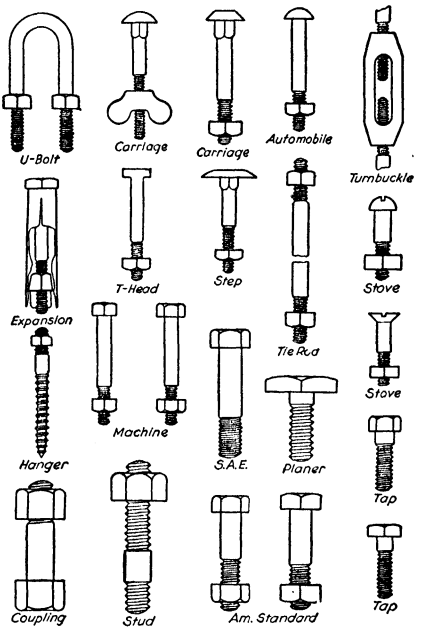
BOLLWORM. Insecta, Lepidoptera The pink cotton bollworm is a small **moth** whose **larva,** the bollworm proper, lives in the flowers of cotton and usually prevents their maturing, and later enters the bolls and damages the seed and lint The species lives on several other species of plants and is therefore difficult to check, although it is not yet as serious a pest as the boll weevil The larva of another moth of larger size, more widely known as the corn earworm, also attacks cotton squares

and bolls, as well as corn and tobacco, and so is known as the cotton bollworm. It is estimated to cause several millions of dollars damage each year. Fall plowing and disking are practiced to destroy this insect in the pupal stage, which is passed in the ground, and dusting as for the weevil is effective. (A.W.L.)

BOLOMETER. A very sensitive **thermometric** instrument of the metallic **resistance** type, devised by Langley and used for measuring feeble **radiation**. It consists of a slender strip of platinum mounted at the lower end of a long cylindrical tube having circular stops across it at intervals to screen off all radiation except that to be observed. A slight amount of radiant energy falling upon the strip causes a measurable deflection in a sensitive galvanometer coupled with it. The sensitivity of the instrument is of the same order as that of the **radiomicrometer** of Boys. When a bolometer tube is mounted as the receiving element of a spectroscope, instead of the usual observing telescope or camera, the instrument may be used to detect and measure the lines or bands of **infrared** spectra. This arrangement is called a spectrobolometer. (L.D.W.)

BOLSON. The term applied to extensive deposits of terrestrial sediments which, as confluent **alluvial fans**, tend to fill up intermontane basins in semi-arid regions. Bolson is most properly applied to a surface feature of alluvial fans rather than to the entire structure. (R.M.F.)

BOLT. A bolt is a **fastening** which depends on screw threads for its holding power. It is made from round bar stock which is **upset** on one end to form a head, and threaded on the other end to receive the **nut**. Because a bolt must be ductile as well as have considerable strength in **tension**, the materials most commonly used are carbon steel, alloy steel, wrought iron, and brass. The shape of the head is generally square or hexagonal. Inexpensive bolts are usually left with a rough surface, but the more expensive ones, employed for automotive work, for couplings, etc., which are expected to fit the hole closely, are finished all over, and the shank between the thread and the head is held to close limits as to dimensions. Bolts which go completely through the hole, and which may be drawn tight by a nut screwed on the threaded end, are called through bolts, while those which hold two machine elements together by passing loosely through one and screwing into the material of the other are called tap bolts or cap screws. The threads of bolts, as used in the United States, have been standardized on the 60° V thread, which has a flattened crest and a filled-in root. Two series of bolt threads are in general use. One is called the American, or United States, standard thread. The nominal sizes of the United States standard bolts begin with ¼ inch in diameter and advance by sixteenths to ⅝ inch, by eighths to 2 inches, and by quarters to 6 inches. The pitch, that is to say, the distance between threads, is not the usual way of denoting the fineness of the thread, rather the number of threads per inch is given. Because the United States standard thread is a rather coarse thread, in fact, undesirably coarse for automotive services where space limitations as well as a fine degree of adjustability would tend to emphasize the advantages of a fine pitch, another series of bolt threads is employed. This is called the SAE series (Society of Automotive Engineers). In the SAE series the threads are somewhat finer. For example, a ¼ inch U. S. standard bolt has twenty threads per inch while the SAE has twenty-eight threads per inch. Below ¼ inch diameter, bolts are sized by a gage number and are called machine screw sizes, beginning with size No. 1, and continuing to size 12, but with the omission of sizes 7, 9, and 11. The SAE standard is also continued into the sizes below ¼ inch diameter by screw numbers, the same as the United States standard machine screw sizes, but with the addition of a No. 0 screw. These threads are cut either by a screw cutting lathe or by hand, using the tool called a die. While the SAE thread is quite suitable for use with steel nuts, the pitch is rather too fine to be useful as a tap bolt or cap screw in cast iron, brass or aluminum, and the United States standard thread is used in these instances. The SAE standard bolt has a somewhat thinner head. It has a transverse hole bored through the threaded portion so that the castellated nut may be locked and kept from turning by



Some examples of bolts.

a cotter pin. While the United States standard hexagonal or square head and SAE bolts are the common forms of machine bolts, other forms are frequently used; for example, the type used to fasten together stove castings has been extensively used for all purposes where a small inexpensive bolt is wanted. A stove bolt has a slotted head for use with a screw driver, and a square nut. Bolts used to fasten wooden members together have larger heads to give more area in bearing on the wood. The nuts are standard since washers are generally used.

Turned bolts are finished bolts used in structural steel erection to fasten members together when **rivets** cannot be driven. (F.T.W.)

BOLTZMANN CONSTANT. Ideal Gas Law.

BOLTZMANN'S PRINCIPLE. A somewhat general law relating to the statistical distribution of large numbers of minute particles subject to thermal agitation and acted upon by a **magnetic**, an **electric**, or a **gravitational field**, or by **inertia**. The number of particles per unit volume in any region of the field, when the system is in statistical **equilibrium**, is given by the equation

$$N_E = N_{0\epsilon}^{-\frac{E}{kT}}.$$

Here E is the **potential energy** of a particle in the given region, N_0 is the number per unit volume in a region of the field where E is zero, k is Boltzmann's constant (ideal gas constant per molecule), and T is the absolute temperature of the system of particles Such an equilibrium may exist, for example, in a mass of electrified colloidal particles kept in suspension by their **Brownian movement** while acted upon by an electric field A well-known special case is Laplace's "law of atmospheres," treated in the **kinetic theory** of gases (L D W)

BOMB, VOLCANIC. Lapilli.

BOMBARDIER BEETLE. Insecta, Coleoptera A **ground-beetle** which discharges a strong-smelling volatile secretion in small jets when disturbed Each discharge is accomplished by an audible report and a visible puff of vapor as the secretion evaporates The numerous species make up the genus *Brachinus* (A W L)

BOND. Chemical bonds are discussed under **valence** Electrical bonds are conductors connected between metal shapes, when those shapes do not constitute an effective electrical circuit Railroad rails, for example, are used for the **block signal** circuit In order to utilize them for that service, the rails must be electrically continuous The bonding of a rail consists of attaching a conductor firmly, between adjacent rail ends so that a positive path for flow of electric current will replace the haphazard and unreliable circuit that would be comprised by the ordinary rail construction in which rails are connected mechanically by fishplates The contact resistance at these plates is too great, and so a short bonding connection is used Bonding may be dispensed with when the rails are welded together Bonding is also necessary where a radio is installed in a metal framework, some parts of which are bolted together These joints, where the electrical contact is a surface contact, are frequently by-passed electrically by a bond Aircraft and automobiles are often bonded this way

Mechanical bonds play an important part in many structures

The grip exerted by one material on another when in contact is called bond The bond resistance is measured in pounds per square inch of contact surface The theory of reinforced **concrete** design takes into account the bond existing between the concrete and the reinforcing steel This bond is the result of the molecular attraction called adhesion and the frictional force resulting from the shrinkage of the concrete around the rods The intensity of the bond depends upon the proportions of the concrete, the age of the mix, the condition of the surface of the rods and the kind of rods used Reinforcing rods which are made with irregular surfaces are called deformed rods and are able to exert a greater bond resistance than plain rods (F T M)

BONE. A rigid supporting tissue of which the skeleton of **vertebrates** is composed Its rigidity is due to deposits of inorganic salts, chiefly **calcium phosphate**, between the living components of the **tissue** Cells are scattered throughout this hard matrix and at intervals it is penetrated by blood vessels and nerves which are necessary for the maintenance of its living parts The matrix is also penetrated by a foundation of organic **fibrils** produced by the cells

Bone occurs in two forms compact bone such as the walls of the long bones of the skeleton, and cancellous bone composed of a reticular arrangement of slender parts which results in a spongy appearance The latter is found in the ends of long bones, among other situations

Compact bone is made up of thin plates called lamellae arranged in a definite plan At the surface they follow the periphery of the bone but inside of the compact mass they are arranged concentrically about slender canals which run lengthwise of the bone These cylindrical components are called Haversian systems, the central Haversian canal contains blood vessels and a small amount of connective tissue, together with the nerve fibers which supply these parts Nourishment reaches the cells which lie among the surrounding lamellae by way of protoplasmic processes lying in minute canaliculi which radiate from the cavities containing the cells and communicate with the Haversian canals Between the Haversian system are irregularly disposed layers known as ground or interstitial lamellae

Bone is of **mesodermal** origin and develops chiefly from the **mesenchyme** The vertebrae, certain bones of the skull, and the long bones are first formed in cartilage which is later replaced by (not transformed into) bone, while others, such as the thin bones of the skull and the bones of the face, are formed directly from mesenchyme, the former are called replacement bones and the latter membrane or dermal bones

The term bone is also used to designate a single structural unit of the skeletal system (A W L)

BONGO. Mammalia, Artiodactyla One of the harnessed **antelopes** or bush-bucks of western Africa It lives in the forests *Boocercus euryceros* (A W L)

BONITO. Pisces, Teleostei *Sarda* Marine fishes (**Pisces**) of several species, related to the mackerel and tuna (A W I)

BONNER DURCHMUSTERUNG The name Bonner Durchmusterung is applied to the monumental catalogue of 324,198 stars observed by that tireless observer F W A Argelander Accompanying the catalogue is an atlas of the heavens upon which each of the catalogued stars is shown by a dot, the size of the dot being proportional to the apparent brightness of the star The catalogue contains practically every star brighter than the tenth **magnitude** north of **declination** $-2°$ The catalogue is commonly referred to as the B D and in many astronomical purposes a particular star is referred to by its B D number (i e, by the number assigned to it in the Bonner Durchmusterung)

The catalogue was continued by Schonfeld down to declination $-23°$, and Thome at Cordoba has extended it still further to $-61°$ It is hoped that the plan will be continued to the south pole

In each of the catalogues stars are numbered in order of increasing **right ascension** within a particular zone of declination Hence, a star known as CDM -48 1116 is the 1116th star in the Cordoba extension of the BD catalogue between declination -48 and -49 (W K G)

BONTEBOK. Mammalia, Artiodactyla A small South African **antelope**, *Damaliscus pygargus* (A W I)

BONY PIKE Pisces, Holostei A fish (**Pisces**) The garpike and **gars** (A W L)

BONY-TAIL. Pisces, Teleostei A fish (**Pisces**) of the Colorado and Gila rivers, related to the minnows and chubs *Gila elegans* (A W L)

BOOK-LOUSE. Insecta, Corrodentia A small **insect** found in old papers, books and rubbish and in collections of biological specimens The order to which they belong is a small one containing winged species found on bark and lichens, and wingless species to which this name is applied

Book-lice must be very numerous to do appreciable damage, and since they frequent damp situations, heating and drying rooms where they are found is usually a simple method of destroying them Severe infestations can be checked by fumigation (A W L)

BOOK SCORPION. Arachnida, Chelonethida A European species of pseudoscorpion which is sometimes found in books and papers (A W L)

BOOM. A boom is a movable inclined arm of wood or steel used on some types of **cranes** or **derricks** to support the hoisting lines which carry the **loads** The loads cause direct **compression** in the boom due to the manner in which the hoisting lines are connected to the member

The word boom also describes a floating chain of logs, which is anchored in such a position in a body of water as to deflect or intercept saw logs, or to prevent floating debris from approaching water intakes to pipe lines, penstocks, etc Nautically, a boom is a spar holding the foot of a fore and aft sail (C W C , F T W)

BOOMER Mammalia 1 The great gray **kangaroo** of Australia, a **marsupial** 2 The mountain beaver, *Aplodontia*, a species of **rodent** which lives in the forests in the mountain ranges of the Pacific Coast It is more closely related to the squirrels than to the true beavers (A W I)

BOOSTER. An electrical booster is inserted in series in an **electric circuit**, and increases the **voltage** of that circuit There are several uses to which the booster can be put It may be employed to compensate for a line voltage drop, or it may be employed to vary voltage in such a way that constant current is maintained The boosting of direct current circuits is accomplished by rotating equipment called booster generators If this booster is driven by an electric motor the set is called a motor-booster The booster generator can be used to raise the line voltage at a feeder point on an electric traction system

The booster transformer is sometimes used in **alternating current circuits** On a simple single phase circuit it boosts the line voltage by connecting the primary of the **transformer** across the line, and the secondary in series There are some disadvantages to this connection, however, since blowing of a fuse, or otherwise open circuiting the primary, leaves the transformer connected as an open circuited series transformer, and the open circuit voltage on the primary winding may be excessive

A mechanical booster is an auxiliary cylinder with which steam locomotives are sometimes equipped It drives on the trailing truck or on a truck of the tender The booster installation is used principally on freight locomotives, especially in the mountain sections where the extra tractive power is needed in starting the train When starting a train from rest the locomotive is obliged to exert a much greater tractive effort than when the train is in motion, because the coefficient of static friction exceeds the coefficient of rolling friction The booster is used only when starting the train, and is disengaged, usually automatically, when the train speed reaches something like 15 miles per hour The booster drives through a geared crankshaft to the trailer truck This extra power is available when starting, by virtue of the fact that with a locomotive moving slowly, the main cylinders are not able to use all the steam that can be produced by the boiler (F T M)

BOOTES (The herdsman) (Map, page 306) While not in the **zodiac**, Bootes is one of the earliest recorded **constellations** It is readily recognized in the early summer skies from the kite-shaped configuration of stars with the bright star Arcturus at the position of the tail of the kite

The star **Arcturus** is the fourth brightest star visible in the northern latitudes It is also a very interesting star from the astronomical point of view, being what is known as a **giant** star In appearance the star is a reddish yellow and the **spectral type** is such as to indicate that its temperature is slightly lower than that of the sun Its angular diameter has been very carefully determined, and, since its distance is known, we find its linear diameter to be about 30 times that of the sun

Many of the other brighter stars in Bootes are **double stars**, several of them forming interesting objects of study with relatively small instruments (W K G)

BORACITE. Boracite is a **borate** of **magnesium** containing some **chlorine.** It appears to be **isometric** but probably becomes so only at 265° C below which temperature it is believed to be **orthorhombic** Its hardness is 7, specific gravity, 2 9, luster, vitreous, color, white to gray, sometimes yellow or green, translucent to subtransparent It occurs in beds with **gypsum** and salt in Germany, particularly at Stassfurt in Saxony (E S C S)

BORAX Boron.

BORER. Insecta Any insect which burrows into the tissues of plants Among the more common pests of this kind are the peach-tree borer, *Synanthedon*, the squash borer, *Melittia satyriniformis*, and the wheat sawfly borer, *Cephus pygmaeus* In the garden, borers frequently kill young plants by hollowing out the stem and they may even kill larger plants or weaken them so that they break off in the wind The borers include insects of several orders and various habits, hence it is impossible to suggest general methods of treatment A knowledge of the habits of the insect, particularly of the time of year when the eggs are laid or when the larvae enter the plants, is important since at other times the insect is beyond reach In the home garden the hole made by the insect on entering the stem is often readily visible and by slitting the stem the invader can be found and killed, but unfortunately the weakening of the plant is the first indication of trouble (A W L)

BORING. Boring is the process of forming a circular hole by cutting up or washing out the material which is encountered Drilling is the specific name given to the action of boring holes in rock or metal Earth augers are used for making holes in the ordinary types of soil Wood augers or tools, called bits, are used to cut holes in wood Wash borings are frequently used to examine the subsurface formations in connection with deep **foundation** work The equipment consists of a hollow pipe called a jet pipe and a larger hollow pipe called a casing Water under pressure is forced down the jet pipe This water washes the disintegrated material up through the space between the jet pipe and the casing to the surface where it may be retained for future examination As the material at the bottom of the casing is washed away the casing is slowly forced downward Where hard materials are encountered the equipment consists of a drill bit, a hollow drill stem and a casing Water is forced down the hollow drill stem and out through the end of the drill which is used to break up the subsurface material (C W C)

BORNEOL Alcohols and Ethers.

BORNITE (Peacock Ore) (Horse-flesh Ore). Named for the German mineralogist of the 18th century, Ignatius von Born, this mineral is a **sulfide** of **copper** and **iron** corresponding to the formula $Cu FeS_4$ It is **isometric** with a cubic habit, although crystals are rare, usually occurring as granular or compact masses Its fracture is conchoidal to uneven, brittle, hardness, 3, specific gravity, 4 9–5 4, color, copper red to reddish brown (hence the name horse-flesh ore) when freshly fractured, it soon assumes an iridescent tarnish (hence the name peacock ore) Luster, metallic, streak, grayish black, opaque

Bornite as a primary mineral has been observed in **pegmatite** veins and in **igneous rocks** and is also a common secondary mineral

Bornite crystals have been obtained in Austria and England As an ore it is important in Tasmania, Chile, Peru and in Montana Bornite has been found in Connecticut and in the Province of Quebec (E S C S)

BORON. Symbol B Atomic number 5 Atomic weight 10 82 Density 2 54 (for the crystalline form), 2 45 (for the amorphous form) Hardness 9 5 (for the crystalline form) Melting point 2300° C Boiling point 2550° C Isotopes 10 (20 6%), and 11 (79 4%).

Boron is (1) a yellowish-brown crystalline solid, (2) an amorphous greenish-brown powder Both forms are unaffected by air at ordinary temperatures but when heated to high temperatures in air form oxide and nitride Crystalline boron is unattacked by **hydrochloric** or **nitric acid**, or by **sodium** hydroxide solution, but with fused sodium hydroxide forms sodium borate and **hydrogen**, reacts with **magnesium** but not with **sodium** Discovered by Davy and by Gay-Lussac and Thenard in 1808

Boron occurs as **rasorite** or kernite (sodium tetraborate tetrahydrate, $Na_2B_4O_7\ 4H_2O$) and **colemanite** (calcium borate, $Ca_2B_6O_{11}\ 5H_2O$) in California, as **sassolite** (boric acid, H_3BO_3) in Tuscany, Italy, and also locally in Chile, Turkey, and Tibet The borates are transformed to boric acid, which is heated to form the oxide, and this last reduced to boron by ignition with **aluminum** powder The aluminum is then dissolved by hydrochloric acid or sodium hydroxide solution, leaving boron residue

Acids boric acid (ortho H_3BO_3 or $B_2O_3\ 3H_2O$, pyro or tetra $H_2B_4O_7$ or $2B_2O_3\ H_2O$, meta HBO_2 or $B_2O_3\ H_2O$), white solid, soft and smooth to the touch, moderately soluble in the cold but very soluble in the hot, made by reaction of solution of a borate and hydrochloric, nitric, or sulfuric acid of proper concentrations, forms boron oxide glass upon ignition, forms borates by precipitation reactions or by fusion methods, used as an antiseptic, and in cosmetics and skin powders, hydrofluoboric acid (HBF_4), colorless solution, by reaction of boron fluoride with **hydrofluoric acid** solution forms fluoborates by neutralization method

Borates sodium tetraborate, borax ($Na_2B_4O_7\ 10H_2O$), white solid, soluble, used (1) in soaps and laundry starch glazes, (2) in ceramic glazes and enamels, and special glasses, (3) in metallurgical **fluxes**, (4) as source of boron containing substances, **calcium** borate, white solid, insoluble, **silver** borate ($AgBO_2$), white precipitate, by reaction of borate solution and silver nitrate solution (silver oxide, brown solid, may accompany in this reaction), potassium fluoborate (KBF_4), white solid, moderately soluble, by reaction of hydrofluoboric acid and **potassium** carbonate, and then crystallizing, sodium perborate ($NaBO_3$), white precipitate, by reaction of sodium borate solution and **hydrogen peroxide**, used (1) as germicide and antiseptic, (2) as oxidizing and bleaching agent, (3) in cosmetics and soaps, methyl borate, and ethyl borate, see below

Borides carbon boride (CB_6) and silicon borides (SiB_3 and SiB_6) are hard, crystalline solids, produced in the electric furnace, magnesium boride (Mg_3B_2), brown solid, by reaction of boron oxide and magnesium powder ignited, forms boron hydrides with hydrochloric acid, calcium boride (Ca_3B_2), forms boron hydrides and hydrogen gas with hydrochloric acid

Chloride boron chloride (BCl_3), colorless fuming liquid, by reaction of boron, or boron oxide plus carbon, heated with **chlorine**, boiling point 12 5° C

Fluoride boron fluoride, boron trifluoride (BF_3), colorless gas, by reaction of boron oxide, **calcium** fluoride and hot concentrated **sulfuric acid**, reacts with water to form boric acid plus hydrofluoric acid, and the latter, with excess boron fluoride, forms hydrofluoboric acid, combines with ammonia (e g , $BF_3\ NH_3$)

Fluoborate potassium fluoborate (KBF_4), white solid, slightly soluble, decomposed, upon heating to 500° C

Hydrides tetraboron hydride, tetraborane, borobutane (B_4H_{10}), colorless liquid 16° C , by reaction of **magnesium** boride and **hydrochloric acid**, followed by fractional purification of the gas, tetraboron hydride is the best known hydride, others lower and higher in the series are known

Nitride boron nitride (BN), white solid, insoluble, reacts with steam to form **ammonia** and boric acid, formed by heating anhydrous sodium borate with **ammonium** chloride, or by burning boron in air

Oxide: boron oxide, boron trioxide, boric acid anhydride (B_2O_3), white, glassy solid, reactive with water to form boric acid and used as a dehydrating agent, melting point about 575° C , formed by heating boric acid to high temperature with loss of water, used as a nonvolatile acidic oxide

Sulfide boron sulfide (B_2S_3), white solid, unpleasant odor, irritating to the eyes, reactive with water to form boric acid and hydrogen sulfide, formed by reaction of boron oxide plus carbon heated in a current of **carbon disulfide** at red heat

Organic compounds methyl borate, trimethoxy boron ($B(OCH_3)_3$), colorless liquid, boiling point 65° C , by reaction of boric acid, even in very dilute solution, and methyl alcohol, and recognized by the green color of the flame when ignited, ethyl borate, triethoxy boron ($B(OC_2H_5)_3$), colorless liquid, boiling point 120° C , by reaction of boric acid, even in very dilute solution, and ethyl alcohol, and recognized by the green color of the flame when ignited

Boron trimethyl ($B(CH_3)_3$) is a colorless gas, boron triethyl ($B(C_2H_5)_3$), a colorless liquid, boiling point 95° C , boron diethyl dihydroxyl ($(C_2H_5)_2B(OH)_2$), sublimes at 40° C

Borate solution when slightly acidified, or dilute boric acid solution imparts a characteristic reddish color to turmeric paper, intensified upon drying, and turned a characteristic bluish color upon moistening with ammonium hydroxide

When borates are treated in a porcelain dish with methyl alcohol and concentrated sulfuric acid, the mixture stirred and ignited, a green bordered flame will appear (R K S)

BORROW PIT. The section of ground from which earth is excavated for the purpose of being used as fill at some other point is called a borrow pit Borrow pits are used extensively in connection with highway construction since it is often more economical to obtain fill from some nearby source than to carry it from some distant point along the line where there is an excess of cut When it is necessary to ascertain the amount of material taken from a borrow pit the ground surface is divided into rectangles or triangles before any material has been removed This grid system is referred to an arbitrary **base line** and elevations are taken on each of the corners After the required material has been removed the system of rectangles or triangles is reproduced by means of the base line and elevations are again taken on the corners The volume of material which has been excavated then consists of the sum of the volumes of the individual prisms (C W C)

BORT or BOART. Diamond

BOSS. The term boss or stock is used to indicate a cross-cutting mass of **igneous rock** which has ascended into the crust of the earth and may or may not represent the roots of volcanic conduits Bosses are roughly circular or elliptical in ground plan and usually of greater cross-sectional area than a volcanic neck and lack **pyroclastic** materials Most probably bosses are the irregular upward extensions of **batholiths** the main parts of which are as yet unexposed (E S C S)

BOSTONITE A rather rare rock type, dense, with an occasional feldspar **phenocryst** and grayish in color It is composed almost wholly of alkaline feldspar, being analogous to **aplites** The type locality is Salem Neck, Massachusetts, not many miles from Boston, for which it was named (E S C S)

BOTANY. Botany is the science which deals with plants It is divided into many sections, each dealing with a specific part of the subject One section, which describes plants and arranges them in classes, is called taxonomy, another section, morphology, considers the form of the various parts of a plant, while its subsec-

tions include anatomy and histology, the study of the internal structure of plants, and cytology, the study of the cell and its parts A third, physiology, deals with the functions of the parts In addition, one may study plant geography, or the distribution of plants on the earth, ecology, the relations of plants to each other and to their environment, phytopathology, or the diseases of plants, paleobotany, the science of fossil plants, and economic botany, which considers the uses which man has found for plants and plant products

The science of botany is very old Since the welfare of man is closely connected with plants, it is natural that they should receive attention early Undoubtedly plants were known and observed by men long before the period of Greek supremacy Various recorded observations suggest that such is true But only with the intellectual curiosity of the Greek mind do plants receive close attention Aristotle (384–322 B C) studied them attentively and cultivated many species from widely separated regions His disciple Theophrastus (371–287 B C) carried on the work and wrote about them in his "Enquiry into Plants," in which he describes some five hundred species and gives extensive and keen observations concerning them In Rome another naturalist, Pliny the Elder (23–79 A D), writes extensively on Natural History, setting forth information on some thousand species of plants His facts are largely drawn from sources other than the plants themselves and are often grossly exaggerated His Natural History was of immense importance, however, and largely controlled the thought of botanists for many centuries Another ancient naturalist, Dioscorides, also studied plants He was mainly interested in them because of the important place they held in the medical practice of that time Indeed, the study of plants was for a long period of time considered the province of physicians and doctors, whose main interest was in plants as remedies or supposed remedies for various ills After this, centuries followed in which little attention was given to plants, all knowledge thereof was drawn directly from the works of the ancient writers

Beginning with the sixteenth century, however, interest in plants was revived Men began observing the native plants around them and recording these observations, often accompanied by illustrations, in herb books or herbals Such observations led to attempts to arrange and classify the various plants Among the first herbals were those of Brunfels (1530) and Fuchs (1542), both of them containing excellent illustrations, but relying for their descriptions largely on the ancient writers of Greece and Rome Hieronymus Bock (1498–1554) was another herbalist, who gave in his book extensive first-hand descriptions of the plants which he treats. William Turner and John Gerard published herbals treating of English plants Valerius Cordus (1515–1544) gave even more complete and accurate descriptions of the plants in his books than Bock

As a result of the work of these men and many others, came a need for a better understanding of plants and the necessity for arranging them in some sort of system other than that of size or of the alphabet John Ray (1628–1705) advanced the problem considerably by introducing an exact concept of species, which he held to come from a single parent and to continue to produce like organisms, although he does allow some variation to occur Ray separated flowerless plants from flowering, and divided the latter into **Dicotyledons**, with two seed leaves, and **Monocotyledons**, with only one

The number of plants described was constantly increasing, rendering even more necessary a system of arranging them in order Many systems were proposed, some having great merit As early as 1583 Casalpino had eliminated any classification based on such variable organs as roots, stems or leaves, and had concluded that the flowers and fruit offered the only real basis It remained for Carolus Linnaeus (1707–1778) to bring order to the situation He invented the binomial system of nomenclature, by which each plant (and animal also) should be known by a name designating the genus and a qualifying adjective limiting the species named His system of classification was purely artificial, being based on the number of stamens and pistils (See **Flower**), but did make it easy to refer to a description and so verify an identification He also grouped plants and animals in larger divisions, the classes and orders The present day names of plants date from the time of Linnaeus It has long been recognized that there seemed to be a natural grouping of plants, John Ray apparently understood some of the larger groups of plants With the work of the French taxonomist A L de Jussieu came a definite knowledge of the natural relations of plants, which he grouped into fifteen classes with about a hundred orders

While classification and description occupied a large place in the development of botany, other branches of the science were not neglected, although of necessity many of them waited on advancement in taxonomy The anatomy of plants was studied by Jehemiah Grew (1641–1712) in England, and Marcello Malpighi (1628–1684) in Italy, while casual observations on the internal structures of some plant substances were made by Robert Hook The finely illustrated writings of these men established the foundations for an understanding of the internal structure of plants Subsequent workers in this field showed the similarities existant in the internal structures of plants, and the changes which have occurred during the evolution of plants Out of this have come the later studies of cytology and histology

Any knowledge of the way in which the plant lives and the functions of its various parts was slow to develop The lack of definite organs connected with such functions as digestion, circulation, respiration, etc , made the problem even more difficult Occasional observations had been made from time to time, often leading to erroneous conclusions With Stephen Hales (1677–1761) plant physiology became established He first used instruments to measure various physiological activities which he studied His observations, recorded in his "Vegetable Statics," published in 1727, show how attentively he studied the problem of nutrition in plants and the movements of liquids within the plant Ingen-Housz (1730–1799) gained more exact knowledge of the problem of nutrition in plants, definitely showing that the **carbon** in plants came from the **carbon dioxide** of the atmosphere He had an accurate knowledge of the role of gases in the life of the plant Another worker, Andrew Knight (1758–1838), studied an entirely different field, being largely interested in the problem of direction of growth of root and stem To him is due the use of a rapidly revolving wheel to which seedlings were attached From this experiment he determined that roots grew away from the center of the revolving wheel and stems towards the center Out of his studies came the study of tropisms (See **Movements in Plants**) in general At the present time the study of physiology of plants is one of the most important and most fascinating, engaging the attention of many workers

However, other branches of the science of botany have not been overlooked The study of the distribution of plants has been pursued with great vigor, bringing to light many interesting problems, at times difficult to explain Why should certain similar groups of plants appear in widely separated regions? At present this and many other questions are subjects for speculation, and cause for further study

Another branch of botany which occupies an important position today is that of plant pathology, which treats of the diseases of plants When a single disease such as **wheat rust**, attacking a single crop, causes the loss of millions of dollars in reduced harvests, and with so many crops subject to numerous diseases, this must be recognized as a study of vital importance to man Comprehensive and exact knowledge of the disease-pro-

ducing organism is necessary Often it is obtained only after prolonged, painstaking study Then follows the problem of treatment leading to elimination of the disease, a study in itself Sometimes this is impracticable, it is quicker to attack the problem in another way—to attempt to develop strains of plants which are resistant or immune to the disease In this field new problems are constantly arising, or assuming greater importance, as for example was the case in the outbreak of the Dutch Elm Disease in recent years, or of the Chestnut Blight disease which so nearly wiped out the chestnut trees of America a few years ago.

These and many other problems show how close is the welfare of mankind tied up with the study of botany and the knowledge of the many sides of that science (R M W)

BOT FLY. Insecta, Diptera **Flies** of two families whose larvae live as internal parasites in mammals The adults as a rule have vestigial mouth parts and attack the host only to deposit their eggs

Horses are attacked by two species of bot flies of the genus *Gastrophilus* One deposits its eggs on the lips, whence the **larvae** reach the throat or stomach, and the other attaches them to the hairs of the forelegs, where they die unless the horse takes the larvae into its mouth by licking or biting the legs The larvae develop in the alimentary tract and pass out when mature with the faeces These flies belong to the family Gastrophilidae

The sheep bot adult, *Oestrus ovis*, deposits living larvae in the nostrils of the host, whence they work their way into the sinuses, into the horns, and even into the brain Two other species known as **warble-flies** lay their eggs on the hairs and the young larvae migrate through the skin and ultimately to the **oesophagus** Later they migrate again through the connective tissue to the back, where they complete their development in subcutaneous abscesses which produce the external lumps known as warbles The skin over the abscess is perforated and the larva leaves its host and drops to the ground to pupate These species make up the family Oestridae, together with numerous others which attack wild animals (A W L)

BOTHRIOLEPIS. Fossil Fishes.

BOTHRIUM. A projecting or grooved structure which takes the place of a sucker on the **scolex** of some **leeches** (A W L)

BOTRYOIDAL TISSUE. A peculiar kind of pigmented **tissue** with **cells** arranged end to end and containing intracellular capillaries filled with red liquid, found in **leeches** (A W L)

BOUGAINVILLAEA. Nyctaginaceae A small genus of plants, natives of South America, which are frequently cultivated in the tropics and to some extent as greenhouse plants outside the tropics The flowers of the plants are small and inconspicuous, but are surrounded by showy bracts of various colors The plants are generally grown for these brilliant-colored **bracts** One species, *Bougainvillaea spectabilis*, is a clambering vine which is often grown in cultivation (R M.W)

BOULDER. A large fragment of rock, usually rounded, which has been moved from its place of origin by a natural agency or has been formed in situ by weathering processes Rather arbitrarily, eight inches has been set as the minimum diameter for a boulder (E S.C S)

BOULDER CLAY. Boulder clay is a glacial deposit of clay with subangular rock fragments of different sizes. (E S C.S)

BOULDER TRAIN. Erratic.

BOUQUETIN. Ibex.

BOURNONITE (WHEEL ORE). An **antimony-copper-lead sulfide** corresponding to the formula $_2PbS\ Cu_2S\ Sb_2S_3$ It is **orthorhombic**, and repeated twinning often produces crosses or wheel-shaped crystals. It is brittle, fracture, sub-conchoidal, hardness, 2 5–3, specific gravity, 5 7–5 9, luster, metallic, color and streak, dark gray to black, opaque

Bournonite is found with **galena, chalcopyrite, sphalerite,** etc There are many European localities, it was first found in Cornwall, England, by Count Bournon, for whom it was later named Bournonite occurs in Bolivia and Peru and in the United States in Arizona, Montana, Nevada and Utah. (E S C S)

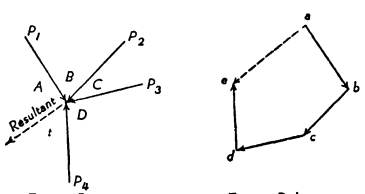
BOUTO. Dolphin.

BOWER-BIRD. Aves, Passeriformes Birds (**Aves**) of several species found in the Australian region They build runs roofed with grass or sticks and decorated with bright articles of all kinds (A W L)

BOWFIN. Pisces, Holostei A species of fish (**Pisces**) *Amia calva*, found in lakes and sluggish streams in the eastern and central United States Related to the gars and, like them, not valuable for food Also called the dogfish (A W L)

BOWMAN'S CAPSULE. Renal corpuscle.

BOW'S NOTATION. Bow's notation is a standard method of representing, by letters of the alphabet, forces and **stresses** in graphical analysis This analysis may consist of such problems as the graphical solution of stresses in simple framed structures or the determination of the **resultant** of an independent system of unbalanced forces lying in the same plane and having a common



point of application The accompanying figure illustrates the method of applying Bow's Notation to the latter system Let P_1, P_2, P_3 and P_4 be a system of unbalanced forces lying in the same plane and having a common point of application Denote the space between the line of action of each force by the letters A, B, C and D Next construct a figure called a force polygon This is accomplished by drawing a line parallel to P_1 and laying off its magnitude to a definite scale denoting the ends of the line by the letters a and b From point b lay off bc equal in magnitude and parallel to P_2 Repeat the operation for the other forces Upon completion of this graphical figure it will be found, in general, that the line representing P_4 will not pass through point a The distance from point a to end of this line, which will be lettered e, represents the value of the resultant of P_1, P_2, P_3 and P_4 according to the scale used The direction of ae determines the line of action of the resultant Thus, in Bow's Notation a force in space is designated by the space letters on either side of it, whereas the forces as part of the force polygon are named by the letters at their extremities This notation is further illustrated in the accompanying figure (C W C)

BOXWOOD. *Buxus sempervirens B balearica* Slow-growing trees or shrubs often planted for ornament because of their dark thick smooth leaves and compact habit. They are tender plants which must be

treated as greenhouse subjects in cold climates *B balearica* is a tree growing to a height of 75 feet or more From it is obtained a dense yellow wood having a very close fine grain This wood is used in wood engraving, in the manufacture of rulers and of musical instruments, and in inlay work (R M W)

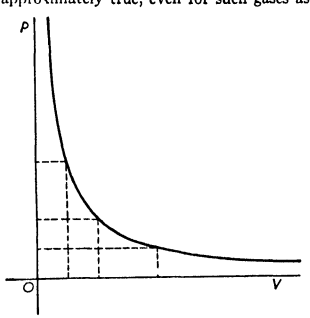
BOYLE-CHARLES LAW. Boyle's law expresses the variation of pressure and volume of a body of ideal **gas** at constant temperature, Charles' law expresses the proportionality of pressure to absolute temperature (at constant volume), while Gay-Lussac's law states the proportionality of volume to absolute temperature (at constant pressure)

A single statement of these relationships is the Boyle-Charles law, which leads to, or is a form of, the **ideal gas law.** Its mathematical expression may be written

$$pv = p_0v_0(1 + at),$$

in which p_0v_0 is the value of pv at temperature $t = 0$, and a is the volume coefficient of expansion for the gas in question If the centigrade scale is used, a is for all gases approximately equal to 1/273 or 0 003663 per centigrade degree (L D W)

BOYLE'S LAW This well-known law, attributed to Robert Boyle (1662) but also known as Mariotte's law, expresses the **isothermal** pressure-volume relation for a body of ideal gas That is, if the gas is kept at constant temperature, the pressure and volume are in inverse proportion, or have a constant product The law is only approximately true, even for such gases as hydro-



Equilateral hyperbola representing Boyle's law The rectangular areas (pv) are all equal

gen and helium, nevertheless it is very useful Graphically, it is represented by an equilateral hyperbola If the temperature is not constant, the behavior of the ideal gas must be expressed by the **Boyle-Charles law** or by the **ideal gas law.** See **Characteristic equation** (L D W)

BRACHIAL Pertaining to the arm, from the Latin term *brachium* (A W L)

BRACHIATION. Locomotion.

BRACHIOPODA. A phylum of marine animals which resemble the **bivalve** molluscs superficially In the remote past they were much more abundant, as is shown by extensive fossil remains of many more forms than exist today

The brachiopods are characterized by the following structures 1 The body is enclosed by a shell consisting of dorsal and ventral valves 2 The animal is **triploblastic** and coelomate but not segmented 3 A **ciliated** organ called the **lophophore** projects about the mouth It maintains currents of water which carry food and oxygen to the animal and wash the wastes away

The phylum is divided into two orders:

Order Ecardines Valves of shell not joined by a hinge Anus present

Order Testicardines Valves of shell joined by a hinge Alimentary tract without an anus (See also **Invertebrate Paleontology**) (A W L)

BRACHIOSAURUS. Fossil Reptiles.

BRACHYBLAST (OR SHORT SHOOT). In many plants, especially in the **Gymnosperms,** the display of leaves to light is considerably advanced by the formation of short lateral branches called brachyblasts In the **larch** this short shoot is well developed In this plant it persists, year after year, bearing at its tip a small group of leaves It does not, however, increase in diameter even after several years of growth The brachyblast develops from a bud formed in the axil of a leaf The **maidenhair tree** or *Ginkgo* is another tree having well-developed short shoots In both these plants and in many others the short shoot bears at its tip a terminal bud from which the leaves of the following year develop In the **pines,** on the contrary, the short shoot is very much reduced and bears no terminal bud In these plants the short shoot is reduced to a single bundle of leaves which persist for a year or two and then drop off completely That this condition in pines is a reduced condition is clear from the condition found in fossil pines, which have a well-developed brachyblast, bearing many leaves and having a terminal bud (R M W)

BRACHYCEPHALIC Short-headed As applied to measurement of the human skull, with a width which is more than four-fifths of the length (A W L)

BRACKET FUNGI Polyporaceae (also called Shelf fungi) A large group of **fungi** the fruit-body of which forms a characteristic shelf-like outgrowth from the trunks of trees This fruit-body arises from a mycelium of fine hyphae, which penetrate throughout the woody tissue of the host plant, from which they derive nourishment and which they slowly destroy The fruit-bodies are often perennial, showing on sectioning the successive growth-layers, which are added each year (See **Basidomycetes**) (R M W)

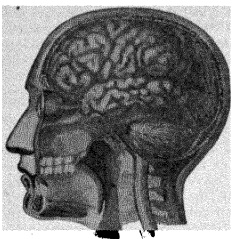
BRACT. In many flowering plants there is found at the base of the flower stalk a small leaf, often considerably modified this is called a bract In many plants its minute size causes it to be overlooked, in others it is a conspicuous object In the Poinsettia, for example, the large showy red "flower" is really composed of bracts, as also is the conspicuous white petal-like structure surrounding the very small flowers of the Dogwood (R M W)

BRAGG'S LAW. The law expressing the condition under which a **crystal** will reflect a beam of **x-rays** with maximum distinctness, at the same time giving the angle at which the reflection takes place For x-ray reflection it is customary to use the complement of the angle of incidence and reflection, that is, the angle which the incident or the reflected beam makes with the crystal planes, rather than with the normal Let this "Bragg angle" be θ If the planes or layers of atoms are spaced at a distance d apart, and if λ is the wave length of the x-rays, Bragg's law is expressed by the equation

$$\sin\theta = \frac{n\lambda}{2d}.$$

The condition for an intensity maximum is that n must be a whole number For example if the planes of rock salt parallel to the natural cubical faces are spaced at $d = 2\,814 \times 10^{-8}$ cm or 2814 x-units, and if the incident rays have a component of wave length $\lambda = 714$ x-units, the above equation gives $\sin\theta = 0\,1269n$ Then if the crystal is rotated slowly, there will be a distinct reflection when θ reaches 7° 17′ ($n = 1$), again at 14° 42′ ($n = 2$), also at 22° 23′ ($n = 3$), etc. (L D W)

BRAIN. The principal central organ of the **nervous system**, consisting of a mass of nervous tissue lying in the head or in an equivalent position in animals which have no head.



Brain. (The outer half of the skull has been removed.)

A true brain appears only in bilaterally symmetrical animals. In its simplest form it is relatively small and is known also as the cerebral **ganglion.** Such a brain occurs in the **worms.** In **cephalopod** molluscs and in some of the **arthropods** the brain is larger and more complex but in no invertebrates does it attain the degree of development which is found in the vertebrates.

The **vertebrate** brain develops as a series of three expansions of the embryonic neural tube. Beginning at the anterior end these are known as the fore brain, mid brain, and hind brain, or as the prosencephalon, mesencephalon, and rhombencephalon. Later the first and last subdivide, producing a total of five vesicles called the telencephalon, diencephalon, mesencephalon, metencephalon, and myelencephalon. These give rise to various adult structures as follows: The telencephalon produces two expansions, the cerebral hemispheres, which reach their highest development in man; they are the centers of reasoning and dominate all other regions. The telencephalon also gives rise to the **olfactory** centers and certain parts for which no simple description can be given. The diencephalon is important as the source of the **thalamus**, the retina of the **eyes**, the optic nerves, and the pars nervosa of the **pituitary gland**. The mesencephalon contains the centers of visual and auditory reflexes. The metencephalon gives rise dorsally to the cerebellum, which is a center of complex muscular co-ordination. The myelencephalon becomes the medulla oblongata, composed chiefly of great fiber tracts running between the higher centers and the spinal cord. In short, the human brain is made up of five portions: the **cerebrum**, cerebellum, midbrain, pons varolii and medulla **oblongata.**

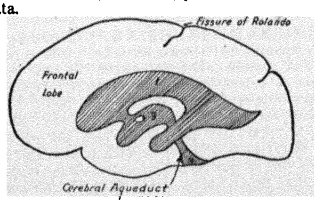


Diagram to show the ventricles of the brain in position. 1, lateral or first ventricle, of which there are two, one in each cerebral hemisphere; 3, third ventricle, and 4, beginning of fourth ventricle. (From Kimber and Gray, *Textbook of Anatomy and Physiology*, Macmillan & Co.).

The average weight of the human brain varies between 44 and 49 ounces. Growth of the brain ceases about the nineteenth to twentieth year. It loses weight as age advances.

The surface of the brain is irregular, being divided into fissures and ridges (convolutions). The brain as well as the spinal cord is covered by three layers of membranes called from without inward, the dura mater, arachnoid, and pia mater. The cerebrospinal fluid surrounds the brain and spinal cord lying beneath the arachnoid layer. This fluid is produced in the cavities of the brain (**ventricles**) and serves as a protective and nutritive medium for the brain and spinal cord. (A.W.L., R.S.M.)

BRAKE. Bracken. *Pteridium aquilinum.* A common **fern** widely distributed in temperate regions. It has an extensive **rhizome** creeping deep in the ground and bearing solitary leaves at intervals along its length. These erect leaves, called fronds, have a petiole (See **Leaf**) from one to four feet long and a much dissected blade. The margin of this blade grows over and protects the spores born on the under side of the frond. Where it is at all abundant, as on abandoned rocky hillsides, the leaves may be gathered and used as bedding for livestock or even used as a coarse fodder in case of need. (R.M.W.)

BRAKE HORSEPOWER. The mechanical output of an engine, turbine, or motor is called the brake horsepower because one of the most common methods of testing for mechanical output is with the **Prony Brake.** However, the output available at the shaft is called brake horsepower whether measured by brake or not. For example, when an **engine** drives an electric **generator** by direct connection, the horsepower available at the coupling between the machines is termed brake horsepower, but would not, under these circumstances, be measured by a brake. In the case of direct connected electric generating sets, the brake horsepower of the prime mover is found by dividing the electrical output from the generator, converted to horsepower, by the efficiency of the generator. The result is the generator input, which is the same as the mechanical output of the prime mover.

To measure brake horsepower by a Prony brake, readings of the weight registered on the scales and the speed of rotation of the brake drum are taken. In addition, the measured distance from the center of rotation to the force on the scales must be known. These quantities are substituted in the following formula to obtain brake horsepower:

$$\text{Brake horsepower} = \frac{2\pi WRN}{33{,}000}$$

W = net load on the scales, in pounds.
R = radial distance in feet to the line of action of the force registered on the scales.
N = rotative speed, in revolutions per minute.

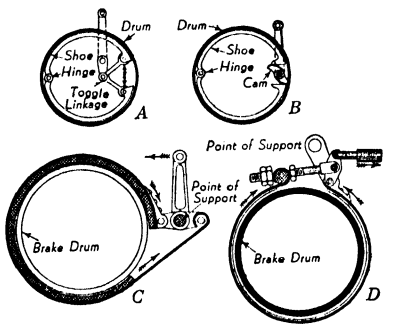
The W of the above formula is less than the load actually recorded on the scales because the tare weight must be deducted from the scale reading to give net effective weight. The tare weight is an allowance for the fact that the arm of the Prony brake itself gives some reading on the scale due to its unbalanced position, relative to the center of rotation. The tare weight is that weight which, acting at the scales, will give the same moment about the center of rotation that the unbalanced dead weight of the brake would produce. (F.T.M.)

BRAKES. A brake absorbs mechanical energy by transferring it into heat through frictional resistance The most frequently seen brake at present is a mechanical type used to reduce the speed of a machine or to bring it to a state of rest. Complete control of automotive vehicles necessitates brakes adequate to bring the vehicle from maximum speed to rest in a reasonable distance. Stationary machines such as hoists or elevators have mechanical brakes, and numerous other applications will be found outside the automotive field.

The parts of a brake are the rotating part, which is generally, though not always, the drum, and a stationary part, the brake shoe. The shoe is pressed against the drum, generating a friction force at the contact surface. The brake shoe is frequently surfaced with a special material called brake lining, whose function is to provide for a high coefficient of friction, together with smooth braking action. The wear is largely taken by the lining. When not in use, the contact surfaces are separated by a light spring. Braking action may be

applied by a mechanical linkage, such as lever or toggle joints, forcing the shoe against the drum, or by cables and pulleys, or by hydraulic means, incorporating a cylinder and plunger.

To bring a freely moving vehicle having velocity of V feet per second, and a weight of W pounds, to rest, requires the absorption of $\frac{1}{2}\frac{W}{g}V^2$ foot pounds of work at the brake drum. This energy must be equaled by the product of the friction force acting at the braking surface multiplied by the speed of rubbing, multiplied by the time during which the brake is in action, i.e., the time taken to stop. According to the theory of friction, as long as the pressure between brake shoe and drum remains constant, the friction force generated is independent of the rubbing speed.



Types of brakes.

There are many possible arrangements of brake shoe and drum. Some of these are shown in the accompanying figure, which shows internally expanding and externally contracting brakes, as well as methods of applying pressure between the friction surface. To lower a load at constant speed, the brake shoes can be mounted on the rotating shaft of the hoist drum, free to move outward under the centrifugal force set up by rotation. The brake drum is stationary. Any tendency of the load to increase the speed of rotation is counteracted by an increased centrifugal force pressing the brake shoes more firmly against the drum. (F.T.M.)

BRAMBLING. Aves, Passeriformes. A **finch** of the Old World which nests in northern Europe and Asia. *Fringilla montefringilla.* (A.W.L.)

BRANCHIAL. Pertaining to **gills.** (A.W.L.)

BRANCHIAL ARTERIES. Blood vessels which lead both to and from the **gills** in the fishes. Those which lead into the gills are the afferent branchials and those which lead out are the efferent branchials. (A.W.L.)

BRANCHIAL HEARTS. Muscular expansions of the branchial veins in the **squids** and related species which pump the blood through the **gills.** (A.W.L.)

BRANCHIAL VEINS. Branches of one of the large veins, the vena cava, of **cephalopod** molluscs which carry the blood to the gills on its way back to the heart from the anterior part of the body.

BRANCHIOPODA. A subclass of **crustaceans.** Not to be confused with Brachiopoda, the name of a phylum. (A.W.L.)

BRANCHIOSTEGITE. A lateral fold of the body wall which covers the **gills** in some of the **crustaceans.** (A.W.L.)

BRASS. Alloys.

BRASSICA. Cruciferae. A genus of plants, largely wild in Europe and adjacent Asia, which give us many of our garden vegetables. All have characteristic and often noticeable odors due to various sulphur compounds which they contain. Many of them become obnoxious weeds when introduced into new countries. Among the species cultivated are the following:

Brassica oleracea is a native of the coast of Europe from England to the Mediterranean. The wild plant is a stout branching biennial bearing large white or pale yellow flowers, and having no tendency to "head." From this have arisen, perhaps as mutants, cabbage and brussels sprouts, in which the leaves form tight heads, kohlrabi with its swollen stem, the cauliflower and broccoli with their compact, swollen inflorescences. Another form is red cabbage, used mainly for pickling. Sauerkraut is finely cut cabbage fermented in a salt juice made from its own sap; the sour taste is caused by **lactic acid** resulting from fermentation.

Brassica rapa is the turnip, a yellow-flowered biennial, growing wild in Europe and western Asia. It is a plant adapted to cool climates and much used as human food. Ruta-bagas are a related species.

Brassica napus or rape, is a biennial two to three feet high. It is used as a green manure plant, being plowed under to improve the soil, and as a forage plant. From its seeds rape oil is obtained and rape cake.

Brassica nigra, or Black mustard, an annual of Europe and Asia, is used as a garnish, and as a salad plant. The ground seeds, mixed with water, give us table mustard. *Brassica alba* is very similar to black mustard.

Brassica chinensis and related species are Chinese Cabbages, annual plants used in salads. (R.M.W.)

BRAZIL-NUT. *Bertholletia excelsa.* Lecythidaceae. In the forests of northern Brazil grows the giant tree, the **seeds** of which are the familiar Brazil-nuts. These seeds are borne in a hard capsule six to eight inches in diameter and containing about two dozen seeds. The fruits develop high up in the air and fall to the ground without opening. This favors the gathering of the fruits, which are then split open and the seeds within removed. Immense quantities of the seeds are eaten yearly in Brazil and the United States. From the seeds an oil is obtained which is used in salad dressings, in paints and as a fine lubricant. (R.M.W.)

BRAZING AND SOLDERING. The process of uniting two metallic parts with an alloy metal through the medium of surface cohesion between the base metal and the alloy is called brazing or soldering, depending on whether a **copper** alloy or a **lead** alloy metal is used for the uniting action. Soldering and brazing differ from welding in that the base metal and the soldering or brazing metal have different melting points, therefore the uniting is one of surface cohesion between the molecules to a limited depth below the surface of the base metal, whereas welding is the fusion of identical metals into a single homogeneous piece, chemically uniform.

Soft soldering is a means for uniting copper or brass by a lead-tin alloy having a relatively low melting point. The soft solder is widely used in obtaining electrical continuity between adjacent lengths of copper wiring, and the soft solders are mainly tin. A somewhat harder solder, called plumber's solder, consists of two parts lead to one part tin. Solders containing different proportions of tin and lead have melting points varying between 450 and 620 degrees Fahrenheit, the lower temperature being that for pure tin, the upper for pure lead. Hard solder, sometimes called silver solder and used where more strength is required, is made of **silver, copper,** and **zinc.** The silver content usually ranges above 50%. The melting temperature of this solder is about 1400° Fahrenheit.

Brazing is used principally on iron or steel parts. It consists of uniting the parts by means of a bond of brass,

bronze, or copper-zinc mixture **A boric acid flux is** used for the purpose of shielding the molten bonding metal from oxides When the bonding metal is brass or bronze, it is applied in the form of a rod which is melted into the brazing region by means of a torch, using a neutral flame If a brass or bronze rod is used, the base metal surfaces to be united must first be "tinned" by alloying the surface layer with the brass by rubbing in the brass in the presence of flux and sufficient heat

Brazing spelter consists of an equal mixture of zinc and copper, and is available commercially in granular form Steel parts may be brazed by being dipped in the melted spelter (at about 1600° Fahrenheit) Brazing with spelter also may be accomplished by melting the spelter and flux on the parts by the use of a torch Brazed parts should never be loaded in such a way that the brazed joint will be stressed other than by shear Brazing is not considered satisfactory for primary load carrying members or for joints whose breakage would constitute a hazardous condition in the structure (F T M)

BREADFRUIT. *Artocarpus incisa* Moraceae. The breadfruit tree is a native of the East Indian and Pacific Islands, but has been widely planted in tropical regions everywhere It is an attractive shade tree with large leaves deeply cut into pinnate lobes The large ovoid fruits have a rough surface Each fruit is composed of many **achenes** each surrounded by a fleshy **perianth** and growing on a fleshy receptable These fruits are very rich in starch Before being eaten they are roasted or boiled Some of the improved varieties bear seedless fruits (R M W)

BREAM. Pisces, Teleostei Several species of freshwater fishes (**Pisces**) of the Northern Hemisphere, allied to the carps Two of the European species are known as the zope and the zarthe and one of the North American species is called the golden shiner (A W L)

BREAST. 1 The front of the **chest.** 2. The **mammary gland.** (A W L)

BRECCIA. Breccia, derived from the Latin meaning broken, is a rock formed of angular fragments in a **matrix** which may be of similar or of different material

Fault breccias result from the grinding action of the two **fault** blocks as they slide past each other Subsequent **cementation** of these broken fragments may occur by means of mineral matter introduced by the ground water **Talus** slopes may become buried and the talus cemented in a similar manner

Volcanic breccias result from the cementation of fragments that have been broken by volcanic action Sometimes the surface of a lava flow will harden while the interior will be yet liquid, the fracturing of this surface material and its subsequent cementation by the uncooled lava produces a flow breccia

The intrusion of **plutonic rocks** will often shatter the invaded country rock forming a shatter breccia In the case of plutonic rocks partly cooled and subsequently broken by further invasions of the magma, we have intrusive breccias (E S C S)

BREED. A type of animal produced within the species by artificial selection, distinguished by definite hereditary characteristics but usually capable of interbreeding freely with other members of the species and so maintained only through artificial control of its propagation Thus Guernsey and Angus cattle are breeds which would soon cease to exist in a state of nature, while the Michigan beaver and the Pacific beaver are self-maintaining in nature and are called subspecies. (A W L)

BREWSTER'S LAW. In 1815 Sir David Brewster discovered that for any dielectric reflector there is a simple relationship between the polarizing angle (See **Polarized Light**) for the reflected light of a particular wave length and the **refractive index** of the substance for the same wave length The relationship is that the tangent of the polarizing angle is equal to the refractive index For example, if the refractive index of flint glass for sodium light is 1 66 the polarizing angle for the reflection of sodium light by this glass is 50° 56′

An interesting consequence of this relationship may be deduced If the angle of incidence is the polarizing angle p, and the corresponding angle of refraction at a boundary with refractive index, n, is ρ, then, by Brewster's Law we have

$$\tan p = \frac{\sin p}{\cos p} = n = \frac{\sin p}{\sin \rho}.$$

Hence $\cos p = \sin \rho$ or $p + \rho = 90°$ It follows that when the light is incident at the polarizing angle, the reflected and refracted rays are perpendicular to each other This might be used as a means for measuring the refractive index of highly absorbing **dielectrics** such as polished obsidian, pitch, etc (L D W)

BRIAR. *Heath Family*

BRICK. Brick ordinarily refers to a rectangular prism of clay which has been burned in a kiln Clay is no longer the only material for brick manufacture, being supplemented by slag, cement, lime, etc However, when other than the ordinary structural clay brick is meant, a descriptive term such as fire brick, sand-lime brick, etc, is employed The principal classifications of brick are for structural purposes in buildings, for paving, and for lining furnaces, the latter known as refractory brick, or fire brick Ordinary bricks are made from a selected clay soil first by preparation of the clay by grinding and thoroughly mixing with enough water to make the mud The brick are then formed in the required shapes by one of several methods In the soft mud method the prepared clay is quite plastic and the bricks are molded to shape by hand or machine This is the principal method for making bricks by hand The commercial manufacture of bricks is more frequently by the stiff mud process, in which the mud is less plastic, and is extruded through a die by pressure and wire cut to the proper size Brick made from clay that is hardly more than dampened must be formed in molds by application of a great deal of pressure As hydraulic presses are frequently used, these dry-pressed bricks are sometimes referred to as hydraulic pressed brick This process gives to the brick a dense surface which makes them suitable for facing work

After the bricks have been molded they are air dried and piled in the kiln for burning It is quite difficult in any other than the continuously fired kilns, in which the bricks move slowly through the kilns on conveyors, to obtain uniform characteristics in all the brick, and so the product of the ordinary brick plant consists of various grades, ranging from hard brick to softer bricks, such as salmon brick Hard burned brick should be used for face work exposed to the weather, and soft brick for filling, for foundations, and the like The standard brick measures approximately 2¼″ x 4″ x 8″, and has a crushing strength of between one and three thousand pounds per square inch, depending on the quality A highly impervious and ornamental surface may be laid on brick either by salt glazing, in which salt is added during the burning process, or by the use of a "slip," which is a glaze material into which the bricks are dipped Subsequent reheating in the kiln fuses the slip into a glazed surface integral with the brick base

A **refractory** brick is built primarily to withstand temperature Good resistance to heat flow is not to be secured simultaneously with refractoriness Indeed, the most refractory bricks usually have the highest thermal conductivities It is important for the refractory brick

to have high resistance to erosion by ash-laden gases and to the fluxing action of molten slag. It should not spall badly under rapid temperature changes, and its structural strength should hold up well under rapid temperature changes. Fire clay bricks are made from certain clays, including a plastic clay which binds the others into brick form. The firing in the kiln is carried out at a temperature such that the brick is partly vitrified. For special purposes they may be glazed by one of the methods previously described. The fire clay brick contains from 30% to 40% of alumina (See **aluminum**), and about 50% silica (See **silicon**). Progress in the art of combustion of fuels in furnaces has advanced the service requirements of refractory brick, sometimes to the point where they are so severe that a refractory superior to fire clay is needed. High alumina brick containing from 50% to 80% alumina, and correspondingly less silica, and silicon carbide, a product of the electric furnace, are typical of these super-refractories. Of course fire clay brick are preferred wherever they give satisfactory service because they are lowest in cost of all the refractory bricks. The standard size of fire brick is 9" x 4½" x 2½". (F.T.M.)

BRICKWORK. When laid, **bricks** are bedded into a mortar which, hardening, bonds the separate bricks into a brickwork unit. A solid brick wall of more than one layer thickness has the different layers of brick bonded into each other by the use of headers, that is, brick laid perpendicular to the face of the wall. There are different systems of bonding, each of which gives somewhat different appearance to the wall. In the common **bond** every fourth or fifth course is composed entirely of headers. In the English bond, every other course is a header course, while in the Flemish bond headers and stretchers alternate in each course.

The strength and durability of brickwork depend on the quality of mortar and excellence of workmanship with which the brickwork is laid. The proportions of the mortar are from one to three parts of dry sand to one part of Portland **cement**, depending on the strength needed. The cement mortar is much stronger than lime mortar, but the addition of a small amount of lime (See **calcium**) to cement mortar renders it more readily worked without materially impairing its strength. In estimating brickwork, one rule is to allow a thousand standard brick and one-half cubic yard of mortar for each two cubic yards of brickwork in place. Some masons estimate number of bricks by assigning seven to each superficial square foot of area of wall one brick thick. Brick work varies in weight from 1.5 to 1.9 tons per cubic yard, depending on the density of the bricks used. The maximum crushing strength to which brickwork should be subjected is 170 pounds per square inch when set in cement mortar, although this may be increased to 250 pounds if the effects of eccentric loading and lateral forces are fully analyzed. (F.T.M.)

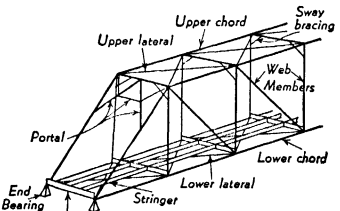
BRIDGE. The bridge of a ship is an elevated platform, sometimes having a weather enclosure, which extends across or over the deck of a vessel. It offers the executive officer a salient outlook upon much of the exposed area of the ship, including the sides.

The electrical bridge is a term referring to any one of a variety of electric networks, one branch of which, the "bridge" proper, connects two points of equal potential and hence carries no current when the circuit is properly adjusted or "balanced." This is well illustrated by the **Wheatstone bridge** and the **Carey-Foster bridge** for measuring **resistances.** Among many other important special types may be mentioned the following: the decade bridge, of the Wheatstone type, in which the ratio coils are decimal multiples of an ohm; the percentage bridge, in which a change of one division on the slide-wire scale corresponds to a change of one percent in the ratio of the compared resistances; the Callendar and Griffiths bridge, a special adaptation of the Carey-Foster type; the Thomson (Kelvin) double bridge, having eight arms and used for comparing low-resistance standards; the Wien bridge for alternating current capacitances, the Nernst high-frequency capacitance bridge, and the farad bridge which reads capacitances directly in farads; the inductance bridge and the Heaviside mutual inductance bridge; the resonance and the Maxwell bridges for comparison of inductance with capacitance; and the frequency bridge, resembling the Wheatstone bridge but used for the measurement of alternating current frequencies. For details, the reader should consult works on advanced electrical measurement.

In civil engineering, a bridge is a structural unit or a series of structural units called spans designed primarily for the purpose of supporting moving loads, in addition to its own weight. The term bridge is generally associated with a structure which provides a means for foot, highway, or railroad traffic to pass over water, ground depressions or congested districts, although certain kinds of traveling cranes used for loading or unloading bulky materials such as ore or coal are sometimes referred to as bridges. All bridges are either stationary or movable. The so-called stationary bridges may be subdivided into spans of the **arch** type and those in which one end is allowed to move longitudinally so as to eliminate the horizontal force at the supports and so the stresses that would otherwise be induced by temperature changes. Movable spans are used in connection with low level bridges over navigable waters where these bridges interfere with shipping.

There are three general types of movable spans: namely, the bascule, the vertical lift, and swing bridge. The bascule bridge pivots about a horizontal axis or rolls back on circular segments. If the entire span rotates about a horizontal axis near one end, it is called a single leaf bascule. A double leaf bascule is one which is made up of two cantilevers, each of which rotates about a horizontal axis forming a single span when closed. When the entire movable section may be lifted vertically, parallel to its original position, the bridge is called a vertical lift span. Swing bridges are those which turn in a horizontal plane about a vertical axis located at the center of the bridge. Movable bridges, when closed, are similar and perform the same service as the stationary types. Bridges may also be classified as framed **truss,** beam, or suspension bridges depending upon the way in which they support the loads. All bridges are either straight or skew. When the end supports are not on lines at right angles to the longitudinal center line of the span, the resulting structure is called a skew bridge.

Bridges are usually constructed of **steel** or reinforced **concrete** although wood is sometimes used for temporary spans. Stone or **brick** are occasionally used for very short spans of the arch type. Reinforced concrete is particularly well adapted for use in connection with the beam or arched bridge since it can be molded into any desired form. The span length is limited, as in any bridge, by the strength of the component parts.



Skeleton Diagram
Through-Type Truss Bridge
Figure 1.

The ordinary framed bridge as illustrated in Figure 1 is composed of two vertical trusses, a floor system, upon which the roadway or railway is directly supported, a certain amount of bracing and the end **bearings.** The floor system consists of longitudinal beams called stringers which transfer the effects of the moving loads to transverse beams known as floor beams The floor beams are connected to the trusses at the lower intersection points of the truss members Each intersection point is called a joint or panel point The truss is composed of an upper and lower chord and web members which are joined together in the form of triangles Figure 2 shows some typical trusses Since the loads are applied to the truss at the panel points, the primary **stresses** will be axial In this particular illustration the top chord will be in **compression** and the lower chord in **tension.** Some of the web members will be in tension, others in compression, but there are certain web members near the center of the span which may have either tension or compression depending upon the position of the moving loads The bracing is usually made up of an upper and lower **lateral** system, sway frames, and portal bracing These bracing systems resist the horizontal loads caused by wind, and, together with the floor system, tie the truss together forming a relatively rigid unit Short span framed bridges which do not require trusses sufficiently deep to allow for top chord, sway or portal bracing, because of interference with

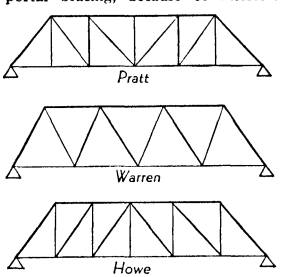


Figure 2 Typical Framed Bridge Trusses.

vehicular traffic are called pony truss spans The trusses are the principal load carrying components of the bridge, since they must support their own weight and the weight of the floor system in addition to the moving loads and wind loads The total load on each truss is transferred through a horizontal **pin** to the end bearings or shoes, generally castings, which distribute the load to the supporting masonry At one end of the bridge the bearings will be firmly fastened to the masonry, but at the other end they will be of the expansion type, which allows a limited amount of longitudinal movement to take care of the temperature changes in the structure The separate structural members of a truss bridge are composed of rolled steel shapes or built-up sections formed by riveting two or more rolled shapes together The truss members are connected at their intersections by **gusset plates** or pins

Beam bridges are composed of two or more beams laid parallel to the direction of traffic The roadway or track may be supported directly on the beams or by a stringer and transverse floor beam system connected to beams called **girders** The construction of a simple deck **plate girder** bridge, frequently used for short railway spans, is shown in Figure 3 Each girder is composed of a steel plate called the web to which are riveted four angles Additional plates called covers are riveted to the angles The two top or bottom angles and the attached cover plate form the flanges The girders are stiffened laterally by the lateral system and the cross frames A through bridge is a span of the beam or framed truss type in which the floor system is placed between the girders or trusses usually near the plane of the bottom flange or chords In deck spans the floor system is placed between the girders or trusses near the plane of the top flanges or chords, or rests upon them

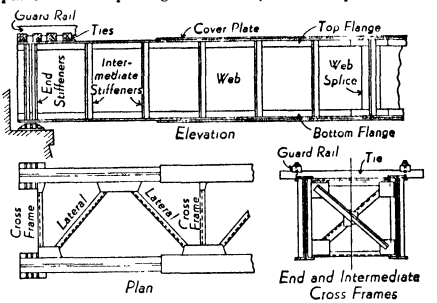


Figure 3 Deck type girder bridge (Reprinted by permission from *Modern Framed Structures, Part III,* by Johnson, Bryan and Turneaure, published by John Wiley & Sons, Inc.)

The simplest type of suspension bridge, applicable for short spans, consists of a floor system connected by hangers, to two cables or chains The latter pass over towers and are firmly anchored at the end of the span For longer spans it becomes necessary to connect the floor system to stiffening trusses which distribute the moving loads more uniformly to the hangers This method of distribution reduces the distortion of the cable or chain The hangers are formed of twisted wire ropes while the cable may consist of twisted wire ropes or a number of parallel wires securely bound together into a compact unit of circular cross-section The chain is made up of a number of separate tension links called **eye-bars** The floor system, stiffening truss and towers are constructed of rolled steel shapes

A pontoon bridge is a floating roadway which is used to bridge narrow bodies of water It consists of barges called pontoons which carry a roadway made up of beams which, in turn, support a plank floor The pontoons must be firmly anchored so that they will not float out of position The pontoon bridge is generally used for military purposes although there are instances in which this type of bridge has been constructed for ordinary vehicular and pedestrian traffic

The type of bridge to be used at a particular location depends upon many considerations Typical arched

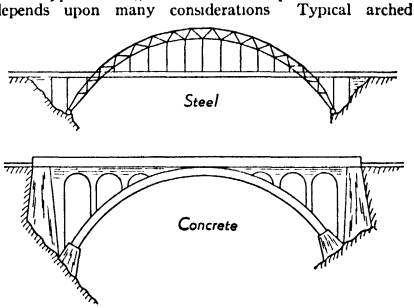


Figure 4 Typical arched bridges

bridges are shown in Figure 4 Satisfactory **foundations,** possible **pier** locations, and access to the bridge are some of the local conditions which will influence the selection of a particular type From an architectural standpoint the type which is used should harmonize with

the natural surroundings When the cost of a bridge project is limited to a predetermined amount certain types of bridges are automatically eliminated (LDW, FTM, CWC)

BRIGHTNESS. The brightness of a surface giving out light is the quantity of light emitted in the direction perpendicular to the surface, per unit area of surface. This term may be applied either to a self-luminous body, as a white-hot metal plate, or to an illuminated diffuse reflector If every square centimeter is giving out one lumen of light in the normal direction, the brightness is said to be one lambert, while one lumen per square foot, likewise, is called a foot lambert (See **Photometry**)

For a good diffuser (like a hot, sooty plate), the apparent brightness is the same in all directions Thus a white-hot cylindrical rod photographs as a uniformly white streak, as if it were a flat strip The well known **cosine emission** *law* may be deduced from this fact (LDW)

BRIGHT'S DISEASE. Nephritis.

BRILL. Pisces, Teleostei A flat-fish, *Psetta laevis*, found in British waters and valued as food The more familiar members of this group are the **flounders, turbot,** and **soles.** (AWL)

BRINE-FLY. Insecta, Diptera **Flies** whose larvae live in strong briny or alkaline waters They belong to the family Ephydridae which also contains species whose larvae live in fresh water and one remarkable insect which lives in pools of crude petroleum in the California oil fields

Large quantities of the **larvae** of certain species are washed ashore along some of the western alkaline lakes and are gathered by the Indians as food under the native name koo-tsabe (AWI)

BRINNELL. Hardness.

BRITISH THERMAL UNIT. Calorimetry.

BRITTLE-STAR. Echinodermata, **Ophiuroidea.**

BROACHING. In production processes there frequently arises the problem of forming and finishing a hole which is not circular The hole might be squared, or splined, or any shape which could not be drilled, and be successfully executed by broaching Most broaching is done on an interior surface The process consists of pushing or pulling a broach made up of a number of sections having cutting edges of the same shape as desired in the hole A circular hole is first drilled through the stock, and then the broach is either pushed through by a press, or pulled through in a regular broaching machine The broach itself consists of a number of teeth held on a stem The teeth which enter the hole first are smaller than the finishing teeth, and as successive teeth enter the hole, their slightly larger size causes them to cut away the metal Often pieces are completely finished with a single pass of the broach (FTM)

BROADBILL Aves, Passeriformes Oriental birds (**Aves**) with a shallow but very broad beak (AWL)

BROADTAIL. Aves, Psittaciformes A group of **parrots** or parraquets found only in Australia, Norfolk Island, and Tasmania (AWL)

BROCCOLI. Brassica.

BROCHANTITE A mineral composed of basic **copper** sulfate corresponding to the formula $CuSO_4 \cdot 3Cu(OH)_2$, crystallizing in the **orthorhombic** system in needle like prisms, or forming **druses** or masses Hardness, 3 5–4, specific gravity, 3 9, vitreous luster, color, **green,** streak, green, transparent to translucent.

Brochantite is a secondary mineral occurring in the oxidized zones with other copper minerals, and is found in the Urals, in Rumania, in Sardinia, Cornwall, England, Chile In the United States this mineral has been found at Bisbee, Arizona, Utah, in the Tintic District and in Inyo County, California Brochantite was named for Brochant de Villiers (ESCS)

BROCKET. Mammalia, Artiodactyla *Cariacus* Small South American **deer** of several species Unlike most deer they are solitary in habits (AWL)

BROMIC ACID AND BROMATES. Bromic acid ($HBrO_3$) is a colorless liquid, miscible with water A solution of bromic acid is decomposed upon boiling, but can be concentrated in vacuum up to 51% $HBrO_3$, with considerable decomposition A strong oxidizing agent, e g, **sulfides, sulfur, sulfites** to **sulfuric acid, thiosulfates** to tetrathionates (but depending upon the conditions), **oxalates** to **carbon dioxide.**

Prepared by reaction (1) of barium bromate solution and sulfuric acid, and filtering off barium sulfate

Potassium bromate is formed (1) by **electrolysis** of **potassium** bromide solution, with stirring, heated, and over some hours, (2) by reaction of bromine and potassium chlorate solution, (3) by heating potassium **hypobromite** solution

Metallic bromates are solids, soluble in water, except that **silver, lead, barium, thallous** bromates are slightly soluble Basic bromates require the presence of a little free acid for solution Bromates when heated, evolve oxygen and leave the bromide (or oxide) as residue

Upon addition of hydrobromic acid (or bromide plus dilute sulfuric acid) bromate liberates bromic acid, which reacts with hydrobromic acid to form bromine (RKS)

BROMIDE. Bromine.

BROMINE. Symbol Br Atomic number 35. Atomic weight 79 916 Density 3 12 Melting point: −7 2° C Boiling point 58 8° C (**Isotopes** page 238)

Bromine is a brown liquid, volatilizing at room temperature to a red vapor, which has a very irritating effect on eyes and throat Liquid bromine causes painful sores upon contact with the flesh Somewhat soluble in water, soluble in carbon tetrachloride to reddish brown solution Discovered by Balard in 1825 Used chiefly in photography, and in the preparation of organic chemicals, among which is ethylene dibromide, which is used in conjunction with lead tetraethyl in gasoline Many bromides are used in medicine, especially those of potassium, sodium, ammonium, lithium, strontium and calcium They are used chiefly as sedatives to lessen nervous excitability and irritability, to inhibit vomiting, to prevent or lessen the extent, discomfort or frequency in convulsive or spasmodic states, especially **epilepsy.** The drug is given orally or rectally When given over too long a period, especially in sensitive subjects, a stubborn skin eruption may develop

Bromine occurs as bromide in sea water (0 188% Br), in the mother liquor from salt wells of Michigan, Ohio, West Virginia, and in the potassium deposits of Germany and France Separated from solutions by treatment with **chlorine,** and purified by distillation

Bromine is soluble in water, 3 6 grams per 100 grams of water at 20° C, in ether, ethyl alcohol, carbon disulfide, chloroform, carbon tetrachloride, and potassium bromide solution Bromine reacts (1) with **sodium** thiosulfate solution to form sulfate, (2) with **sulfurous acid** to form sulfuric acid, (3) with **hydrosulfuric acid** to form sulfur, (4) with unsaturated **hydrocarbons** to form organic bromo-compounds, e g, ethylene bromide, acetylene tetrabromide, (5) with benzenoid **hydrocarbons** to form organic bromo-compounds, e g, bromobenzene, dibromobenzene

Acids: hydrobromic acid (HBr), hypobromous acid (HBrO); bromic acid ($HBrO_3$) See each acid.

Bromate See **Bromic Acid.**

Bromides· **sodium** bromide (NaBr), **potassium** bromide (KBr), **ammonium** bromide (NH_4Br) are soluble bromides, **silver** bromide (AgBr), **mercurous** bromide (HgBr), **mercuric** bromide ($HgBr_2$), **lead** bromide ($PbBr_2$) are insoluble bromides See **Hydrobromic acid.**

Organic bromo-compounds, see Bromine, Organic Compounds, below

Chloride bromine chloride (BrCl)

Fluoride brominetrifluoride (BrF_3)

Iodide bromine iodide (BrI)

Hydride hydrogen bromide (HBr), colorless gas when pure (frequently contains free bromine as reddish gas), melting point —86° C , boiling point —67° C , very soluble in water yielding hydrobromic acid Formed by reaction of (1) red **phosphorus,** bromine and water under the proper conditions, (2) bromine and **hydrogen** gases.

Hypobromite See **Hypobromous Acid.**

Sulfide See **Sulfur,** Bromide

Organic bromo-compounds·

Paraffin and benzenoid **hydrocarbons,** e g , ethane and benzene, respectively, react with bromine by *substitution* of bromine for hydrogen (hydrogen bromide also formed), e g , ethane to yield ethyl bromide (C_2H_5Br) plus further substitution products, benzene, in the presence of a **catalyzer,** e g , iodine, phosphorus, iron, to yield bromobenzene (C_6H_5Br) plus further substitution products, toluene, under like conditions to benzene, to yield ortho-bromotoluene and para-bromotoluene ($CH_3C_6H_4Br$) plus further substitution products, but at the boiling temperature, in sunlight, dry, and in the absence of a catalyzer, to yield paraffin-side-chain substitution products, benzyl bromide ($C_6H_5CH_2Br$), benzal bromide ($C_6H_5CHBr_2$), and benzotribromide ($C_6H_5CBr_3$)

Olefin, acetylene, and benzenoid **hydrocarbons,** e g , ethylene, acetylene and benzene, respectively, react (A) with bromine by *addition,* e g , ethylene dibromide ($C_2H_4Br_2(1,2)$), acetylene tetrabromide ($C_2H_2Br_4(1,1,2,2)$), benzene hexabromide ($C_6H_6Br_6$), also carbon monoxide yields carbonyl bromide ($COBr_2$), (B) with hypobromous acid by *addition,* e g , olefins form, for example, ethylene bromohydrin ($CH_2Br\ CH_2OH$), (C) with hydrogen bromide by *addition,* to form, for example, ethyl bromide ($CH_3\ CH_2Cl$) from ethylene When the two olefin carbons have an unequal number of hydrogens attached, bromine of hydrogen bromide and hydroxyl of hypobromous acid attach to the carbon having the smaller number of hydrogens

Oxygen-function compounds, e g , **ethyl alcohol, acetaldehyde, acetone, acetic acid,** react (A) with bromine, to form *bromo-substituted* corresponding or related *compounds,* e g , ethyl alcohol or acetaldehyde to yield bromal ($CBr_3\ CHO$), acetone to yield bromoacetone ($CH_2Br\ CO\ CH_3$) acetic acid to yield, at the boiling temperature, dry, and in the absence of a catalyzer, monobromoacetic acid ($CH_2Br\ COOH$), dibromoacetic acid ($CHBr_2\ COOH$), tribromoacetic acid ($CBr_3\ COOH$), the substitution taking place on the alpha-carbon (the carbon next to the carboxyl-group (—COOH)), (B) with **phosphorus** bromides, to form corresponding *bromides,* e g , ethyl bromide (C_2H_5Br), ethylidene dibromide (CH_3CHBr_2), acetone bromide ($(CH_3)_2CBr_2$), acetyl bromide (CH_3COBr), (C) with hydrobromic acid, concentrated, alcohol forms the corresponding bromide

Bromoform is made by reaction of acetone or ethyl alcohol with sodium hypobromite, carbon tetrabromide by reaction of carbon disulfide (CS_2) plus bromine (Br_2) in the presence of iron heated sulfur monobromide (S_2Br_2), boiling point 56° C at 0 2 mm also formed

Use is made of the diazo-reaction (See **Azo and Related Compounds**) to introduce bromine into benzenoid compounds

Many of the bromo-compounds are used as reagents or as intermediate compounds in organic chemistry When paraffin bromo-compounds are treated (1) with **sodium** hydroxide dissolved in alcohol, hydrogen bromide is removed, e g , ethyl bromide ($CH_3\ CH_2Br$) yields ethylene ($CH_2\ CH_2$), ethyl dibromide ($CH_2Br\ CH_2Br$) yields acetylene ($CH\ CH$), (2) with magnesium or zinc and alcohol, bromine is removed, e g , ethylene dibromide ($CH_2Br\ CH_2Br$) yields ethylene ($CH_2\ .\ CH_2$), acetylene tetrabromide ($CHBr_2\ CHBr_2$) yields acetylene ($CH{:}\ CH$)

SELECTED REPRESENTATIVE ORGANIC COMPOUNDS OF BROMINE

	Name	Formula	Melting Point	Boiling Point
1	Methyl bromide	CH_3Br		5
2	Ethyl bromide	C_2H_5Br		38
3	Normal-propyl bromide (1-bromopropane)	$C_2H_5\ CH_2Br$		71
4	Iso-propyl bromide (2-bromopropane)	$CH_3\ CHBr\ CH_3$		60
5	Vinyl bromide (bromoethylene)	$CH_2\ CHBr$		16
6	Allyl bromide	$CH_2 \cdot CH\ CH_2Br$		16
7	Bromoacetylene	$CH : CBr$		−2
8.	Alpha-bromostyrene	$C_6H_5CBr\ CH_2$		160 (75 mm)
9	Beta-bromostyrene	$C_6H_5CH\ CHBr$		219
10	Benzyl bromide	$C_6H_5CH_2Br$		198
11	Glycol bromohydrin (ethylene bromohydrin)	$CH_2Br\ CH_2OH$		150 (750 mm)
12	Alpha-glycerol bromohydrin	$CH_2Br\ CHOH\ CH_2OH$		
13	(Mono)bromoacetic acid	$CH_2Br\ COOH$	50	208
14	Alpha-bromopropionic acid	$CH_3\ CHBr\ COOH$	26	205
15	Beta-bromopropionic acid	$CH_2Br\ CH_2\ COOH$	63	
16	Bromosuccinic acid	$COOH\ CH_2 \cdot CHBr\ COOH$	160	
17	Acetyl bromide	$CH_3\ COBr$		76 (750 mm)
18	Benzoyl bromide	$C_6H_5\ COBr$		219
19	Bromoacetone	$CH_2Br\ CO\ CH_3$		127
20	Alpha-bromocamphor	$C_{10}H_{15}O\ Br(3)$	77	274
21	Cyanogen bromide	$CN\ Br$	52	61 (750 mm)
22	Bromofurane	$C_4H_3O\ Br(2)$		101
23	Bromofuroic acid	$(3)Br\ C_4H_2O\ COOH$	128	
24	Bromobenzene (phenyl bromide)	C_6H_5Br		156
25	Ortho-bromotoluene (1,2-)	$C_6H_4(Br(2)(CH_3)(1)$		182
26.	Meta-bromotoluene (1,3-)	$C_6H_4(Br)(3)(CH_3)(1)$		184
27	Para-bromotoluene (1,4-)	$C_6H_4(Br)(4)(CH_3)(1)$	29	184
28.	Ortho-bromobiphenyl	$Br(2)C_6H_4\ C_6H_5$		297
29.	Para-bromobiphenyl	$Br(4)C_6H_4\ C_6H_5$	90	310

(Continued on next page)

SELECTED REPRESENTATIVE ORGANIC COMPOUNDS OF BROMINE—*Continued*

	Name	Formula	Melting Point	Boiling Point
30	Alpha-bromonaphthalene	$C_{10}H_7Br(1)$	5	281
31	Beta-bromonaphthalene	$C_{10}H_7Br(2)$	59	281
32	Ortho-bromophenol (1,2-)	$C_6H_4(Br)(2)(OH)(1)$	6	194
33	Meta-bromophenol (1,3-)	$C_6H_4(Br)(3)(OH)(1)$	32	236
34	Para-bromophenol (1,4-)	$C_6H_4(Br)(4)(OH)(1)$	63	238
35	Ortho-bromoaniline (1,2-)	$C_6H_4(Br)(2)(NH_2)(1)$	31	229
36	Meta-bromoaniline (1,3-)	$C_6H_4(Br)(3)(NH_2)(1)$	18	251
37	Para-bromoaniline (1,4-)	$C_6H_4(Br)(4)(NH_2)(1)$	63	
38	Ortho-bromonitrobenzene (1,2-)	$C_6H_4(Br)(2)(NO_2)(1)$	43	261
39	Meta-bromonitrobenzene (1,3-)	$C_6H_4(Br)(3)(NO_2)(1)$	56	256
40	Para-bromonitrobenzene (1,4-)	$C_6H_4(Br)(4)(NO_2)(1)$	126	255
41	Ortho-bromobenzoic acid (1,2-)	$C_6H_4(Br)(2)(COOH)(1)$	149	Subl
42	Meta-bromobenzoic acid (1,3-)	$C_6H_4(Br)(3)(COOH)(1)$	154	
43	Para-bromobenzoic acid (1,4-)	$C_6H_4(Br)(4)(COOH)(1)$	252	
44	Alpha-bromoanthraquinone	$(1)Br\ C_6H_3(CO)_2C_6H_4$	188	Subl
45	Beta-bromoanthraquinone	$(2)Br\ C_6H_3(CO)_2C_6H_4$	204	
46	Methylene bromide	CH_2Br_2		97
47	Ethylene dibromide (1,2-Dibromoethane)	$CH_2Br\ CH_2Br$		131
48	Acetylene dibromide, cis	$CHBr\ CHBr$		110 (754 mm)
49	Acetylene dibromide, trans	$CHBr\ CHBr$		108
50	Ethylidene bromide (1,1-Dibromoethane)	$CH_3\ CHBr_2$		110
51	Benzal bromide (benzylidene bromide)	$C_6H_5\ CHBr_2$		140 (20 mm)
52	Dibromoacetic acid	$CHBr_2\ COOH$	49	233 (decom)
53	Dibromosuccinic acid	$COOH\ CH_2\ CBr_2\ COOH$	166	180 (decom)
54	Carbonyl bromide	$COBr_2$		64
55	Ortho-dibromobenzene (1,2-)	$C_6H_4Br_2(1,2)$	2	221
56	Meta-dibromobenzene (1,3-)	$C_6H_4Br_2(1,3)$	−7	219 (755 mm)
57	Para-dibromobenzene (1,4-)	$C_6H_4Br_2(1,4)$	87	218
58	Dibromoanthracene (9,10-)	$C_6H_4(CBr)_2C_6H_4$	221	Subl
59	Bromoform	$CHBr_3$		151
60	Methyl bromoform (1,1,1-tribromoethane)	$CH_3\ CBr_3$		
61	Benzotribromide (phenyl bromoform)	$C_6H_5\ CBr_3$		
62	Tribromoethylene	$CHBr\ CBr_2$		163
63	1,2,3-Tribromopropane	$CH_2Br\ CHBr\ CH_2Br$	16	220
64	Tribromoacetic acid	$CBr_3\ COOH$	135	245 (decom)
65	Tribromophenol, sym	$C_6H_2(OH)(Br)_3(2,4,6)$	96	
66	Bromal	$CBr_3\ CHO$		174
67	Bromal hydrate	$CBr_3\ CH(OH)_2$	53	
68	Carbon tetrabromide	CBr_4	92	189
69	Bromotrichloromethane (trichlorobromomethane)	$BrCCl_3$		104
70.	Acetylene tetrabromide (1,1,2,2-tetrabromoethane)	$CHBr_2\ CHBr_2$		151 (54 mm)
71.	Tetrabromoethylene	$CBr_2\ CBr_2$	56	226
72.	Naphthalene tetrabromide	$C_{10}H_8Br_4$		
73.	Tetrabromofluorescein (Eosin)	$C_{20}H_8O_5Br_4$		
74.	Hexabromoethane	$CBr_3\ CBr_3$	200 (decom)	
75	Benzene hexabromide, alpha, trans	$C_6H_6Br_6$	212	
76	Hexabromobenzene	C_6Br_6	316	(R S M, R K S)

BROMLITE. **Alstonite** The mineral Bromlite or Alstonite is a rare **barium-calcium carbonate** that may contain small amounts of **strontium** carbonate as well It occurs at Bromly Hill, near Alston, Cumberland, England (whence the two names) in association with **calcite** and **witherite.** (E S C S)

BRONCHIECTASIS. An acute or chronic infection of the **bronchial** tissue of the **lung,** resulting in saculation of the bronchi filled with pus of particularly offensive odor There is usually no cure for the disease except surgical removal of that portion of the lung affected in those cases where the disease is localized The disease is characterized by a chronic cough with foul expectoration (R S M)

BRONCHITIS Bronchitis, either acute or chronic, is usually secondary or associated with other respiratory diseases which may be more important or more serious than bronchitis itself The organisms causing bronchitis are those that cause other respiratory infections—usually the most common invaders are the **Streptococcus,** *Pneumococcus* and *Bacillus influenzae.*

Acute bronchitis may be an extension downward from a head cold or laryngitis and may be followed by **pneumonia** Certain forms of broncho-pneumonia in their early stages are indistinguishable from a severe acute bronchitis Bronchitis is also seen as part of the picture of measles, whooping cough, influenza, typhoid, etc

Predisposing factors are similar to those that predispose to respiratory infection It is common in the very young and old

Bronchitis may follow inhalation of irritating vapors and dust as well as the lodgment of foreign bodies in the bronchi

The most prominent symptoms of bronchitis are, of course, the cough It may be dry or loose, accompanied by pain or soreness in the chest In the later stages there is abundant sputum Constitutional symptoms vary—they may be slight or severe High fever is most usually seen with bronchitis in run-down individuals, infants or the old-age group This disease may last for two or more weeks Chronic bronchitis that lasts a month or more suggests **tuberculosis,** especially when accompanied by wasting, blood-streaked sputum and continued low fever which persists in the afternoon

The prognosis is good except in the run-down, aged, etc, where it frequently progresses into pneumonia (R S M)

BRONCO or **BRONCHO** Mammalia, Perissodactyla **Horses** of western North America, descended from stock originally brought in by the Spanish conquerors They are noted for endurance and spirit There is no certain distinction between the terms broncho and mustang, and both are embraced by the name Indian **pony** (A W L)

BRONZE. Alloys.

BRONZE AGE Paleontology of Man.

BRONZITE Enstatite.

BROOD SAC. A pouch in which the eggs are retained during development in some of the **crustaceans.** (A W L)

BROOKITE. Brookite, composed of **titanium** dioxide, TiO_2, is an **orthorhombic** mineral of the same chemical composition as **rutile** and **octahedrite.** It was named for the English mineralogist H J Brooke (E S C S)

BROOM CORN. *Andropogon Sorghum* var Gramineae A variety of a tropical grass, **sorghums,** characterized by having an inflorescence in which the branches are very long and slender, growing in loose **panicles** The plant is extremely drought resistant and so adapted for regions having an arid climate The close-bunched stiff inflorescent-branches account for the principal use of broom-corn, i e, the manufacture of brooms and whisk-brooms Large quantities are grown in Oklahoma (R M W)

BROWN BODY. In the **bryozoa** the entire active portion of the individual, known as the polypide, degenerates in certain conditions to form a compact mass known as the brown body The enclosing sheath or zooecium forms a new polypide whose stomach sometimes encloses the brown body representing the previous individual In such cases the mass is later discharged by way of the anus (A W L)

BROWNIAN MOVEMENT. The random movement observed among microscopic particles suspended in a fluid medium The phenomenon was observed in 1827 with suspensions in liquids, **colloids,** by Robert Brown, English botanist, who is said to have attributed it to living organisms Not until the kinetic theory was developed was it generally understood to be due to the thermal agitation of the suspending medium A smoke particle floating in the air, for example, is battered on all sides by the high speed air molecules The resultant impulse is for the most part nearly zero, but there are statistical inequalities which now and then reach such magnitude as to produce motions visible in a high-powered microscope, and which result in an irregular migration of the particle In fact, such particles may be regarded essentially as huge molecules, with mean square speeds of thermal motion proportionately smaller as their masses are larger than that of the true molecules of the surrounding medium A mathematical analysis of the problem by Einstein in 1905 led to an equation connecting the observed motions with the **Boltzmann constant,** the development being based upon the law of **equipartition of energy;** and the agreement between the predictions of this theory and experimental results is very satisfactory (L D W)

BROWN ROT. Ascomycetes and Bacteria.

BROWN-TAIL MOTH. Insecta, Lepidoptera A European species, *Euproctis chrysorrhea,* related to the tussock moths of this continent It was introduced into **Massachusetts** during the last century and together with the **gypsy moth,** another introduced species, has become an important pest in the New England states and the adjacent Canadian provinces, attacking shade and fruit trees Spraying with **lead** arsenate in the late summer has been found an effective method of control, as well as the collection and destruction of the winter nests in which the caterpillars hibernate

The hairs of the **larva** are very irritating to the human skin (A W L)

BRUCINE. Alkaloids.

BRUCITE. The mineral brucite is **magnesium** hydroxide corresponding to the formula $Mg(OH)_2$, **iron** and **manganese** may occasionally be present The crystals are usually tabular **rhombohedrons** of the **hexagonal** system, it may also occur fibrous or **foliated.** Brucite has one perfect cleavage parallel to the prism base, hardness, 2 5, specific gravity, 2 38–2 4, luster, pearly to vitreous, commonly white but may be gray, bluish or greenish, transparent to translucent Brucite is a secondary mineral found with **serpentine** and **metamorphic** dolomites It has been found in Italy, Sweden, and the Shetland Islands, and in the United States in New York, Pennsylvania, Nevada and California Brucite was named in honor of Archibald Bruce, an American physician (E S C S)

BRUSH A brush is a device for conducting current to or from a rotating part The brush is stationary, and is held and guided by a fixed brush holder in which it slides freely The rotating member may be the **commutator** of a direct current **generator** or **motor,** or it may be the collector rings of an alternating current motor, or generator Examples of brushes might also include those used in magnetos and static electricity machines

Brush material is usually carbon, though spring leaf copper and copper gauze are used in special cases Circuit connections to carbon brushes are made directly to the brush by means of short flexible cables from the external circuit because the contact surface between brush holder and brush is an unreliable conductor

Brushes wear and must be replaced periodically Also, their ends should fit commutators so as to make good contact over the entire brush surface They may sometimes need periodic redressing with sandpaper in order to maintain the proper arc for contact The most serious fault of a brush is the formation of electric **arcs** between the rotating member and the brush This may be due to condition of the brush, vibration of the brush in the holder, or improper setting of the brush The position of the brushes on a commutator is near the no-load neutral point of the commutator, although this is approximately opposite the center line of the pole The best brush position should be found by trial and error by noting the amount of arcing at different settings (F T M)

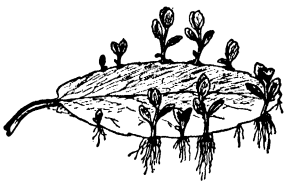
BRUSH DISCHARGE. Ionized Gases.

BRUSH TURKEY. Aves, Galliformes Large dull-colored birds (**Aves**) of several species found in New Guinea and Australia They deposit their eggs in large heaps of decaying vegetation (A W L)

BRUSSELS SPROUTS. Brassica.

BRYOPHYLLUM CALYCINUM AND OTHER SPECIES Crassulaceae A genus of tropical plants which are frequently seen in cultivation because of their habit of reproducing by means of their leaves If a mature leaf is removed from one of the plants and placed on damp sand, within a short time there appear in the notches of the leaf margin tiny roots and later small green plants which soon become independent of the parent leaf Infrequently the little plants appear in the notches while the leaf is still attached to the parent plant.

The explanation of this uncommon habit is that in the development of the leaf certain cells in the leaf notches remain permanently **embryonic**. For some reason their

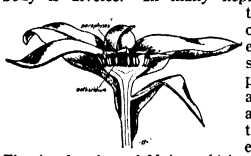


Vegetative reproduction of *Bryophyllum calycinum*. New plants develop in the notches of the leaves.

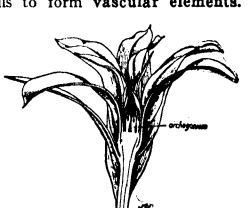
development is inhibited so long as the leaf remains attached. Severing the leaf removes the inhibition and the embryonic cells resume active development. (R.M.W.)

BRYOPHYTES. The second subdivision in the Plant Kingdom, comprising Mosses and Liverworts (or Hepatics), is a small group of plants, having some 20,000 species. Most of these are terrestrial plants. The bryophytes inhabit a wide range of habitats, from dry barren rocks to submerged objects, but are most frequent where an abundance of moisture is assured. They are found on trunks and branches of trees, on the soil, and even on the leaves of some tropical plants.

The body of these plants is small and without much structural complexity. Rhizoids, slender outgrowths which serve mainly to attach the plant to its substratum and which serve only slightly as absorbing organs, are common. They may be single celled or multicellular, but are colorless. The habit of the plant body is diverse. In many hepatics it is a thin flat thallus, one to several cells thick. Often the edge of the thallus is so lobed that it appears to be differentiated into a central stem and lateral leaves. In the mosses this differentiation is much greater. There is an erect central stem which bears many thin radiating leaves. However complex the structure may be, the cells of the plant-body of a bryophyte show very little differentiation. The central cells may be longer; other cells may have thicker walls; cells nearer the surface contain more **chloroplastids**, but there is never any real modification of cells to form **vascular elements.** The latter are entirely wanting in this group, which are therefore sometimes called Atracheata, that is, plants without any vascular cells, to distinguish them from the ferns and seed plants, the Tracheata, characterized by a highly developed tissue.

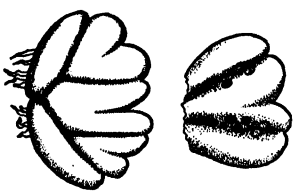


The tip of a plant of *Mnium* which bears antherida, cut lengthwise to show the antheridia. Diagrammatic.



The tip of an archegonial plant of *Mnium*, cut lengthwise to show the archegonia. Diagrammatic

The sex organs of the bryophytes are highly developed objects, which distinguish this group very sharply from the lower plants, both **algae** and **fungi**. The **antheridium**, in which the sperm cells are formed, is a club-shaped multicellular body. The **archegonium** is a flask-shaped body, also multicellular. Antheridia and archegonia may be formed on the same plant or on different plants; often they appear at different times so that self-fertilization is largely prevented. The sperm, a biciliate actively motile cell, swims to the egg which is located in the swollen basal portion of the archegonium. There a sperm unites with the egg to fertilize the latter and incite growth of a new generation. But the plant resulting from this fertilized egg is one entirely unlike the parent plant. Commonly it is a well-developed plant, but less conspicuous than the one on which it is usually entirely dependent for its food supply. When mature it forms a large mass of small spherical cells called spores, which are freed from the body in which they are formed and carried away by currents of air. On reaching a suitable environment each spore germinates and eventually forms a plant like that which bore the sexual organs. There is then in the bryophytes a very definite **alternation of generations**, a sexual generation called the gametophyte, bearing male and female sex organs and an asexual generation called the sporophyte, in which are formed asexual



Gametophytes of a liverwort, *Riccia*. The bodies embedded in the right-hand plant are sporophytes.

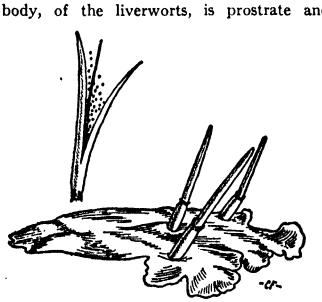
spores. The gametophyte plant is green and carries on **photosynthesis**. In most cases it is terrestrial. The sporophyte plant, however, depends on the gametophyte for its food supply and water.

Bryophytes are separated into two classes, the Hepaticae or liverworts and the Musci or mosses. Each class is subdivided into three orders, as follows:

Class I. Hepaticae.
- Order 1. Marchantiales.
- " 2. Jungermanniales.
- " 3. Anthocerotales.

Class II. Musci.
- Order 1. Sphagnales.
- " 2. Andreaeales.
- " 3. Bryales.

The liverworts are generally considered lower in the scale of evolution than the mosses. The thallus, or plant body, of the liverworts, is prostrate and flat.



Anthoceros, one of the horned liverworts. The "horns" are sporophytes. A portion of a sporophyte is shown separately to illustrate the method of liberation of spores.

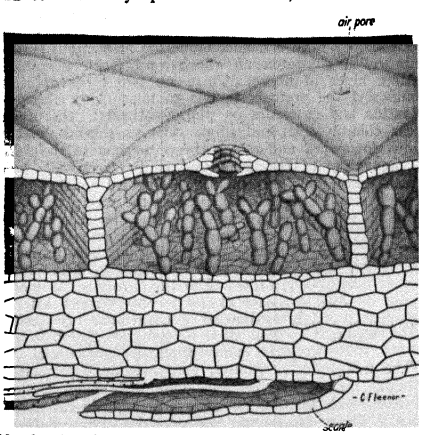
When it forks, the two branches are equal, a method of branching known as dichotomous. In the second order of liverworts the thallus is so divided as to appear

leafy, the order often being called the leafy hepatics. All liverworts have unicellular **rhizoids** borne on the lower side of the thallus by which they are anchored firmly to the substratum. The sex organs are borne embedded in the body of the thallus or in special outgrowths called gametophores, which rise from the thallus. The small sporophytes are dependent on the gametophyte for their nutrients. In these plants an asexual reproduction occurs by means of small masses of cells which develop from the gametophyte to which they are attached by a very slender stalk. These small bodies, called gemmae, are easily separated from the parent plant. They develop into a new gametophytic plant when they are carried by wind or water to a suitable environment.

The three orders of the liverworts form an interesting series, of increasing complexity. The Marchantiales include forms which have a prostrate thallus, often showing a structure of considerable complexity. The sporophyte is very simple. Growth of the thallus is by repeated divisions of a single apical cell which itself sometimes forms two such cells, whose continued divisions form a dichotomous branching of the thallus. As the thallus increases in length at the apical end, death of the cells occurs at the other end, so that the plant slowly grows ahead until in time a fork is reached and the two halves separated by progressive disintegration of the older portions.

One of the simplest members of this group is *Riccia,* a small plant found either floating on still waters or growing on wet mud. Some species are thick and fleshy, others are slender much-branded bodies, having a very evident median groove.

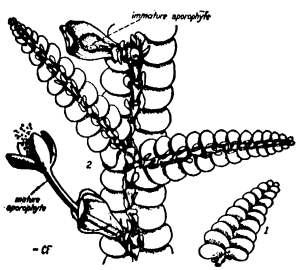
From the lower surface single-celled rhizoids grow downward. From this surface also, thin scales or plates are developed, forming an overlapping row along the middle of the thallus. Both antheridia and archegonia are formed on the upper surface along the midrib. The antheridia have a wall a single cell in thickness, and contain many sperm mother cells, each of which



Marchantia. Section through a thallus showing air chambers.

divides to form two biciliate sperms. The archegonial wall is also a single cell in thickness, and encloses a row of six cells, four of which are the canal cells, the other two a ventral cell and an egg cell. When the latter is mature, the other five disintegrate, while at the same time the apical cells of the archegonium split apart, forming a canal through which the sperm swims to fuse with the egg. The sporophyte which develops from the fertilized egg remains embedded in the gametophyte thallus; when mature it is nearly all sporogenous tissue enclosed in a thin-walled capsule. A more complex member of this order is *Marchantia.* In this the gametophyte thallus is several inches long and from a half an inch to an inch broad. Its lower surface bears rhizoids and scales, or lamellae, quite like those of *Riccia.* The upper part of the thallus, just beneath the upper surface, contains a number of large chambers, each connected with the outside air by a large pore. The sexual organs in this plant are not formed in the thallus, but are borne on special erect branches called gametophores. Antheridia and archegonia are borne on different plants, the plants thus being dioecious. They are quite like the antheridia and archegonia of *Riccia.* The sporophyte is considerably larger than that of *Riccia,* with a well-developed foot attaching it to the gametophyte, a short thick stalk which pushes the spore-containing capsule out from the tissues of the gametophore. Not only does this capsule contain large numbers of spores, but also, scattered among the spores, slender elongate cells called elaters, whose walls have spiral thickenings. These are affected by differences in humidity which cause the elater to twist about, apparently to stir up and loosen the spores. In *Marchantia* the gametophyte is very elaborately developed; the sporophyte, very simple.

The second order of liverworts is divided into two suborders, the Anacrogynae, in which the archegonia are borne on the upper surface of the thallus, and the Acrogynae, in which they are borne at the apex. In the species of the Acrogynae the thallus is so incised



Porella, a leafy liverwort. 1, a branch seen from the upper side. 2, a portion of a plant seen from the lower side; sporophytes also are visible attached to archegonial branches, each partially enclosed in a perianth.

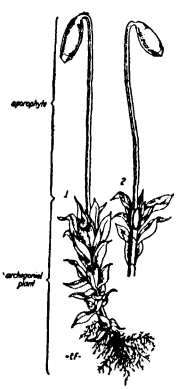
on its margins that it appears to bear two rows of small leaves. The Jungermanniales are small plants, many of them very delicate, growing in wet places, either on the ground or on rocks and tree trunks. Cellular differentiation in the thallus is very slight. In them the sporophyte is much more highly developed than in the first order. It has a long slender erect stalk which bears the capsule. When the latter is mature, it splits into four valves, which spread apart and free the spores within. Members of this suborder also form a series more or less as do the Marchantiales. The third order, the Anthocerotales, is a small group containing three genera. In all of them the gametophyte thallus is of a very simple type, with no great cellular differentiation, and with the sex organs always embedded. In this order the sporophyte is a most interesting object, far advanced in comparison with those of the other liverworts. It is an erect slender more or less cylindrical object composed of a basal foot and a long capsule. The central portion of the capsule is a rod of sterile tissue called the columella. Around it is the sporogenous tissue. The spores are formed in zones alternating with narrow bands of sterile tissue. Outside the sporogenous tissue is a wall of sterile tissue composed of chlorophyll (See **Pigments in Plants**)

containing cells. The epidermal portion of this wall contains many stomata. (See **stoma**). The basal portion of the sporophyte, just above the foot, is composed of meristematic cells, which by their divisions cause the capsule to elongate. When mature this capsule splits into two valves which pull apart, resembling horns. These plants, with their very simple gametophyte and very elaborate sporophyte, contrast strikingly with the Marchantiales, with their elaborate gametophyte and simple sporophyte.

Mnium, a common genus of mosses.

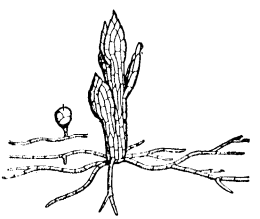
The liverworts are of no economic importance, but are of interest because they suggest what may have been the habit of those plants which first left the water and grew on land. They have never become independent of water, since it must be present if fertilization is to occur.

The number of mosses known is much larger than the number of liverworts. Mosses are found in many different regions, being much more abundant than liverworts, and able to grow under a wide range of environments. They are found in greatest abundance in moist shaded regions where they often cover an extensive area. Other species grow on the trunks of trees, often well above the ground, where they are exposed for long periods of time to desiccation. In tropical forests mosses often clothe not only the trunks but also the branches of trees with a thick green covering; they may even succeed in growing on the thick evergreen leaves which characterize many tropical trees. Some species of mosses grow well on the exposed surfaces of barren rocks. A few are aquatic, living entirely submerged in running water throughout their existence.

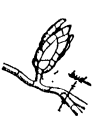


The sporophyte of a moss *Mnium*, 1, the sporophyte attached to the gametophyte. 2, The same, the gametophyte being cut away to show the enlarged venter of the archegonium in which the foot of the sporophyte is anchored.

Usually moss plants are small (often tiny), and seldom exceed a few inches in length. A few genera, such as *Fontinalis*, which grows in water, and several tropical members, grow to lengths of ten to fifteen inches, which is very unusual in this group. Moss plants show a much higher development than hepatics. Usually the gametophyte, the part ordinarily seen and called a moss, has a very distinct, often erect stem, which bears many small radiating leaves. In each leaf there is generally a fairly evident midrib. There are many **rhizoids**, growing from the lower part of the stem and attaching the plant to the ground. The rhizoids of mosses are longer than those of liverworts and are multicellular. There is no true vascular system in any moss, though the cells of the central portion of the stem are often much longer and more slender than those surrounding them. The sexual organs of mosses are very similar to those of hepatics and are borne at the tips of the stem or branches. Biciliate sperms are formed which must have water in which they can swim to the egg. The fertilized egg gives rise to a sporophyte which is much more highly organized than that of liverworts but still entirely dependent on the gametophyte. The basal portion of the sporophyte is the foot, a mass of cells in close contact with those of the gametophyte. Above the foot there is a stalk which in most mosses is very long and slender. It bears at its top a capsule or spore-bearing sac. This capsule has a very specialized structure. The axis of the capsule is a mass of sterile tissue called the columella. Around this the sporogenous tissue occurs, in turn surrounded by a wall many cells thick and with large cavities within it. The basal part of the capsule is also a mass of sterile tissue, often considerably swollen, known as the apophysis. The apical portion of the capsule is very complex. Over its surface is the operculum, a layer of cells, which completely covers it and which falls off like a lid when mature. Beneath this and distinct from it is the peristome, which when mature, splits into a number of slender teeth which react to changes in humidity, rolling back when dry and closing together when wet. Surrounding the developing capsule and remaining around it for some time is a loose jacket of cells in no way connected with it. This is the calyptra, formed from cells of the gametophyte which were originally cells of the archegonal wall. The ripe spores of mosses are shaken out through the apical opening and scattered by currents of air. On germinating, these spores do not give rise to a new moss plant directly. Instead they form a slender branching filamentous structure called a protonema which very much resembles certain kinds of **algae**. There are two types of cells composing the protonema: one contains many **chloroplastids** and so carries on **photosynthesis**: the other lacks chloroplastids and forms colorless rhizoids which grow downward and attach the protonema to the soil. A peculiarity of the protonema is the cross-walls between cells: they are commonly diagonal to the long axis of the filament rather than at right angles. From the cells of the protonema short erect branches ending in small buds are formed. These buds develop into erect moss plants. The life-history of a moss plant shows a very distinct **alternation of generations**. In addition there is the juvenile phase of the gametophyte, the protonema.



Moss protonema, showing the production of the buds which become the upright, leafy shoots.



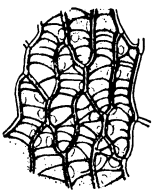
The bud of a moss *Mnium*.

The first order of mosses, the peat- or bog-mosses, contains the single genus *Sphagnum* with many species of world-wide distribution, always growing in low, wet bogs. These mosses are considered very primitive. The gametophyte has an erect stem from which arise numerous branches, all of two kinds, either spreading, or pendent against the stem. The many leaves are small and but a single cell in thickness. Some of the cells are small and elongated, forming a fine anastamosing network in the leaf. These are living cells containing chloroplastids. The openings of the network are filled by very large inflated cells with thin walls and no cytoplasm. Large pores in the walls of these dead cells permit free passage of water into the cell cavity. The small sporophyte has a spherical capsule, which is black

or dark brown, and a very short stalk. The sporophyte is borne at the end of a specialized structure called a pseudopodium which lifts the sporophyte above the tuft of branches at the top of the gametophyte. The protonema of *Sphagnum* is a small flat thallus resembling that of the Anthocerotales.

Sphagnum sporophyte attached to a leafy plant.

Peat-mosses are the only members of the Bryophyte group which have any commercial value. Growing slowly for long periods of time, they gradually accumulate in the wet bogs in which they are found. Gradually the lower parts amass, together with such debris as may have accumulated, forming a compact mass known as peat, and used as fuel. The ability of the large hollow cells of the leaf of *Sphagnum* to absorb and retain large quantities of water leads to the extensive use of *Sphagnum* moss as a material in which to pack live plants for shipment. For this reason also, and because *Sphagnum* is naturally a sterile substance, harboring few bacteria, certain species have been used as surgical dressings, especially in times of great need.


A portion of a leaf of *Sphagnum*, the peat moss. Surface view.

Individual plant of *Bryum*. Leafy axis bearing young sporophyte, with calyptra on top.

The Andreaeales is a small group of small mosses growing on the surfaces of siliceous rocks. They are unimportant.

Most mosses belong to the third order, the Bryales, which are the true mosses.

As a group the Bryophytes are of little importance. They are recognized as primitive plants which developed from some simple ancestral forms from which they have gradually diverged independently along several different lines. The existing forms do not form a single series, representing stages in the development of the most advanced forms, nor are they plants from which the higher plants have taken their origin. In this group the gametophyte appears in its most advanced form. (See also **Paleobotany.**) (R.M.W.)

BRYOZOA. One of the smaller divisions of the animal kingdom, made up of **sessile** animals which are mostly colonial, forming branching or encrusting colonies or large jelly-like masses. The appearance of certain branching colonies is the source of the name Bryozoa, which meahs moss-animals. Both marine and freshwater forms are known.

These animals are distinguished by the following characters: 1. The individual consists of two parts, a sheath-like zooecium or body wall and an enclosed polypide consisting of the alimentary tract, tentacle sheath and tentacles. 2. The body is coelomate but not segmented. 3. A circlet of **ciliated** tentacles occurs at the free end of the body, in most species they can be retracted when the animal is disturbed or at rest. 4. The alimentary tract is sharply bent, mouth and anus opening near each other at the free end.

The phylum is divided into two classes:

Class Endoprocta. Primitive bryozoans whose tentacles cannot be retracted but are folded inward and covered by a fold of the body wall. The anus opens inside the circlet of tentacles.

Class Ectoprocta. Tentacles retractile. Anus opening outside the circlet of tentacles. (A.W.L.)

BUBO. The infection and swelling of a lymphatic gland, particularly in the groin. They are frequent after infection with **gonorrhea, syphilis,** or lympho-granuloma inguinale. (R.S.M.)

BUCCAL CAVITY. The cavity of the mouth. (A.W.L.)

BUCCAL FUNNEL. The funnel-like depression leading to the mouth in the **lampreys.** (A.W.L.)

BUCK. The male **deer** and sometimes the male **sheep.** Also applied to entire species in some cases, as the water-buck and prongbuck. (A.W.L.)

BUCKWHEAT. *Fagopyrum esculentum.* Polygonaceae. Outside of the grasses, buckwheat is the only plant used to any extent as a cereal in the United States. It is an erect branching plant from one to four feet tall, with a small root system and a smooth rather weak stem at each node of which is borne a single heart-shaped leaf. The **inflorescence** is a many-flowered **raceme,** the individual flowers being white or pink-tinged. The **calyx** lobes, five in number, are colored; there is no **corolla.** There are eight **stamens** and a single one-celled **ovary** which bears three curved **styles.** Cross-pollination is brought about by the numerous insect visitors attracted by the pleasant fragrance of the flowers. The mature fruit is a triangular brown or black **achene.** The single seed within contains an abundance of white **endosperm** high in starch content.

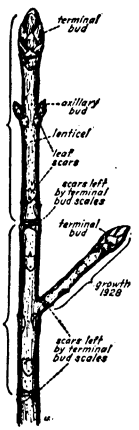
Buckwheat is an Asiatic plant which is cultivated in widely scattered regions. It grows well in cool climates, on poor soils, and where the growing season is short.

The plant is often used as a green manure, being turned under to enrich the soil. Pancake flour is made from buckwheat seeds. The grain is also used as food for poultry and other domestic animals, either whole or divested of the hulls. Buckwheat flowers are an important honey source, producing a very finely flavored product. (R.M.W.)

BUD. In zoology, a bud may be defined briefly as an outgrowth from the body which develops into a new individual. In botany a bud is an undeveloped shoot and normally occurs in the axil of a leaf or at the tip of the stem, unless a flower or cluster of flowers has formed at the stem tip and so terminated stem growth. Once formed a bud may remain for some time in a dormant condition, or may develop into a stem immediately. Various factors may cause dormant buds to grow, such as removal of the apical bud or of the part of the stem above the bud.

The buds of many plants, especially those plants of temperate or cold climates, are protected by a covering of modified leaves called scales which tightly enclose the more delicate parts of the bud. Many bud scales are covered with a gummy substance, which serves as added protection. When the bud develops, the scales may enlarge somewhat but usually drop off, leaving on the surface of the growing stem a series of horizontally elongated scars. By means of these scars one can determine the age of any young branch, since each year's growth ends in the formation of a bud, the development of which causes the appearance of an additional group of bud scale scars. Continued growth of the branch causes these scars to be obliterated after a few years so that the total age of older branches cannot be determined by this means.

In many plants scales are not formed over the bud, which is then called a naked bud. The minute undeveloped leaves in such buds are often excessively hairy. Such naked buds are found in shrubs like the **Sumach** and **Viburnums** and in herbaceous plants. In many of the latter, buds are even more reduced, often consisting of undifferentiated masses of cells in the axils of leaves. A head of cabbage (See **Brassica**) is an exceptionally large terminal bud, while brussels sprouts are large lateral buds.



Twig of buckeye, *Aesculus glabra*, showing two years' growth.

Since buds are formed in the axils of leaves, their distribution on the stem is the same as that of leaves. So we find alternate and opposite buds, as well as the terminal bud at the tip of the stem. Less frequently rings of buds are found around the stem at a node, a condition known as whorled buds. These are found in many coniferous trees, as the fir or spruce. In many plants buds appear in unexpected places: these are known as **adventitious buds.**

Often it is possible to find in a bud a remarkable series of gradations of bud scales. In the Buckeye, for example, one may observe a complete gradation from the small brown outer scale through larger scales which on unfolding become somewhat green to the inner scales of the bud, which are remarkably leaflike. Such a series suggests that the scales of the bud are in truth leaves, modified to protect the more delicate parts of the plant during unfavorable periods. (A.W.L., R.M.W.)

A series of stages in the growth in the Spring of a bud of buckeye, *Aesculus glabra.*

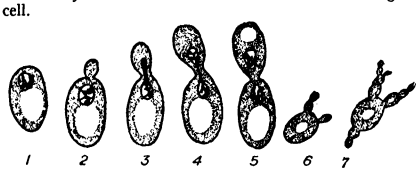
BUDAN'S THEOREM. Budan's theorem is of help in locating the real **roots** of a **polynomial equation;** it is stated as follows:

Let $P(x) = 0$ be a polynomial equation of degree n with real coefficients. Let a and b be real numbers, neither of which is a root of $P(x) = 0$, and suppose $a < b$. Let V_a denote the number of variations of sign of

$$P(x), \quad P'(x), \quad P''(x), \quad \cdots, \quad P^{(n)}(x)$$

(successive **derivatives**) for $x = a$, after vanishing terms have been deleted, and similarly V_b the number of variations for $x = b$. Then $V_a - V_b$ is either the number of real roots of $P(x) = 0$ between a and b or exceeds the number of these roots by a positive even integer. A root of multiplicity m is here counted as m roots. (L.L.S.)

BUDDING. This term is used to designate a process of **asexual reproduction** in which the young are formed as outgrowths of the parent body. It is limited to animals of relatively simple structure. In this process a portion of the wall of the parent **cell** softens and pushes out. The protuberance thus formed enlarges rapidly while at this time the nucleus of the parent cell divides. One of the resulting nuclei passes into the bud. Presently the bud becomes cut off from its parent cell and the process is repeated. Often the daughter cell starts to bud before it becomes separated from the parent, so that whole colonies of adhering cells are formed. Eventually cross walls cut off the bud from the original cell.



1, 2, 3, 4, and 5. Reproduction by budding. Yeast cells stained to show nucleus. (Redrawn from Guillermond, The Yeasts, John Wiley & Sons, Inc.). 6 and 7. Colony formation by rapidly growing yeast. Nuclei not stained.

The term budding is also applied to a process of embryonic differentiation in which new structures are formed by outgrowth from preexisting parts.

A third use of the term budding is in reference to one method of **grafting.** (A.W.L., R.M.W.)

BUDGERIGAR, BUDJERIGAR. Aves, Psittaciformes. An Australian **parraquet,** chiefly green with a blue tail and yellow face. Also known as the Australian love-bird in captivity. (A.W.L.)

BUERGER'S DISEASE. Thrombo-angiitis Obliterans.

BUFFALO. Mammalia, Artiodactyla. Hoofed animals of several species, some of which have been domesticated. They are strongly built, with short heavy neck and a broad muzzle. The horns are hollow and are not twisted nor branched.

The Cape buffalo, *Syncerus caffer,* is an African species with short curved horns whose bases are broadly expanded over the upper part of the head. It is found in swampy ground. In western Africa is another species, the short-horned buffalo or bush cow. The Indian buffalo, *Anoa bubalis,* is another water loving species whose sweeping curved horns extend back toward the withers. This species is domesticated and in the Philippines is called the carabao. Another smaller species of the Philippines is known as the tamarao, *Anoa mindorensis.*

The term buffalo does not apply correctly to the American bison. (A.W.L.)

BUFFALO CARPET-MOTH. Insecta, Coleoptera. More properly known as the carpet **beetle** but misnamed through the similarity of habits of its **larva** and those of the clothes moths.

The true carpet beetle is an introduced European species, *Anthrenus scrophulariae,* whose larva eats woolen materials of all kinds as well as furs and feathers. The adult is a compact oval insect about one-eighth inch long and marked with brick-red, black and white, and the larva is a brown hairy grub. A number of other species, native to North America, have the same habits and may be equally troublesome. The adults frequent flowers and eat pollen, hence they may migrate readily to houses. They are important pests in museums.

In the home, good housekeeping methods are usually an adequate safeguard against these pests. In special

cases fumigation is necessary to destroy them but as a rule the use of sprays now supplied commercially for application to clothing and other fabrics is the only unusual measure required. Fumigation with **carbon disulfide** is the method commonly used in museums to destroy them; the explosive nature of this fluid and its vile odor do not recommend it for home use. (A.W.L.)

BUFFALO FISH. Pisces, Teleostei. *Ictiobus.* North American food fishes (**Pisces**) of three species, related to the suckers. (A.W.L.)

BUFFALO-GNAT. Black-fly.

BUFFLEHEAD. Aves, Anseriformes. *Charitonetta albeola.* A small North American **duck** of wide distribution. (A.W.L.)

BUG. Insecta, Hemiptera. **Insects** with sucking mouth parts usually arising near the front of the head, with antennae usually long but few-jointed, and with wings, when present, thicker at the base and membranous at the tip, overlapping when folded to form a more or less conspicuous X on the back. The bugs are so diverse that no concise definition can be generally adequate. The term bug is not synonymous with insect. (A.W.L.)

BUHR-STONE. Relatively porous, calcareous, and siliceous **sandstones** with sharp or angular grains, used in making millstones. (R.M.F.)

BULB. A thick short stem which grows many thick leaves in which food reserves are stored. In many bulbs the leaves are closely wrapped together, forming a compact body called a tunicated bulb, as is the case in the onion. In other bulbs the fleshy leaves are loosely arranged to form a scaly bulb, such as the Easter Lily. Bulbs are particularly common in **monocotyledonous** plants, and aid the plants greatly in surviving long dry seasons. So regions subject to regularly recurrent dry seasons are particularly rich in bulb-forming plants. Commonly the term bulb is applied to any fleshy underground plant part, regardless of its nature, so that **rhizomes, corms** and **tubers** are all popularly classed as bulbs. (R.M.W.)

BULBIL (OR BULBLETS). In a few plants there occur small reproductive bodies called bulbils. An example is found in the small black objects growing in the axils of the leaves of Tiger Lilies. These are really buds in which the scales are very much swollen; when mature the whole body falls to the ground and under favorable conditions puts out roots and in time grows into a new plant. Similar bodies are found in the familiar onion sets, and in several sedges. Serving the same purpose are the small globose bodies which develop on the leaves of several species of ferns, as for example, *Cystopteris bulbifera.* All such bodies form one method of vegetative propagation. (R.M.W.)

BULBUL. Aves, Passeriformes. Birds (**Aves**) of several species found in Africa and the Oriental region, related to the **babblers.** They are said to be melodious singers. (A.W.L.)

BULBUS ARTERIOSUS. A muscular expansion of the ventral aorta at its origin from the **heart** in bony fish. Distinguished from the bulbus cordis or conus arteriosus by the lack of cardiac muscle. (A.W.L.)

BULBUS CORDIS. Conus arteriosus.

BULKHEAD. A bulkhead is a partition or a transverse strengthening frame. Ships' bulkheads are the important transverse partitions which subdivide the hold into separate watertight compartments, being built from the keel to the bulkhead deck. They must be not only watertight, but have sufficient structural strength to resist the bursting pressure to which they will be subjected when one bulkhead space is filled with water, while the adjacent one is empty. (F.T.M.)

BULK MODULUS. Elasticity.

BULL. The male of certain animals, as domestic cattle, the bull elephant, and the bull alligator. (A.W.L.)

BULLFINCH. Aves, Passeriformes. *Pyrrhula.* Birds (**Aves**) of northern Europe and Asia, related to the grosbeaks. (A.W.L.)

BULLHEAD. Pisces, Teleostei. Small **catfishes** native to the streams and lakes of the eastern and central United States. Excellent food fishes. The common bullhead is also called the horned pout, *Ameiurus nebulosus.* (A.W.L.)

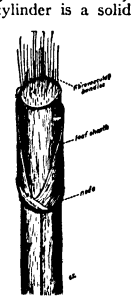
BUMBLEBEE. Insecta, Hymenoptera. Stoutly built hairy **bees** of moderate to large size. Some species are colonial, building nests on the surface of the ground, while others live as parasites in the nests of other bumblebees.

Unlike the honey-bee, bumblebees are not permanently colonial in temperate regions. Only the queen lives through the winter. When she emerges from hibernation in the spring she builds a nest or occupies an abandoned nest of a bird or mouse, and in it makes waxen cells in which she lays eggs and a waxen honey pot in which to store surplus food. She feeds her young until they mature, and only when they emerge as worker bees does the colony take on an organization like that of the honey-bee. In the fall, males and queens appear and the colonies break up. The queens mate before hibernating. Most authorities include all of these bees in the genus *Bombus.*

The parasitic bumblebees, making up the genus *Psithyrus,* enter the nests of other bumblebees and lay their eggs to be cared for by the hosts. Their chief structural difference is the lack of pollen-gathering organs in the females.

Bumble bees are important in the cross-fertilization of red clover and other deep-throated flowers. (A.W.L.)

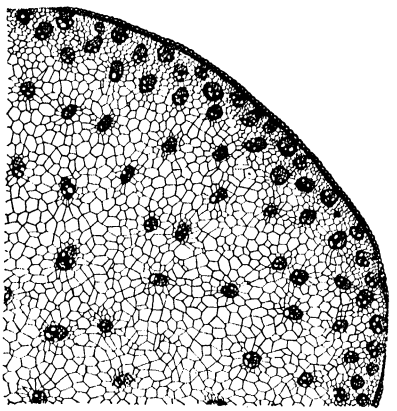
BUNDLE. Also often called vascular bundle or fibro-vascular bundle. In most **vascular** plants the vascular tissues are arranged in the form of a cylinder. In many cases, notably in woody plants, this cylinder is a solid mass of cells. But in many plants, particularly in herbaceous **dicotyledons** and **monocotyledons,** the vascular tissues occur in strands which are more or less distinctly separated from one another, and are called vascular bundles. Such bundles appear as discrete objects when seen in a cross section of the stem. However, they really form a continuous conducting system which extends from the root through the stem and into the leaves and other parts, and becomes an elaborate system of inter-connecting parts.



Portion of corn stem (*Zea mays*) with the vascular bundles protruding; illustrating the structure of a typical monocotyledonous stem.

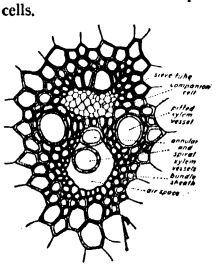
In the axis of the plant each bundle consists of masses of **xylem** and **phloem** cells which may appear in various arrangements; frequently the xylem and phloem cells appear in radially adjoining masses, forming a collateral bundle; less frequently one kind of cells is surrounded by cells of the other kind, forming a concentric bundle; in roots a third arrangement is found, the xylem and phloem masses alternating with one another in the cylinder, a distribution of cells which is often called radial bundles, though strictly it is inap-

propriate to designate such strands of conducting cells as bundles. Bundles vary greatly in size, often appearing as single cells, especially in monocotyledons, and in



Cross section of corn stem showing the distribution of fibro-vascular bundles in a typical monocotyledon.

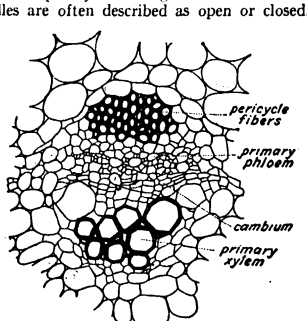
leaves where they end. In other plants they form massive strands made up of a very large number of cells.



Cross section of a single fibro-vascular bundle of corn, *Zea mays*.

While a bundle consists normally of associated masses of xylem and phloem cells, in many plants there appears with them strands of fibers whose presence may give protection to the bundle, and additional rigidity to the stem. Because of the frequent occurrence of such fibrous masses as part of a bundle, the term fibro-vascular bundle has been used to describe them. In many plants the fibrous cells form a mass on the outer side of the bundle, between it and the surface of the stem, while in other plants, particularly in monocotyledons, the fibers form a sheath completely encircling the bundle.

Bundles are often described as open or closed. Open



A cross section of a single fibro-vascular bundle of a young sunflower stem.

bundles are those in which **cambium** cells are found, so that by the repeated division of the cambium cells, the size of the bundle constantly increases. Closed bundles are those in which no cambium occurs, they being composed entirely of primary tissues and so once formed remain constant in size. (R.M.W.)

BUNION. A swelling of a bursa or fluid filled sac on the outer part of the large joint of the great toe. This condition is caused by too tight or too short shoes. It frequently accompanies the condition of hallux valgus. (R.S.M.)

BUNKER. A bunker is any large bin, but its technical meaning is confined to receptacles for the storage of fuel or loose materials in bulk. The bunker is frequently constructed of plate steel which, for some purposes, must be lined with a substance such as **concrete** or wood to protect the metal. One prevalent type, the Berquist suspension bunker, has a profile of such a shape that **tension** is the only **stress** produced in the steel. Since the bunker is usually placed so that the material is deposited from the top, and withdrawn by gravity from the bottom, a suspension type is particularly advantageous. One of the most common uses for bunkers is to hold the coal required for the combustion equipment of **power plants**. It may be able to hold from three to five days' supply for a small plant, but space limitations will govern the capacity for large power plants. However, the bunker should hold enough to supply the plant during minor repairs to the coal conveying equipment. (F.T.M.)

BUNSEN SCREEN. Bench Photometers.

BUNTER SANDSTONE. Triassic.

BUNTING. Aves, Passeriformes. Birds (**Aves**) related to the finches and sparrows, including the British yellowhammer, not to be confused with the North American woodpecker which bears this name, the ortolan, and the snow bunting. In North America the indigo bunting *Passerina cyanea*, is the most widely distributed species, ranging over the eastern half of the country and sometimes to western Texas. The lazuli, varied, painted, and lark buntings are characteristically western birds. The painted bunting, *Passerina ciris*, is also called the nonpareil. (A.W.L.)

BUOY. A buoy is a float used in connection with marine navigation to indicate the definite location of a channel, dangerous shoal or sunken wreck. It may vary from a simple barrel type float to a plate-steel cylindrical or conical float mounting special warning devices, such as a bell with clapper actuated by the wave motion, a light or a brightly painted spar. (F.T.M.)

BUOYANCY. The familiar lifting effect of a fluid upon a body wholly or partly submerged in it, known as buoyancy or buoyant force, was first closely studied by the Greek philosopher Archimedes in the third century B.C. What is now known as the "principle of Archimedes" states that the buoyant force is equal to the weight of that body of the fluid which the submerged body displaces, and may be treated as a single force acting vertically upward through the center of gravity of the displaced fluid (center of displacement). This statement applies whether the submersion is partial or complete. The principle readily follows from the consideration that if the submerged body were withdrawn and the resulting cavity allowed to fill with the fluid, the latter would be in equilibrium under the joint action of its own weight and the external forces formerly exerted by the surrounding fluid upon the submerged body.

If the buoyant force equals the weight of the submerged body and acts through its center of gravity, the body will be in equilibrium. This might be true

if the body had exactly the same mean density as the fluid. It would then remain at rest when completely submerged at the proper level. A balloon, for example, may rise to a certain height and remain suspended or drift along horizontally. But a solid body completely submerged in a liquid does not come so readily to stable equilibrium, because of the very slight compressibility of liquids, the presence of highly compressible gases in pores of the body or in bubbles clinging to it, and the unequal coefficients of expansion of the body and the liquid.

If, however, the body has a lower mean density than the liquid, it will "float," partly submerged to a level, and in a position with reference to the vertical, determined by the Archimedes principle. An important phase of flotation, especially in ship design, is the degree of stability. This may be expressed in terms of the position of the "metacenter." When a boat is tipped very slightly in a given plane, the center of displacement shifts to one side. There is one point of the boat, called the metacenter, which remains vertically above the center of displacement. This point must be higher than the center of gravity, as the resulting couple then tends to restore the boat to its normal position; if it is lower, the boat is unstable and will capsize. The height of the metacenter above the center of gravity (metacentric height) is a measure of the stability in the given vertical plane. It is in general different for different planes; for example a boat has a transverse and a longitudinal metacenter and metracentric height, corresponding, respectively, to its rolling and its pitching. Thus one may usually change seats in a rowboat without danger, while an equal shift across the boat might overturn it. (See **Weighing Methods.**) (L.D.W.)

BURBLE. Burble describes the action of air over the upper surface of an **airfoil** when the **angle of attack** has been increased to the point where the air stream no longer follows the profile of the airfoil and breaks away from it. The space between the airfoil and the detached air stream is filled with eddying, burbling air, and the lift is largely lost. The wing is then said to have reached the burble point, and this is synonymous with "stalled." (F.T.M.)

BURBOT. Pisces, Teleostei. The fresh-water representative, *Lota lota*, of the **codfish** family. It is found in streams and lakes of Europe and North America, more commonly north of latitude 40°. The species also goes by the names eel-pout, ling and lawyer. (A.W.L.)

BURDOCK. *Arctium lappa.* **Composite Family.**

BURIN. Paleontology of Man.

BURLAP. Jute.

BURNER. An arrangement for mixing a fluid **fuel** with air and burning it is called a burner. Burners are commonly provided for liquid and gaseous fluids, but **pulverized coal,** when mixed with a certain amount of air which lubricates it, flows much as a fluid, and is burned by burners. Burner designs for gaseous fuels are the simplest because gas and air are easily mixed and a gas burner may consist of little other than a means to subdivide the total flow of the fuel into a large number of small jets which will present a large surface exposure to the combining oxygen. A liquid fuel will approach the efficiency of gas firing after it is sufficiently atomized or vaporized so as to present a large surface for combustion. This can be done by wicks, by contact with heated metal as in wickless kerosene burners, by the use of high pressure sprays with very fine holes, or by the use of steam jets. Fuel oil burners of large capacity accomplish an atomization of the oil mechanically by giving the oil a whirl in the burner tip, and discharging it into the furnace through a small orifice. When steam is used, the oil is broken up by a continuous discharge of steam under pressure within the burner and at the tip outlet. Preparation of the oil for use in the burner may include filtering, heating, and pumping. Figure 1 shows typical oil burners and tips.

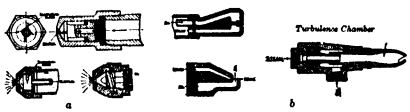


Figure 1. a. Typical mechanical pressure atomizer tips. b. Typical outside-mixing and inside-mixing steam atomizing burners. (*Handbook of Oil Burning,* American Oil Burner Association.)

Pulverized coal offers much more of a problem in burner design than do oil and gas, even though the coal is pulverized to such an extremely small size that 90% of it will pass through a screen having 100 openings to the inch. Small as the coal particles are, they average 25,000 times larger than the oxygen **molecule.** The pulverized coal is floated or air-borne to the burner on a stream of air amounting to some 10% or 20% of the total combustion requirements. This is called primary air. The remainder of the air needed, called secondary air, is admitted directly to the burner the function of which then becomes one of properly proportioning the fuel and air, and thoroughly mixing them. There are two general types of pulverized coal burners, called long and short flame burners. The long flame is produced by moderate tip velocities from a simple form of burner, coupled with an admission of the secondary air through openings in the furnace setting located along the traverse of the flame. Long flame burners are gradually being abandoned in favor of the short flame. The short flame burner produces complete mixture of fuel and air by violently whipping the secondary air through the primary air and fuel. This type is essentially a high capacity, forced **draft** type of burner, whereas the long flame burner is better adapted to induced draft.

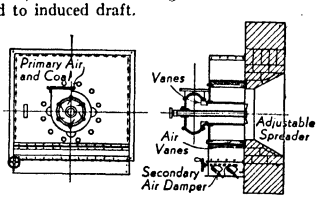


Figure 2. Circular burner. (*Courtesy of Riley Stoker Corp.*)

Figure 2 shows the primary and secondary air inlets into the short flame burner. The rate of combustion is regulated externally by the rate of feed of coal to the burner. Proper proportioning of air is accomplished by a damper in the secondary air passage. Air vanes cause rotation of the secondary air moving into the furnace. A fan type spreader sets the primary air and coal whirling in the opposite direction. With this turbulence, and in the presence of a furnace temperature higher than that required for ignition, the flame will propagate itself back into the incoming air fuel stream at from 15 to 40 feet per second. The velocity of the mixture leaving the burner must exceed this in order to prevent flarebacks, and since friction slows down parts of the incoming stream, burner exit velocities of 80 to 130 feet per second are used. (F.T.M.)

BURNS. This form of injury may be produced by a number of physical or chemical agents. No matter how produced, the burn results in destruction of vary-

ing amounts of skin and underlying tissue Burns are sometimes classified as first, second and third degree, according to the depth of tissue destroyed

Serious burns so often produce serious symptoms, complications and often death because of the following factors involved (1) **Toxic** absorption from broken down **protein** products of the burned tissues (2) Shock due to the toxic absorption plus dehydration due to two factors The loss of the outer layers of the covering tissues of the body causes a copious outflow of tissue fluid There is, in addition to this, a shift of the body fluids into tissues adjacent to the burned area This shift of fluid to this area is nature's effort to overcome toxic poisons by dilution (3) Infection of the burned areas is favored by the presence of devitalized tissue The results of the above factors are high temperature, shock, and kidney and heart damage which if severe enough produce death

Any successful treatment of burns should prevent toxic absorption, loss of body fluids and infection The common lay practice of immediately coating burns with greasy substance—any oil or ointment—not only does no good, but actually does harm When a patient is finally brought to a hospital the oil has to be removed as well as possible before proper treatment can be applied Time is a vital factor in the treatment of burns, the sooner proper treatment is begun the better the chance of avoiding complications and of saving life

The modern treatment of burns minimizes toxic absorption, loss of body fluids, and infection and further lessens the scarring resulting from the healing of the burned area Further, hospitalization time has been reduced to a fourth of that formerly required The treatment of burns requires hospitalization **Tannic acid** is applied to the burned areas and sometimes followed by application of a solution of **silver** nitrate of the proper strength By this treatment all burned tissue is coagulated, there is no absorption and no loss of body fluid Pain ceases soon after the treatment Burns of over half the area of the body have recovered under this treatment (R S M)

BURRO. Mammalia, Perissodactyla A small variety of the domestic **ass** or donkey, used as a beast of burden in the west The burro is incredibly tough and subsists on a diet of almost anything edible, hence it has been valuable in the exploration of the more arid areas (A W L)

BURROWING The habit of living underground and also the preparation of runways and living quarters beneath the surface Many animals such as wolves, that are not specially developed for burrowing, prepare burrows or dens for the birth of their young and for hiding places Others are normally at home in the ground and come to the surface only under certain conditions, here examples range from the worms, of which the earthworm is particularly well known, to highly specialized molluscs, insects, and vertebrates

The less specialized burrowing animals cut away the earth by means of structures whose origin is not associated with this use, such as the claws of reptiles, birds, and mammals, while in many of the more specialized forms these parts are highly developed and modified and other special adaptations are evident The **earthworm** merely eats its way through the earth, and some insects are capable of burrowing into the tissues of plants in the same way The shipworm, a mollusk, has the valves of the shell adapted for cutting burrows into wood

The **moles** are highly developed for burrowing by the powerful build of the fore limbs and by their large claws, and are further adjusted to life underground by the fine moisture-resisting fur The poorly developed eyes are also correlated with conditions underground, since these animals rarely enter the light

Mole **crickets** are in some ways like the moles Their front legs are broadened and provided with claw-like processes and the body is covered with a downy vestiture which repels moisture

Burrowing offers the animal greater safety than can be enjoyed on the surface of the earth, since no predator can compete with the highly developed burrowing animal on equal terms below the surface. (A.W L)

BURSA COPULATRIX. A pouch found in the females of some species of **insects** which receives the seminal fluid of the male during copulation, before it passes to the **spermatheca.** (A W L)

BUS. The word bus has two common usages As an automotive term, it was derived from omnibus, a public vehicle, for use on public highways, designed to carry a relatively large number of passengers The present automotive bus represents the outgrowth of a great deal of specialized engineering effort The service rendered by an automotive bus varies from the comparatively short-haul service for cities and metropolitan areas to the long distance transcontinental type bus service, and naturally the problems of speed, acceleration from a standstill, passenger comfort, fuel capacity, top speed, etc , will vary

Since the bus is usually part of a transportation system involving many similar units, specialized overhaul and maintenance service can be worked out applicable to the fleet of buses Repair centers, emergency stations, etc may be established by a large system which is then in a much better position to take advantage of new mechanical developments than is the case for the ordinary run of business Thus a bus transportation system may employ the **Diesel engine** which has been developed to the point of serviceability as a source of automotive power, but whose progress in this field has suffered from the large investment in equipment and talent to build and service the **Otto** type engine

An electrical bus is a central electrical conductor to which secondary conductors are connected Although the bus is usually rigid copper bar, it is not infrequently found in the form of rigid tubes or rods, or even of cable Buses are sometimes insulated with layers of varnished cambric, but are more often left bare, being mounted on insulators and, if at high voltage, removed from positions where persons might establish accidental contact with them A bus is required to carry the maximum normal current without overheating, and to be strong enough mechanically to remain undamaged by the magnetic forces set up by the short circuit The selection and placing of the insulating bus supports are governed by two factors, either of which may be critical The first is the strength of the insulators, the second the strength of the bus, acting as a continuous beam from insulator to insulator Two parallel conductors are repelled by a force whose magnitude is negligible during normal operation, but which, during severe short circuit, may crack or wrench insulators loose, or permanently distort the bus, unless the original design has anticipated the short circuit conditions The size of a bus is determined from the known heating effect of certain current densities in bars of different sizes The allowable current densities in amperes per square inch are usually based upon a maximum temperature of 70° C The factors which affect the temperature of the bus are the cooling effect from radiation and air convection, skin effect, type of current, whether A C or D C and frequency of the A C (F T M)

BUSH-CRICKET. Insecta, Orthoptera **Crickets** of several species, most of which are found chiefly in shrubby vegetation (A W L)

BUSHING. In mechanical terminology, to bush is to reduce the size of a hole A bushing, therefore, is a circular piece, generally of metal, which will fit a hole, and which has a hole through it One use of the bush-

ing is to provide a renewable bearing surface for a **journal** The bushing material is softer than the journal, so that wear will occur on the bushing, which is the renewable part. A bushing of this nature is sometimes made of **Babbitt**. The Babbitt is generally cast in place by pouring it in the bearing shell around a mandrel which is slightly smaller in diameter than the journal After the bushing is set, the mandrel is removed and the bearing reamed or scraped to fit. An ordinary bearing bushing is made of bronze, machined to size, and held in place by force fit, or set screws, or other similar fashion. The bushing is sometimes drilled for oil lubrication, and its bearing surface grooved for distribution of the lubricant.

A bushing is also a kind of pipe fitting which is employed when it is desired to reduce the size of pipe to a smaller size When pipe is employed to contain electrical wires, the open end from which the wires emerge is often capped by a bushing which substitutes a smoothly rounded surface for the sharp edges of an unbushed conduit. The sharp edges would tend to abraid the insulation on the wires.

In electrical work, the term bushing is also used.

Where a **conductor** at high voltage emerges from one insulated condition to another, an intermediate support must be provided. An electrical bushing is needed to provide the support and insulation between the conductor and the supporting surface. For example, where the conductor leaves the insulated interior of a **transformer** case, a bushing is provided to support the terminal where it passes through the case, and to insulate the voltage difference between the terminal and the grounded case A bushing is also required at terminals of oil **circuit breakers**, and at potheads where the conductors of a multi-conductor **cable** are separated and brought out from the cable sheath for external connections. To obtain sufficient dielectric strength for very high voltage bushings without having the physical dimension of the bushing become excessive, the oil-filled bushing or the condenser type bushing was developed. The condenser bushing is made of thin layers of tin foil wound between concentric layers of **insulation** It is possible in this way to give uniform potential drop through the thickness of the bushing (F T M.)

BUSHMASTER. Reptilia, Sauria A large and deadly **snake**, *Lachesis mutus*, found in the forests of Central and northern South America It is a pit-viper, like the rattlesnakes, water moccasin, and copperhead of North America, but it reaches a length of twelve feet and may have fangs over an inch long, hence it is more to be feared than any but the largest of the related species. (A W L)

BUSTAMITE. Rhodonite.

BUSTARD. Aves, Gruiformes Large birds (**Aves**) of numerous species found chiefly in Africa, although some occur in Europe and Asia. They are chiefly terrestrial in habits but are powerful fliers One of the African species is called the hubara and those of India are known as floricans The bustards are related to the rails and cranes. (A W L)

BUSTARD-QUAIL. Aves, Galliformes *Turnix* Small birds (**Aves**) related to the pigeons and rails, as well as to the gallinaceous birds They are widely distributed in the Old World. Also called hemipodes. (A.W L)

BUTANOL. Alcohols.

BUTTE. Mesa.

BUTTER. Esters.

BUTTERFISH. Pisces, Teleostei A small species of fish (**Pisces**), also called the gunnel (A W L)

BUTTERFLY. Insecta, Lepidoptera An **insect** with four large wings, usually completely covered with scaly vestiture Distinguished from most other members of the order (moths and skippers) by the terminal club of the **antennae** (A.W L)

BUTTERWORT. *Pinguicola* species **Insectivorous plants.**

BUTTER YELLOW. Dyes.

BUTTRESS ROOTS. Roots.

BUTYRIC ACID. Acids, Carboxylic.

BUZZARD. Aves, Falconiformes. Birds (**Aves**) of prey of several species belonging to the genus *Buteo* The North American representatives are commonly called hawks, as Swainson's hawk The same may be said of the nearly related rough-legged buzzards; American representatives of the genus are the rough-legged hawks The name is incorrectly although commonly applied to the turkey buzzard, which is a vulture (A W.L)

BYSMALITH. A plug-like **igneous** intrusion related to a **laccolith** but bounded laterally by faults due to upward "punching" rather than "pushing" of the **magma** as it forces its way into a series of stratified rocks. (R M F.)

BYSSUS. An organ of attachment formed by a special byssus gland in the foot of many **bivalve** mollusks It consists of thread-like processes which are at first adhesive. (A W L)

BYTOWNITE. Feldspar.

C

C.G.S. SYSTEM. The **metric system** of physical units is based primarily on the standard **meter** and the standard **kilogram**, preserved at Sèvres. Experience has shown, however, that the usage of physics is better served by founding its measures upon the centimeter and the **gram** (along with the mean solar second), rather than to use the meter and the kilogram directly The "c g s." (centimeter-gram-second) system is the basis of nearly all present-day physical measurement, except in certain fields still commonly employing English units.

Following are listed the c g s units of certain familiar magnitudes, together with their dimensional makeup in terms of the fundamental units of the system (see **Physical Magnitudes and Physical Equations**):

MAGNITUDE	C G S. UNIT	DIMENSIONS
Area	Square centimeter	$cm.^2$
Volume	Cubic centimeter	$cm.^3$
Speed	Centimeter per second	$cm.\ sec.^{-1}$
Acceleration	Centimeter per second per second	$cm.\ sec.^{-2}$
Momentum	Gram-centimeter per second	$g.\ cm\ sec.^{-1}$
Force	Dyne	$g\ cm\ sec.^{-2}$
Torque	Dyne-centimeter	$g\ cm^2\ sec.^{-2}$
Pressure	Bar	$g.cm.^{-1}\ sec.^{-2}$
Energy and Work	Erg	$g.\ cm^2\ sec.^{-2}$
Power	Erg per second	$g.\ cm.^2\ sec.^{-3}$

(L D.W.)

CABANE. A cabane is a part of the **airplane** structure A monoplane which has a wing not attached directly to the fuselage, but mounted above it, requires a cabane structure to carry the load from the wing to the fuselage. A cabane is also needed for the biplane. A cabane is composed of **struts** triangularly framed to remain rigid against fore and aft loads and braced with wire for rigidity laterally At its upper end it is connected to the wing root fittings and at its lower end to the fuselage If the main structural members of the wing are not continuous from tip to tip the outboard sections are hinged at the cabane joint, and there is a short center section. (F.T M)

CABBAGE. **Brassica.**

CABBAGE BUTTERFLY. Insecta, Lepidoptera A white **butterfly**, *Pieris rapae*, with black-tipped forewings and two or three black spots on the wings of each side Introduced from Europe about the middle of the nineteenth century, this species spread rapidly until at present it is found throughout the United States and much of Canada. The caterpillar feeds on all cruciferous plants, but is especially important as a pest on cabbage and cauliflower, whence it receives its common name

The insect can be held in check by spraying with Paris green. Cabbage heads formed on sprayed plants do not contain enough poison to affect human beings. (A.W.L)

CABLE. A cable is a strong rope composed of several strands of fiber or wire. In nautical terms, large ropes usually ten inches or more in circumference are known as cables, while smaller ropes are called hawsers However, by common usage, a cable is any strong rope. Structural cable, made of straight or twisted steel wires, is used for suspension **bridges**. Twisted wire cables are also used as guy lines and lifting lines for some types of **derricks** Electrical cable is composed of copper wire, being either a stranded conductor or a number of conductors insulated from each other. It is covered with a layer of insulation over which a protective layer of lead tiple braiding or a lead sheath is placed. (F.T M)

CABLEWAY. A suspended steel **cable** acting as track for aerial hoisting and conveying devices is cableway. While occasionally used for transporting pe sons across deep gorges, where the amount of traf does not warrant the building of a **bridge**, the cablewa in its more common application, handles constructi material for building of **dams**, etc , or has a permane use in connection with the handling of material such rock or gravel which is taken from open pits. Cle spans up to a half-mile in length are possible in a cabl way. The carriage which operates on the cableway ma or may not have provision for carrying passengers, d pending on the purpose of the cableway. (F.T.M.)

CACAO. **Theobroma Cacao.**

CACHALOT. Mammalia, Odontoceti. A name fo the sperm **whale** from the French. *Physeter catodon* (A.W.L.)

CACHEXIA. A marked state of ill health accompanied by wasting, malnutrition, great weakness and generally marked pallor It is frequently seen in terminal **cancer** states (R S M.)

CACOMISTLE. Mammalia, Carnivora. Small animals related to the raccoons but of more slender build. Several species, ranging from Mexico to Oregon. Also called **civet cat** and ring-tailed cat (A.W.L.)

CACTUS FAMILY. Cactaceae The cactus is known to all as a prickly inhabitant of dry American deserts. In popular parlance, the name "cactus" applies to any fleshy spine-covered plant But not all spiny plants are cacti, nor are all cacti characterized by spines.

With the exception of a single genus *Rhipsalis*, some of whose members are said to occur in Ceylon and Madagascar, all cacti are natives of America, where they are found widely scattered from latitude 59° in North America through the tropics to the southern Andean region and Argentina They are particularly conspicuous features of the flora of dry desert regions where they are found in a wide variety of forms and sizes.

A few genera, and especially *Pereskia*, are very like ordinary **mesophytic** plants, having well-developed ovate leaves borne alternately on a long slender stem. But in nearly all of the Cactus Family the leaf surface is very much reduced, the leaves appearing as small fleshy bodies which last but a brief time before dropping off. In many species leaves of any recognizable kind are never formed, the green fleshy stem taking over the function of leaves completely In these fleshy stems large amounts of water are stored, a feature which enables these plants to survive in the arid regions in which they so frequently grow Due to the mucilaginous nature of the cell contents and to the greatly reduced surface of the plants the contained water is held most tenaciously and lost very slowly.

In their natural environment Cactus plants have an extensive system of long fibrous roots which not only extend outward from the plant to considerable distances, but also penetrate the soil deeply. In cultivated plants the root system is usually greatly reduced. The stems of cacti show a variety of forms. In addition to the normal-stemmed *Pereskia*, there are the Prickly Pears, species of *Opuntia*. In most of these the stem is a series of flattened, fleshy joints often abundantly protected with

bristling bunches of barbed spines In species of *Mammillaria* and *Cereus* the stem is a cylindrical or globular body, often conspicuously ridged, and armed with numerous spines In *Phyllocactus* and *Epiphyllum* the stem is flattened and largely unarmed, the small weak spines being borne in notches along the edges of the stem The familiar night-blooming "cereus" is of this type

The flowers of most species of cactus are large and brightly colored They are regular, although in some species a definite tendency toward zygomorphic **flowers** is seen The flowers are borne singly The **perianth** is composed of a large number of separate members which show a gradual transition from the outer small sepals (See **Flower**) through to large brightly colored petals The stamens are likewise numerous and have long filaments The single compound pistil contains many ovules and in fruit becomes a many-seeded berry In many species the fruit is edible Species of *Opuntia* are frequently planted in rows to form an impenetrable barrier against intruders These plants were early introduced into the Old World and later into Australia, where in many places they have become a troublesome and almost worthless weed Cactus plants are frequently seen in cultivation, being especially sought by those who like the bizarre effect they give Somewhat similar in appearance are many species of *Euphorbia* from tropical Africa, and of *Stapelia*, a genus of the Milkweed Family, and likewise native to Africa The flowers of these plants are quite unlike Cactus flowers, however, so that the plants are readily distinguished when they bloom

One genus of Cactus, the Living Rock Cactus, *Lophophora williamsii*, is used by the native American Indian to produce a state of extreme exhilaration It is used in the form of dried disks or buttons, sections of the stem, known as peyotl or mescal, a curious-tasting object which gives to the user the most agreeable sensations of color and pleasure While it is not habit-forming, its use is frowned upon by Americans (R M W)

CADDIS OR CADDICE FLY Insecta, Trichoptera The adult of any species of this order The caddis flies are slender insects with four wings, sometimes clothed with hair-like scales which give them a moth-like appearance The mouth parts are formed for biting but are vestigial Since the **larvae** are aquatic the caddis flies are much more abundant in the vicinity of water, but they are attracted to light, often at some distance (A W L)

CADDIS WORM Insecta, Trichoptera The aquatic **larva** of a **caddis fly** They are noteworthy for the silken webs and cases which they build, some for protection and some to catch prey Some species spin silken nets attached to rocks in the bottom of a stream in such a position that the current washes into the wide mouth and passes out through a web at the smaller end In this way the **insect**, which lives in a tube nearby, snares its food Many of the caddis worms live in cases from which only the head and legs protrude These cases are formed of many different materials, held together by silk Some are made of small flat pebbles, some of bits of leaves, and some of small snail shells They are economically of some value as food for fishes (A W I)

CADELLE Insecta, Coleoptera A small brown **beetle**, *Tenebroides mauritanicus*, which infests granaries, feeding on other insects as well as on grain

Fumigation with **carbon disulfide** and **hydrocyanic acid** gas has been used to destroy this and other granary pests Both methods are dangerous and should be employed only by experts It has been found effective also to heat the entire building to a temperature of 120 to 140° F for several hours In mills which have heating plants of ordinary efficiency for winter use these temperatures can be secured in the summer (A W L)

CADMIUM Symbol Cd Atomic number 48 Atomic weight 112 41 Density 8 6 Hardness 2 Melting point 320 9° C Boiling point 767° C

Cadmium is a silver-white metal, malleable and ductile, but at 80° C becomes brittle, remaining lustrous in dry air and only slightly tarnished by air or water at ordinary temperatures, may be sublimed in a vacuum at a temperature of about 300° C, when heated in air burns to form oxide, dissolves slowly in hot dilute **hydrochloric** or **sulfuric acid**, and more readily in **nitric acid** Discovered by Stromeyer in 1817

Cadmium metal is used (1) as a protective coating for iron and steel, (2) in alloys such as solder and low melting point "fusible" alloys

Cadmium occurs as the sulfide (**greenockite**, CdS) in Greenland, Scotland and Pennsylvania, but chiefly in zinc ores (frequently 1 part cadmium to 400 parts zinc), from which it is separated during the process of manufacture by fractional distillation—cadmium is more volatile than zinc and is collected in the initial distillate

Bromide cadmium bromide ($CdBr_2$), white soluble solid Used in photography

Chloride cadmium chloride ($CdCl_2\ 2\frac{1}{2}H_2O$), white soluble crystals by reaction of cadmium metal and **hydrochloric acid**, and crystallizing

Hydroxide cadmium hydroxide ($Cd(OH)_2$), white precipitate by the reaction of cadmium salt solution and **sodium** hydroxide solution, soluble in acids and in ammonium hydroxide, but insoluble in sodium hydroxide solution

Nitrate cadmium nitrate ($Cd(NO_3)_2\ 4H_2O$), white, soluble crystals, by reaction of cadmium metal and **nitric acid**, and crystallizing

Oxide cadmium oxide (CdO), brownish-yellow solid, by burning cadmium metal in air, or by ignition of cadmium hydroxide, carbonate or nitrate

Iodide cadmium iodide (CdI_2), white, soluble solid, by reaction of cadmium oxide, hydroxide, or carbonate with **hydriodic acid**, soluble in alcohol (most iodides are insoluble in alcohol), forms cadmium potassium iodides, soluble, by excess of potassium iodide and crystallizing

Sulfate cadmium sulfate ($3CdSO_4\ 8H_2O$), white soluble solid, by reaction of cadmium metal and dilute **sulfuric acid**, and crystallizing Used in making the Weston standard electromotive force cell

Sulfide cadmium sulfide, "cadmium yellow" (CdS), yellow precipitate, by reaction of cadmium salt solution and **hydrogen sulfide** Used as a yellow paint pigment and when mixed with ultramarine for green pigment, in coloring soap, paper and rubber, and in ceramic glazes

Tungstate cadmium tungstate ($CdWO_4$), yellow insoluble solid Used in fluorescent paint (R K S)

CADUCEUS The wand of Hermes, or Mercury, used as a symbol of the medical profession and of the Medical Corps of the U S Army (R S M)

CAECILIA Gymnophiona

CAECUM Any blind pouch, especially a sac-like appendage of the alimentary tract (See **Anatomy**) The blind pouch with which the large intestine begins is a caecum, it bears the vermiform appendix in man and the anthropoid apes Some of the fishes have **pyloric** caeca at the point of union of the stomach and intestine and in some insects the rectum bears such pouches A pair of blind branching diverticula associated with the vestigial intestine of the starfishes are called rectal caeca (A W I)

CAFFEINE, OR TRIMETHYLXANTHINE An **alkaloid** prepared usually from **tea**-leaves It is present also in **coffee**, Kola and guarana It is a frequently used and valuable drug in medicine, where it serves as a stimulant and **diuretic** (R S M)

CAFFRE CAT. Mammalia, Carnivora **A cat** which ranges throughout Africa and into Asia It resembles the domestic cat and is supposed to represent the ancestral stock from which some strains of the latter are derived (A W L)

CAIMAN. Reptilia, Crocodilia *Caimein* Large **reptiles** of five species inhabiting the waters of Central and tropical South America They resemble the crocodiles but are less dangerous Called by the natives jacare. (A W L)

CAIRNGORM STONE. The name given to the smoky brown variety of **quartz**, particularly when transparent, from Cairngorm, Scotland, a well-known locality. (E S C S)

CAISSON. A caisson is a large, usually bottomless box or cylindrical shell, made of wood, **concrete** or **steel**, which is used in the construction of **foundations** located in water or below the ground-water level It is also useful when quicksand or other unstable soils are encountered during the excavation for a deep foundation Caissons for the foundations of buildings or other land structures are forced down through the soil by means of weights while the underlying material is being excavated A water jet is often used to aid the sinking action of the weights by reducing friction and by breaking up the material under the edge of the caisson As the sinking progresses additional sections are added until the required depth is obtained When the foundation is to be constructed under water, the caisson is built on land, floated to the site and sunk in place by means of weights If it is to be sunk to bed rock through the mud or sand at the bottom of the body of water, the operation is carried on in a manner similar to that described for building caissons In order to withstand **hydrostatic** or earth pressure the caisson should be properly braced or reinforced

The box caisson is a water-tight structure used for **bridge** foundations which are under water It is open at the top so that concrete or stone may be deposited to provide the necessary weight to sink it to the correct position, the bottom having been previously prepared so that a firm footing is assured

An open caisson is a rectangular or cylindrical shell, usually open top and bottom, although it may have a bottom with wells for removing the excavated material It is provided with a cutting edge to penetrate the underlying soil and thus facilitate the sinking operation Double walls or **ballast** pockets are used so that at least a part of the permanent filling may be placed subsequent to sinking and in this way reduce the amount of temporary loading In land operations the bottom of the caisson is assembled over the site of the foundation and the earth within the walls excavated As the material is removed the weight of the caisson and the additional loads, if required, cause it to sink The water jet, whose action has been described, may be used to assist gravity action When the caisson reaches its final position and the remaining earth has been excavated, a concrete seal is poured through the water that is in the bottom of the caisson This makes the bottom water-tight The water is then pumped out and the interior filled with concrete Open caissons may be used for bridge piers if they are constructed in such a manner that the upper end projects above the surface of the water The depth of the seal must be large enough to provide a mass of concrete that will counteract the effects of the **uplift** of water which may seep through the sand or mud at the bottom of the caisson If the depth of the concrete seal is made about one-half the depth of the water, measured from the surface to the bottom of the caisson, the caisson will be safe against flotation, even for 100% uplift Open caissons are generally used for deep building foundations which are carried below the ground-water level The depth to which the shell may be sunk depends upon the friction developed on the sides and upon the material which is encountered. This type of caisson has several disadvantages The character of the bottom cannot be readily ascertained due to the fact that it is under water, the bearing area cannot be properly prepared to receive the caisson and the concrete seal must be placed under water It also has some advantages The use of compressed air, which is a necessary factor of the pneumatic caisson, is not required It may be used for greater depths than the pneumatic caisson when the ground-water level is high and for some types of foundations it is more economical

The pneumatic caisson consists of an inverted box or cylinder which utilizes compressed air to counteract the hydrostatic pressure The essential parts of the caisson are a working chamber, open shafts and **air locks** The working chamber is the place where excavation is carried on under compressed air The shafts provide a means for workmen to enter or leave the caisson and are also used as outlets for the excavated material The air lock is a room where the air pressure is gradually adjusted as the workmen enter or leave the working chamber When the pneumatic caisson is to be used for land foundations, where the water level is high, the bottom containing the working chamber is constructed first This bottom has a cutting edge similar to that for the open caisson The material in the working chamber is dredged out and the caisson gradually sinks into the soil When the ground water is encountered compressed air must be used to keep the water out of the working chamber, and as the sinking progresses, the pressure must be increased to balance the hydrostatic pressure As the caisson is lowered **cofferdams** are used to keep out earth or water Concrete, which is deposited inside the cofferdam, furnishes additional weight for sinking After the caisson has reached its final resting place all loose material is excavated A concrete seal is then used to exclude water The air pressure is reduced to atmospheric pressure, the air locks removed and the remainder of the working chamber and shafts filled with concrete Pneumatic caissons, used for foundations located in water, are usually built on shore and floated into position If the top is made air-tight the air in the working chamber will add to the buoyancy Additional buoyancy may be obtained by means of a temporary water-tight and air-tight bottom The sinking of the caisson through the water is accomplished by pouring concrete inside the walls of the cofferdam When the caisson reaches the bottom the procedure is similar to that described for the pneumatic caisson sunk through earth The sinking of the pneumatic caisson may be controlled more readily than that of the open caisson Obstructions such as boulders or sunken logs can be easily removed and the surface under the caisson properly prepared and inspected The concrete seal does not have to be poured through water as in the case of the open caisson One serious objection is that the depth is controlled by the fact that there is a limit to the intensity of the air pressure in the working chamber which workmen can stand safely. (C W C)

CAISSON DISEASE (COMPRESSED AIR ILLNESS, "THE BENDS," DIVER'S PALSY). This disease occurs in individuals who, having been exposed to increased air pressure, are subjected to too abrupt reduction in the pressure

At present, with engineering operations in digging tunnels and underwater supports, and in deep sea diving, there are numerous opportunities for this disease Great precautions, however, are taken to prevent its occurrence On entering or leaving the caisson where air pressures of 30 to 40 pounds are present, air-locks are provided where gradual compression and decompression are produced In spite of these precautions a number of cases of caisson sickness develop

The cause of this disorder is the rapid liberation of

nitrogen from the fluids and tissues of the body The presence of this nitrogen is due to the increased solubility of the gas under the higher pressures in the caisson The liberated gas forms bubbles in nerve tissue, muscles, brain, and other body tissue

The symptoms produced are localized pain in the abdomen or extremities, vertigo, sensory or motor disturbances, dyspnea, collapse and unconsciousness

Cases treated early usually make a complete recovery Those that reach the stage of collapse usually do not recover

The only treatment is recompression The victim is placed as quickly as possible in an air lock and the air pressure increased until all the air bubbles go into solution The pressure is then very gradually lowered until normal air pressure is realized (R S M)

CALAMARY. Mollusca, Cephalopoda The true **squids**, *Loligo*, including the common squid of the Atlantic Coast and related species (A W I)

CALAMINE. The mineral calamine is **zinc** silicate (H_2ZnSiO_5) occurring in tabular and prismatic **orthorhombic** crystals although often in massive and fibrous forms There is a perfect cleavage parallel to the prism, it is brittle with a sub-conchoidal fracture, hardness, 4 5–5, specific gravity, 3 40–3 50, luster, vitreous, color, white, tending toward light bluish or greenish shades, streak, white, transparent to translucent Calamine differs from **willemite**, also a zinc silicate, in that the former contains considerable water which may be driven off when heated to a high temperature

There are many localities for calamine in Europe, fine specimens having come from Saxony, Sardinia, Cumberland, Alston Moor and Derbyshire, England It is found in Siberia, Algeria and Mexico In the United States calamine has been found at Sterling Hill, New Jersey, in Lehigh County, Pennsylvania, and in Virginia, Missouri, Montana, Colorado, Utah, New Mexico and Nevada

The name calamine is said to have been derived from the Latin *calamus*, a reed, in reference to its occurrence in slender stalactitic forms It is an important ore of zinc

Calamine has also been called hemimorphite because of the tendency to form doubly terminated crystals showing a different grouping of faces at either end The name is derived from the Greek meaning half and form (E S C S)

CALAMISTRUM. A comb-like structure on the fourth leg of some **spiders** It is formed of stiff hairs and is used to manipulate silk for certain purposes (A W L)

CALAMITES Paleobotany.

CALANDRA. Aves, Passeriformes A European **lark**, noted for its song The name is sometimes applied to other related species of the Old World (A W L)

CALAVERITE. Sylvanite.

CALCAREA. A class of the phylum Porifera containing **sponges** whose spicules are calcareous They are marine animals exclusively

The sponges of this class include the simplest of the entire phylum Some are of the ascon type, with canals passing completely through the body wall, and others are sycon sponges with two sets of canals, the incurrent leading into the body wall from the exterior and the radial leading from the body wall to the interior of the sponge Common sponges are available to illustrate both forms, *Leucoselenia* representing the former and *Grantia* the latter These structural differences and the examples mentioned characterize the two orders into which the class is divided·

Order Homocoela Ascon sponges; *Leucoselenia*
Order Heterocoela Sycon sponges, *Grantia* (A W L)

CALCAREOUS ALGAE. Paleobotany.

CALCIFEROUS GLAND. Oesophageal gland.

CALCINATION. The process of calcination involves the subjection of a substance to a high temperature below its **fusion** point, usually to make the substance friable Material so treated may (1) lose moisture, e g , the heating of **silicic acid** or **ferric** hydroxide resulting in the formation of silicon oxide or ferric oxide, respectively, (2) lose a volatile constituent, e g , the heating of **limestone** (calcium carbonate) resulting in the formation of **carbon dioxide gas** and **calcium** oxide residue—destructive distillation of many organic substances is of this type—(3) be oxidized or reduced, e g , the heating of pyrite (iron disulfide) in air resulting in the formation of **sulfur dioxide** gas and ferric oxide residue When the calcination involves oxidation, as in the preceding case, the operation is termed roasting When heating involves reduction of metals from their ores, with separation from the gangue of the liquid metal and slags the process is termed smelting See **Smelting** (R K S)

CALCIPHILE. Plants which require an abundance of **calcium** in the soil for satisfactory growth are known as calciphiles Many important agricultural plants, as for example **alfalfa** and many of the clovers, are of this sort This has led to the practice of liming the soil when these crops are planted (R M W)

CALCIPHOBES. Plants which cannot tolerate **calcium** are called calciphobes Such plants, moreover, prefer an extremely acid soil Members of the heath family are of this group Rhododendrons, for instance, so admired for their beautiful showy flowers and thick evergreen leaves, often fail to grow satisfactorily due to an excess of lime or calcium in the soil Working into the soil around the plants an abundance of leaves often helps to correct this condition The effect may be due to the toxic action of the calcium, or may be because the calcium prevents the absorption of other elements necessary to the plant. (R M W)

CALCITE. The mineral calcite, **carbonate of calcium** corresponding to the formula $CaCO_3$, is one of the most widely distributed of minerals Its crystals are **hexagonal-rhombohedral** although actual calcite rhombohedrons are rare as natural crystals However, they show a remarkable variety of habit including acute to obtuse rhombohedrons, tabular forms, prisms, or various **scalenohedrons** It may be fibrous, granular, lamellar or compact The cleavage in three directions parallel to rhombohedron is highly perfect, fracture, conchoidal but difficult to obtain, hardness, 3, specific gravity, 2 7, luster, vitreous in crystallized varieties, color, white or colorless through shades of gray, red, yellow, green, blue, violet, brown, or even black when charged with impurities, streak, white, transparent to opaque; it may occasionally show phosphorescence or fluorescence Calcite is perhaps best known because of its power to produce strong **double refraction** of light such that objects viewed through a clear piece of calcite appear doubled in all of their parts A beautifully transparent variety used for optical purposes comes from Iceland, for that reason being called Iceland spar

Acute scalenohedral crystals are sometimes referred to as dogtooth spar

Calcite represents the stable form of calcium carbonate, aragonite will go over to calcite at 470° C

Calcite is a common constituent of **sedimentary** rocks, as a vein mineral, and as deposits from hot springs and in caverns as stalactites and stalagmites

Among many localities noted for fine crystals of calcite are Saxony; Cumberland, England, Guanajuato, Mexico, St Lawrence County, N Y ; West Paterson and Bergen Hill, N J ; and Joplin, Mo (E S C S)

CALCIUM Symbol· Ca Atomic number· 20 Atomic weight 40 08 Density 1 54 Hardness 1 5 Melting

point 810° Boiling point· 1170° C Isotopes. 40 (96 76%), 42 (0 77%), 43 (0.17%), 44 (2 3%)

Calcium is a silver-white metal, somewhat malleable and ductile, stable in dry air but in moist air or with water reacts to form calcium hydroxide and hydrogen gas, when heated burns in air to form calcium oxide emitting a brilliant light Discovered by Davy in 1808.

Calcium occurs generally in rocks, especially limestone (average 42 5% CaO) and igneous rocks (average 5 0% carbonate, $CaCO_3$), **gypsum** (calcium sulfate dihydrate, $CaSO_4 \cdot 2H_2O$), **phosphorite**, phosphate rock (calcium CaO), as the important minerals **limestone** (calcium phosphate, $Ca_3(PO_4)_2$), apatite (calcium phosphate-fluoride, $Ca_3(PO_4)_2$ plus CaF_2), **fluorite**, fluorspar (calcium fluoride, CaF_2), in bones and bone ash as calcium phosphate, and in egg shells and oyster shells as calcium carbonate Calcium is the fifth element in abundance, constituting 3 6% of the earth's solid shell, is the most abundant metallic element of the human body (2 0% Ca), is the third most abundant metallic element of vegetation (0 6% Ca, exceeded by potassium and by sodium)

Calcium metal is produced in small amount by **electrolysis** of anhydrous fused calcium chloride, finding a limited use as a reducing metal, and alloyed with lead (0 04% Ca) for sheathing electric cables Calcium compounds are among the most common metallic compounds encountered in industry.

Acetate calcium acetate, "acetate of lime," "lime pyrolignite" ($Ca(C_2H_3O_2)_2 \cdot H_2O$), white solid (technical is "gray" or "brown"), solubility at 0° C, 27 2 grams, at 40° C, 24 9 grams, at 80° C, 25 1 grams of anhydrous salt per 100 grams saturated solution, formed by reaction of calcium carbonate or hydroxide plus **acetic acid** (technical is "pyroligneous acid" by the destructive distillation of wood without access of air) and evaporation Used (1) as one of the sources of acetic acid, (2) as one of the sources of acetone, (3) in dyeing and printing cotton goods

Aluminates calcium aluminates, four in number, have been prepared by high temperature methods and identified ($3CaO \cdot Al_2O_3$, at 1535° C decomposes with partial fusion, $5CaO \cdot 3Al_2O_3$, melting point 1455° C, $CaO \cdot Al_2O_3$, melting point 1590° C, $3CaO \cdot 5Al_2O_3$, melting point 1720° C) These aluminates are important in connection with Portland cement

Aluminosilicates calcium aluminosilicates, two in number, have been prepared by high temperature methods and identified ($2CaO \cdot Al_2O_3 \cdot SiO_2$, gehlinite, $CaO \cdot Al_2O_3 \cdot 2SiO_2$, anorthite) Calcium aluminosilicate mixtures are important in connection with Portland **cement**, and metallurgical **slags**

Arsenate calcium arsenate, arsenate of lime ($Ca_3(AsO_4)_2$), white precipitate, formed by reaction of soluble calcium salt solution and **sodium** arsenate solution Used as an insecticide.

Arsenite calcium arsenite, arsenite of lime ($Ca_3(AsO_3)_2$), white precipitate by reaction of soluble calcium salt solution and **sodium** arsenite solution Used as an insecticide and germicide

Borates calcium borates are found in nature as the minerals **colemanite** ($Ca_2B_6O_{11} \cdot 5H_2O$), **borocalcite** ($CaB_4O_7 \cdot 4H_2O$), and pandermite ($Ca_2B_6O_{11} \cdot 3H_2O$)

Bromide calcium bromide ($CaBr_2 \cdot 6H_2O$), white solid, soluble, formed by reaction of calcium carbonate or hydroxide plus **hydrobromic acid**, and then evaporation Used in medicine and in photography

Carbide calcium carbide, "carbide" (CaC_2), grayish-black solid, reacts with water yielding **acetylene** gas and calcium hydroxide, formed at **electric furnace** temperature from calcium oxide plus **carbon** (coke) Used as the starting point for many organic chemicals (1) from acetylene, (2) from calcium cyanamide

Carbonate calcium carbonate ($CaCO_3$), found in nature as **calcite**, Iceland spar, marble, limestone, coral, **chalk**, shells of **molluscs**, **aragonite** This is the most widely distributed compound of calcium in nature, and the source of calcium for many manufacturing processes, since it is (1) readily dissolved by acids forming the corresponding calcium salt, (2) converted to calcium oxide upon heating Aragonite is an unstable form at room temperature, although no change is observable until heated, when at 470° C it is quickly converted into calcite, calcium hydrogen carbonate, calcium bicarbonate, $Ca(HCO_3)_2$, colorless solution, formed by reaction of calcium carbonate and carbonic acid, either in a test tube or in limestone regions where this action accounts for the caves and holes encountered When the solution loses carbon dioxide by exposure to air or by warming, calcium carbonate is precipitated, e g , in steam boilers or stalactites and stalagmites of limestone caves

Chloride calcium chloride ($CaCl_2 \cdot 6H_2O$), white solid, soluble, absorbs water from moist air, formed by reaction (1) of calcium carbonate or hydroxide plus **hydrochloric acid**, and then evaporation, (2) of calcium hydroxide plus ammonium chloride in the reaction for the production of ammonia gas The latter is the commercial source, where calcium chloride is a final product of the "ammonia-soda" process for **sodium** carbonate Obtainable commercially as fused anhydrous, and as flakes Used as dust preventative, as brine for refrigeration, in freezing mixtures and solutions, as a drying agent for gases (not ammonia), as a dehydrating agent, as a wood preservative

Chromate calcium chromate ($CaCrO_4$), yellow solid, soluble, formed by the reaction of chrome iron ore and calcium oxide heated to a high temperature in a current of air and then extraction with water Used as a pigment

Citrate calcium citrate ($Ca_3(C_6H_5O_7)_2 \cdot 4H_2O$), white solid, solubility at 18° C 0 085 gram crystals per 100 grams of water, at 30° C 2 2 grams, former by reaction of calcium carbonate or hydroxide plus **citric acid** solution Used in effervescent beverages

Cyanamide calcium cyanamide ($CaCN_2$), white solid, formed (1) by fusing cyanamide or urea with calcium oxide, sublimes at 1050° C, (2) industrially, by heating calcium carbide at 1100–1200° C in a current of **nitrogen** The mass is black due to the separation of carbon Used (1) as a nitrogenous **fertilizer**, (2) as the starting point for the manufacture of various organic chemicals, and sodium cyanide

Fluoride calcium fluoride, fluorite, fluorspar (CaF_2), white precipitate, formed by reaction of soluble calcium salt solution plus **sodium** fluoride solution Used (1) as a flux in the production of metallurgical slags, (2) as a source of hydrofluoric acid by reaction with concentrated sulfuric acid

Formate calcium formate ($Ca(CHO_2)_2$, white solid, solubility at 0° C 13 90 grams, at 40° C 14 56 grams, at 80° C 15 22 grams of anhydrous salt per 100 grams saturated solution, formed by reaction of calcium carbonate or hydroxide plus **formic acid**, and then evaporation Calcium formate, when heated with a calcium salt of a carboxylic acid higher in the series, yields an aldehyde

Furoate· calcium furoate ($Ca(C_4H_3O\ COO)_2$), formed by reaction of calcium carbonate or hydroxide plus furoic acid Used for preparing fungicides and bactericides

Hydride· calcium hydride (CaH_2), white solid, reacts with water yielding **hydrogen** gas and calcium hydroxide, when electrolyzed in fused potassium lithium chloride, hydrogen behaves like chloride and is liberated at the anode Used as an easily regulated reducing agent in organic chemistry

Hydroxide calcium hydroxide, hydrated lime, slaked lime, milk of lime, lime water ($Ca(OH)_2$), white solid, soluble slightly (about 0 2 gram per 100 milliliters of water), formed (1) by reaction of calcium oxide and water, with the accompanying evolution of much heat, (2) by precipitation of soluble calcium salt solution and **sodium** hydroxide solution Used (1) as an important and cheap alkali, and so used in many chemical reactions

to form calcium salts or to liberate **ammonia** gas from **ammonium** salts, (2) in lime, mortar, and cements, frequently mixed with sand.

Hypochlorite: calcium hypochlorite, "H.T.H." (High Test Hypochlorite) ($CaOCl_2$) white solid, emits a marked odor in air, contains 60%–65% "available chlorine" and sufficient calcium hydroxide to stabilize, formed by reaction of calcium hydroxide and **chlorine** and evaporating at low temperature. Used as **bleaching** agent for fabrics, as a disinfectant, for the preparation of dilute solution of sodium hypochlorite in laundering, and in the treatment of wounds; "chloride of lime," "bleaching powder" ($CaOCl_2$), white solid, contains 36%–38% "available chlorine." Used as above.

Hypophosphite: calcium hypophosphite ($Ca(H_2PO_2)_2$), white solid, formed (1) by boiling calcium hydroxide suspension in water and yellow **phosphorus** (phosphine gas, poisonous, evolved), and then evaporation, (2) by reaction of calcium carbonate or hydroxide plus **hypophosphorous** acid, and then evaporation. Used in medicine.

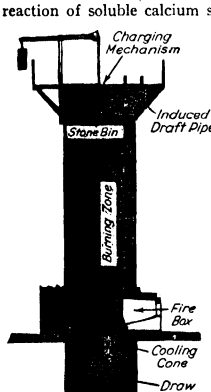
Iodide: calcium iodide (CaI_2), yellowish-white solid, soluble, formed by reaction of calcium carbonate or hydroxide plus **hydriodic acid**, and then evaporation. Used in photography.

Lactate: calcium lactate ($Ca(C_3H_5O_3)_2 \cdot 5H_2O$), white solid, solubility: at 0° C. 3.1 grams, at 30° C. 7.9 grams of anhydrous salt per 100 grams water, formed by reaction of calcium carbonate or hydroxide plus **lactic acid**, and then evaporation. Used in medicine.

Malate: calcium malate ($CaC_4H_4O_5 \cdot 2H_2O$), white solid, solubility: at 0° C. 0.670 gram, at 37.5° C. 1.011 grams of anhydrous salt per 100 grams saturated solution. Formed (1) by reaction of calcium carbonate or hydroxide plus **malic acid**, (2) by precipitation of soluble calcium salt solution and sodium malate solution.

Nitrate: calcium nitrate, "Norway saltpeter" ($Ca(NO_3)_2 \cdot 4H_2O$), white solid, soluble, formed by reaction of calcium carbonate or hydroxide plus **nitric acid**, and then evaporation. Used widely as a nitrogenous fertilizer (initially manufactured in Norway by neutralizing the dilute nitric acid produced in the fixation of atmospheric **nitrogen** by the electric arc process). Also used in pyrotechnics and as a source of nitrate for other nitrates.

Oxalate: calcium oxalate (CaC_2O_4), white precipitate, insoluble in weak, soluble in strong acids, formed by reaction of soluble calcium salt solution and **ammonium** oxalate solution. Solubility: at 18° C. 0.0056 gram anhydrous salt per liter of saturated solution.



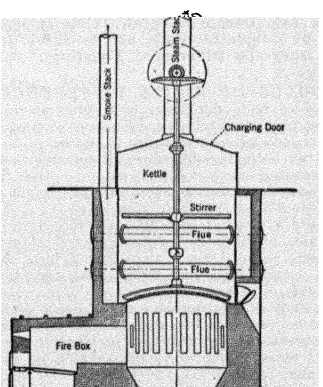
Lime kiln.

Oxides: calcium oxide, lime, burnt lime, quick lime, live lime, caustic lime (CaO), white solid, melting point 2570° C.; reacts with water to form calcium hydroxide with the evolution of much heat; reacts with water vapor and carbon dioxide of the atmosphere to form calcium hydroxide and carbonate mixture (air slaked lime); formed by heating limestone to a high temperature (800° C.) and removal of carbon dioxide also formed. An important and cheap alkali, which is used (1) as calcium hydroxide with water, (2) as calcium carbonate for high temperature reactions (carbon dioxide evolved as gas); calcium peroxide (CaO_2), white solid, only slightly soluble in, but reacts slowly with water, formed by reaction of soluble calcium salt solution and sodium peroxide. Used as a germicide.

Phosphates: tricalcium phosphate, tertiary phosphate of lime, phosphorite, bone ash ($Ca_3(PO_4)_2$), white solid, the source of practically all phosphate and phosphorus containing substances; insoluble in water; reactive with **silicon** oxide and carbon at electric furnace temperature yielding **phosphorus** vapor (later condensed under water) plus carbon monoxide plus calcium silicate molten slag; reactive with sulfuric acid to form, according to the proportions used, the two following calcium phosphates or **phosphoric acid**, dicalcium hydrogen phosphate, secondary phosphate of lime, reverted phosphate ($CaHPO_4$), white solid, insoluble, used as a source of acid in baking powders for leavening; calcium dihydrogen phosphate, primary phosphate of lime, superphosphate ($Ca(H_2PO_4)_2 \cdot H_2O$), white solid, soluble, formed (1) by reaction of tricalcium phosphate and sulfuric acid, yielding calcium dihydrogen phosphate plus calcium sulfate, the mixture constituting the widely produced and utilized "superphosphate" **fertilizer**, (2) by reaction of tricalcium phosphate and sulfuric acid yielding phosphoric acid plus calcium sulfate, and, after separation, the resulting phosphoric acid is treated with tricalcium phosphate yielding calcium dihydrogen phosphate, known as "treble superphosphate."

Silicates: calcium silicates, four in number, have been prepared by high temperature methods, and identified, $3CaO \cdot SiO_2$, prepared by heating the constituents to a temperature below the melting point (melting point is 1700° C. but substance unstable); $2CaO \cdot SiO_2$, melting point 2080° C., but upon slow cooling changes to forms of different volume; $3CaO \cdot 2SiO_2$, melting point 1475° C.; $CaO \cdot SiO_2$, wollastinite, melting point approximately 1400° C. These silicates are important in connection with Portland cement.

Sulfate: calcium sulfate, **gypsum** ($CaSO_4 \cdot 2H_2O$), plaster of Paris ($CaSO_4 \cdot \frac{1}{2}H_2O$), **anhydrite** ($CaSO_4$), white solid, soluble slightly (about 0.2 gram per 100 milliliters of water), formed by reaction of soluble calcium salt solution and sodium sulfate solution. Used (1) in plaster, stucco and cement, frequently mixed with fillers.



Calcining kettle for **the production of plaster of** Paris from gypsum.

Dry plaster is gypsum which has been heated until about one-fourth of the original water remains. This dry plaster, when mixed with water, can be worked or shaped but soon sets to a coherent and adherent solid, which is composed of interlacing crystals of gypsum, (2) as a filler for **paper** and **paints**.

Sulfides: calcium sulfide (CaS), grayish-white solid, reactive with water, formed by reaction of calcium sulfate and **carbon** at high temperatures. Used as a depilatory, and in luminous paints; calcium hydrogen **sulfide**,

calcium bisulfide ($Ca(HS)_2$), formed in solution by saturating calcium hydroxide suspension with hydrogen sulfide Used as a depilatory

Sulfites calcium sulfite ($CaSO_3$), white precipitate, formed by reaction of soluble calcium salt solution and **sodium** sulfite solution, or by boiling calcium hydrogen sulfite solution, calcium hydrogen sulfite, calcium bisulfite, sulfite liquor ($Ca(HSO_3)_2$), formed in solution by saturating calcium hydroxide or carbonate suspension with **sulfurous acid** Used as cooking liquor (with excess sulfurous acid) in converting wood chips into paper pulp

Tartrate calcium tartrate ($CaC_4H_4O_6\ H_2O$), white solid, solubility at 0° C 0 0875, at 80° C. 0 180 gram anhydrous salt in 100 milliliters saturated solution, formed by reaction of calcium carbonate or hydroxide and **tartaric acid**, (2) by precipitation of soluble calcium salt solution and **sodium** tartrate solution. (R K S)

CALCULUS, DIFFERENTIAL AND INTEGRAL.

The Differential and Integral Calculus is a branch of Mathematics dealing with the rate of change of a function and with the inverse process

Sir Isaac **Newton** (1642–1727), the famous English scientist and mathematician, and Gottfried Wilhelm Leibnitz (1646–1716), a famous German philosopher and mathematician, are considered the founders of the Calculus

Some indication of the subject-matter usually included under the term Calculus may be found by consulting the following topics

Variable, Constant, Functions, Continuous Functions, Limits, Derivative of a Function of One Variable, Differentials, Differentiation Technique, Higher Derivatives, Tangents and Normals to Plane Curves, Maxima and Minima, Partial Derivatives, Infinite Series, Expansion of Functions in Series, Indeterminate Forms, Concavity and Convexity of a Plane Curve, Curvature of a Plane Curve, Indefinite Integrals, Integration Technique, Definite Integrals, Area under a Plane Curve, Length of Plane Curve Arc, Double Integral, Triple Integral, Volumes by Double Integrals, and by Triple Integrals, Line Integrals, Differential Equations (I L S)

CALCULUS OF FINITE DIFFERENCES

The calculus of finite differences is a study of methods of treating problems involving differences of functions

If we have given a sequence $u_0, u_1, u_2, \ldots, u_n, \ldots$, and if we form the differences of consecutive terms of this sequence, as $u_1 - u_0, u_2 - u_1, \ldots$, we call these differences the first differences of the original sequence and denote them by $\Delta u_0, \Delta u_1, \Delta u_2, \ldots, \Delta u_n, \ldots$, so that $\Delta u_n = u_{n+1} - u_n$ We may then form the first differences of these first differences and obtain second differences, denoted by $\Delta^2 u$, so that $\Delta^2 u_n = \Delta \cdot (\Delta u_n) = u_{n+2} - 2u_{n+1} + u_n$, and similarly we may form third and higher differences

The study of the properties of successive differences is applied to problems in **interpolation** and quadratures (**approximate integration**), to problems in the summation of series, and also to the solution of **difference equations** (L I S)

CALCULUS OF VARIATIONS.

The calculus of variations is concerned with the problem of maxima and minima of functions of functions In the ordinary differential calculus, the problem of extreme values of functions is dealt with, in which a function of one or more independent variables is examined to determine the values of the variable or variables for which the function takes maximum or minimum values The calculus of variations is a natural extension of this problem In the calculus of variations, a curve or surface (or corresponding function) plays the role of the independent variable of the former problem

The function to be minimized or maximized in the calculus of variations is essentially of the form

$$\int_a^b f(x,y,y')dx,$$

where y is a function of x and $y' = dy/dx$, or some generalization of this The central problem of the calculation of variations is then to find the function $y = F(x)$ or the corresponding curve which will make the above integral take a minimum value or a maximum value

A few of the simplest problems of the calculus of variations are (1) to find the shortest distance between two given points, (2) to find the path along which a particle will move under the action of gravity from one given point to a lower given point in the shortest time, (3) to find the minimum surface of revolution

The calculus of variations is applied to many important problems of geometry, and also has many valuable applications to physics, as in Hamilton's principle and the principle of least action

Problems in the calculus of variations may be solved either directly, by approximation, as in Ritz's method, or indirectly, by reduction to **differential equations** (L L S)

CALDERA Derived from a Spanish word meaning caldron, the term caldera has been given to great crater-like depressions which are either the result of subsidence of lava within the body of a **volcano** or of an explosive eruption of terrific violence Examples of these craters of explosion or subsidence are Crater Lake, Oregon, Mt Tamboro, in the Dutch East Indies, and the original *La Caldera* in the Canary Islands The caldera, Crater Lake, is 2000 feet deep and about twenty-five square miles in area, surrounded by cliffs whose maximum height is 2000 feet above the lake (E S C S)

CALEDONIAN DISTURBANCE. Silurian.

CALENDAR The problem of time keeping has always been a vexing one to mankind There are three "natural" units, the solar **day**, the lunar **month**, and the tropical **year** The normal or true solar day had to be abandoned with the improvement of mechanical time-keeping devices and the mean solar day has been adopted as the standard short unit for keeping records The task of the calendar builder is to combine this unit with the two longer units and, since the three are mutually incommensurable, a rigorous solution of the problem is impossible and compromises must be made

The fact that the economic world is largely dependent upon agriculture introduces one important restriction on the freedom of the calendar builder The seasons should remain at approximately the same place in the completed calendar from year to year The date upon which the sun apparently passes through the **vernal equinox** is of fundamental importance to the agriculturalist and for many centuries was considered as the time of starting a new year One of the earliest calendars on record started the year on this date and then proceeded through ten lunar months Such a calendar would cover only 295 3 mean solar days, while the period from one passage of the sun through the vernal equinox to the next is 365 2422 days The period between the end of one year to the beginning of the next was determined by the priesthood and politicians with hopeless confusion resulting

The first step toward the modern calendar was made by Julius Caesar with the advice of the astronomer Sosigenes The so-called Julian Calendar discards the lunar month and adopts 365 25 days as the length of the year This year is divided into twelve periods (months) of 30 or 31 days The normal year was 365 days in length but, to make up the extra ¼ day, an extra day was intercalated (i e, put into the normal calendar) every four years

Running parallel with the Julian calendar we find the far more ancient calendar of the Jewish and Mohamme-

dan peoples, which holds rigorously to the lunar month Division of the number of days in the tropical year by the days in the lunar month will indicate that there are 12 36 lunar months in a tropical year. To retain the synchronism between the calendar and the seasons, this calendar is variable in the number of months which it contains and the process of intercalating months becomes very complicated However, the eastern calendar exerts a powerful effect upon the calendar of the western world, because of the fact that the date of Easter is fixed by a date on the eastern calendar

In AD 325 the Christian Church took its first step in calendar building and at the Council of Nice made two decrees a decree that the sun should pass through the vernal equinox on the 21st of March on the Julian Calendar, and a second decree relative to the date for the celebration of Faster The latter of the two decrees was within the province of the Church and can be followed, the former, however, applies to factors beyond the control of man

It should be noted that the length of the tropical year is 0 0078 day less than the 365 25 days of the Julian Calendar This means that after the lapse of 1000 years the sun will pass through the vernal equinox 7 8 days earlier than the 21st of March, assuming it was at the vernal equinox on this date in the first place By 1582 the date of the vernal equinox was the 11th of March instead of the 21st and Pope Gregory decided to return the sun to its proper date and to modify the calendar in such a way that the error would not reappear The Gregorian Calendar is identical with the Julian except in the fact that only such century years are leap years as are divisible by 400 This is equivalent to dropping three days every four hundred years leaving an average length for the year of 365 2425 days which differs from the tropical year by only 0 0003 day This calendar was immediately adopted by all Catholic countries but the Greek Church and most protestant countries refused to recognize it The confusion following this change persisted well down into the present century (Rumania used the Julian Calendar until 1919) and is still felt by historians in reading records of the early years of this country when both calendars were in use

Within the past twenty years a strong movement has been on foot to modify the calendar in the attempt to have dates and days of the week agree in successive years Any such scheme involves the necessity of introducing one day each year without date or day of the week, and two such days on leap years, if the year and the seasons are to retain the present synchronism This intercalation of a day will break the six day sequence between Sabbaths, an idea which is abhorrent to many religious sects However, the movement is gaining in strength and there seems to be a fair chance of the adoption of a new calendar within the next few years The scheme which has the most general support is one in which the year is divided into four equal quarters of three months each In each quarter the first month has 31 days and the second and third, 30 each This gives exactly 13 weeks in each quarter, and 52 weeks in each year The days are to be intercalated without date or day of the week between December 30 and January 1 each year and between June 30 and July 1 every leap year (e g, the normal calendar would read Saturday, Dec 30, New Year's Day, Sunday, Jan 1) (W K G)

CALF. 1 The young of cattle and of related wild species 2 The fleshy mass formed by the muscles at the back of the leg below the knee (A W L)

CALICHE. An important natural fertilizer occurring in Chile as an **alluvial** deposit containing **sodium** nitrate and other soluble salts These deposits were of great economic importance, prior to the development of present-day methods for the fixation of atmospheric **nitrogen.** (R M F)

CALIPASH. A structure beneath the carapace of **turtles** containing a greenish fat, sometimes regarded as a delicacy (A W L)

CALIPEE A structure lying near the plastron of the **turtles,** similar to the calipash (A W L)

CALLA LILIES. Aroids.

CALLUS. There are five common meanings with which this term is used throughout biological science

1 Callus is a thickened horny mass found in the outer layer of the skin, which is the result of continued pressure or friction

2 Callus designates a thickened spot near the **umbilicus** in the shells of certain snails

3 Callus also denotes a tissue formed about the fragments of a broken bone This tissue eventually develops into bone, and by this means the fracture heals

4 Callus is a term applied to colorless glistening pads of substance which close the sieve plates of **sieve tubes** which have ceased to function The formation of these callus pads usually ends the activity of the cell, although they may be dissolved later and activity resumed

5 Callus designates a certain protective tissue which occurs widely in plants When the root or stem of a **gymnospermous** or a **dicotyledonous** plant is wounded, exposing the tissues within, the cambium cells around the wound begin to divide rapidly, forming a protective mass of soft parenchymatous tissue These living cells are called callus, or wound tissue, and in time will entirely close the wound if the latter is not too extensive Callus tissue may even grow over such a wound as results when a tree is girdled, that is, when a ring of bark is removed completely round the stem Ordinarily, however, such a wound is fatal After the tissue is formed, cell differentiation goes on and a new **phellogen** layer may be formed, as well as the other tissues composing the cortex of the **stem.** The **cambium** becomes once more a continuous layer When wounds are made in pruning, that is, when a branch is cut off, callus tissues gradually form a ring which spreads over and finally completely closes the wound (A W L, R S M, R M W)

CALOMEL Mercury.

CALORESCENCE. This term refers to the production of visible light by means of energy derived from invisible **radiation** of frequencies below the visible range Tyndall found it possible to raise a piece of blackened platinum foil to a red heat by focusing upon it infrared radiation from an arc or from the sun, the visible wave lengths having been filtered out It is to be noted that the transformation is indirect, the light being produced by heat and not by any direct stepping up of the infra red frequency A somewhat analogous phenomenon is the production of visible sparks or the glowing of a fine platinum wire in a resonant circuit energized by long-wave Hertzian radiation (I D W)

CALORIE. The gram calorie is the quantity of heat required to raise the temperature of one gram of pure water from 15° to 16° C Since the specific heat of water is not quite constant, it is necessary to specify the degree interval used in defining the calorie, this one being chosen because water has its average specific heat at this point The calorie is equal to about 1/252 of a British thermal unit, and is dynamically equivalent to about 41,852,000 ergs of energy The heat unit thus defined is the one most commonly employed in physics For some purposes it is convenient to use a larger unit, the kilogram calorie, which is equal to 1000 gram calories The calorific values of foods are, for example, usually expressed in terms of this unit (L D W)

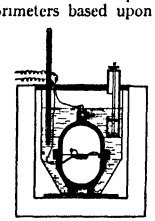
CALORIFIC VALUE. Heating Value.

CALORIMETRY. The measurement of quantity heat; any apparatus used for the purpose being called a "calorimeter" The most obvious result of the application of heat is the rise in temperature of the body to which it is applied, hence it is natural that this readily measurable effect should be utilized in heat measurement Since the application of heat melts solids and vaporizes liquids, these effects also furnish the basis of valuable calorimetric methods

The common units of heat are based upon the temperature-raising effect Thus we have the gram **calorie**, the kilogram **calorie**, and the "British thermal unit" The latter, equal to about 252 gram calories, is the quantity of heat required to raise the temperature of one pound of water one Fahrenheit degree Gas companies sometimes use a large unit called the "therm," viz, 100,000 B t u, but this name has also been applied to various multiples of the calorie and is hence ambiguous

The so-called water calorimeter is essentially a thermally insulated metal cup containing water and furnished with a thermometer The quantity of heat to be measured is applied to the water, and the rise of temperature resulting, multiplied by the mass of the water, gives the number of heat units received Corrections must of course be made for the heat absorbed by the cup, thermometer, and other accessories, the "water equivalent" of which is in the computation simply added to the mass of actual water Allowance must also be made for heat lost or unintentionally introduced through radiation and conduction, for which purpose **Newton's law of cooling** is commonly used

Since the **heat of fusion** of ice is known to be very nearly 79 25 calories per gram, the heat to be measured may be applied to the melting of ice without change of temperature, and the mass of ice melted, multiplied by the heat of fusion, gives the quantity of heat Bunsen, Lavoisier and Laplace, Black, and others devised calorimeters based upon this principle



Bomb calorimeter for determining the heating value of solid and liquid fuels

A steam calorimeter was perfected by J Joly (1886) and used for the accurate determination of specific heats of solids, liquids, and gases In principle this apparatus consists of a balance, with the specimen hung from one pan and surrounded by an enclosure which can be flooded with steam The mass of moisture condensing on the specimen, multiplied by the heat of vaporization of water, gives the quantity of heat imparted to the specimen

Other calorimetric methods have been proposed and tested, and many special calorimeters have been designed for measuring heats of combustion of fuels, food values, heats of chemical reaction, heat from electric currents, etc , most of these methods depend upon one or another of the principles mentioned above (L D W)

CALYX. For the use of this term in botany, see **Flower.** In zoology, a calyx is a cup-shaped or funnel-like structure, such as the body of a **sea-lily** and the chambers branching from the principal cavity of the vertebrate **kidney.** (A W L)

CAM. A cam is a moving part having a surface which transmits a predetermined irregular motion to a second machine part called the follower While the great majority of cams have a rotating motion, some have an oscillating or reciprocating motion The cam is employed to give motion to a follower either where the motion is complicated, or where a simple reciprocating motion is better obtained with a cam than with a **crank.** The cam follower frequently has a reciprocating motion, but not necessarily The accompanying

Figure 1 shows several forms of cams of the rotating type, with various types of followers, some of which are reciprocating, some oscillating The figure also illustrates the simple face cam and the positive motion cam The

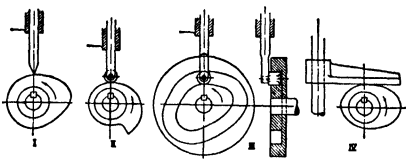


Figure 1 Various types of cams and followers

followers of the simple face cams must follow the surface of the cam by being held against it either by the force of gravity, or by spring pressure

A cam may be designed to give any desired motion, no matter how complicated it may be Very often the marvelous features of automatic machinery which may seem to operate with human intelligence are obtained by the use of large numbers of specially designed cams In addition to complicated motions, simple cams are used to reciprocate followers such as pump plungers, valves, etc , whose motion, while not especially complicated, can be most easily and simply obtained by the use of cams

To lay out a cam to execute any given predetermined

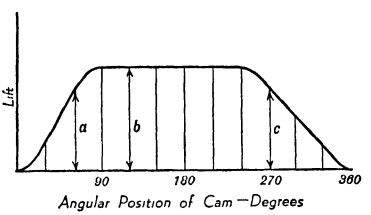


Figure 2

motion, a chart of this motion is made as in Figure 2, with the desired motion of the follower plotted against a time sequence or against an angular position of the cam To develop the profile of a simple plate cam to produce this definite motion in a reciprocating follower, the mechanism is inverted, that is, the cam is considered stationary while the follower rotates about it, taking up successive positions in accordance with the displacement

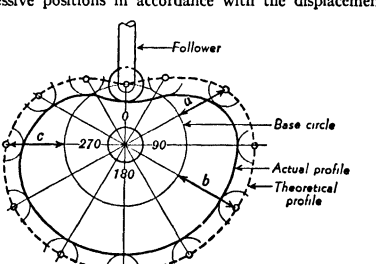


Figure 3.

diagram First a base circle is chosen of such size that the roller of the follower will have a smooth action Then a theoretical cam profile is developed for a follower having pointed contact, the point of which coincides with the axis of the actual follower's roller Upon this theoretical profile as a center are swung a succession

of arcs with a radius equal to that of the roller, and the envelope of these arcs is the actual cam profile (Figure 3) (F T M)

CAMBER. Camber is a term which describes the curvature of bodies having a convex form and differs from the curvature of an **arch** in that it is limited to shapes of slight convexity only In structural engineering camber is used to describe the fabricated shape of **girders** and **trusses** which is necessary to counteract the effect of the distortion of the individual parts under **loads.** These distortions cause **deflections** which are objectionable, from the standpoint of appearance Girders are cambered by fabricating them in such a way that the top and bottom flanges have a convex shape Camber is produced in short span trusses by making the top chord panel lengths longer than the corresponding panels of the lower chord by about 1/8 inch for each ten feet of length Long span trusses are cambered by shortening each **tension** member an amount equal to its maximum elongation under a certain assumed loading and lengthening each **compression** member in a similar manner The assumed loading is generally the dead weight of the structure plus a certain percentage of the live (moving) loads (C W C)

CAMBIUM. In **Gymnosperms** and **dicotyledonous Angiosperms,** a large part of the tissues of the stem is derived from a special layer of cells known as the cambium The cambium originates from certain cells of the procambial strand In the procambial strand of the stem (that part of the growing tip in which **cell** differentiation first takes place), cell differentiation commences at the tangential edges of the strand and progresses towards the center, forming primary xylem cells towards the center of the stem and primary **phloem** cells towards the surface Some of the cells in the middle portion of the procambial strand do not differentiate into **xylem** or phloem, but become meristematic cells, dividing actively These are the cambium cells Often they begin to divide before the other cells of the procambial strand have ceased elongating

At first the cambium is a vaguely defined layer of cells occupying the middle portion of the procambial strand In **roots** the cambium appears on the inside of the primary phloem strands, which alternate with the primary xylem strands

Gradually additional cells are formed laterally, either from those cambium cells already formed or by differentiation of parenchyma cells of the medullary ray, until a complete cylinder of cambium exists Once formed, the cambium of woody plants persists throughout the life of the plant, in herbaceous plants its existence is rather brief, all cells of the stem becoming mature early in its development

There are two types of cells present in the cambium of any plant The cells of one type are isodiametric, that is, all dimensions are more or less equal, these cells give rise to the cells of the vascular rays The other cambium cells are long cells with tapering ends, the cells which result from the division of these become either tracheids, vessels, fibers, or sieve tubes The elongate cambium cells vary in dimensions in different plants In various Gymnosperms they may be 3000–4000 microns or more in length; in dicotyledons they are much shorter, varying from 100–800 microns In width cambium cells vary in different plants from 20–40 microns, and in thickness, or radial dimension, 5–15 microns Cambium cells have a dense **cytoplasm** in which **vacuoles** are either lacking or very minute Each cell of the cambium has a single **nucleus** which is usually elongated The walls, especially the tangential ones, are very thin Division of the cambium cells occurs in a longitudinal tangential plane, that is, the cell divides lengthwise to form two slender elongate cells, one of which lies outside the other, towards the outside of the stem or root It is probable that the division is always mitotic (**mitosis**) One of the cells resulting from this division soon begins to change its form If this differentiating cell is on the inside of the cambium cylinder it may elongate even more, its ends sliding by and between those of other cells about it Presently thickening of the wall occurs through deposits of cellulose which are laid down on the primary wall The cytoplasm of the cell gradually disappears When mature, this cell, now a **tracheid,** is a long slender tapering cell with thick wall and no cytoplasm In the wall are numerous **bordered pits,** which are continuous with pits of adjoining cells In Gymnosperms, all cells derived from the cambium become tracheids, except in those forms which have wood parenchyma cells In these, transverse divisions occur to form a linear row of short cells In angiosperms other types of cells are formed One of these, the fiber, differs little from the tracheid except that it has a thicker wall, in which there are few small pits The other type is quite distinct The cambium derivative which is going to form one of these does not elongate noticeably, but does increase greatly in diameter As it increases, a large central vacuole forms, and the nucleus moves to a position near the middle of the end wall At that stage, the vessel appears as a series of very large vacuolate cells separated from one another by distinct end walls. When full size is reached, secondary wall thickening occurs Then the end wall breaks down, leaving a series of cells forming a long open tube, in many plants perforations are formed in the end wall, so that direct continuity from cell to cell exists. The tremendous increase in diameter of the vessel cells causes the cells around it to be flattened and crowded into angular shapes and irregular arrangements Once the walls have formed and the cell matured, no further change takes place Its structure is fixed permanently

The cells which are formed externally to the cambium become phloem cells The manner of differentiation is not so well known in these cells as in the xylem cells Apparently divisions of these phloem mother cells, cut off from the cambium cells, are much more frequent than are divisions of the xylem mother cells Phloem parenchyma results from the transverse division of one of these cells to form a longitudinal series In angiosperms each phloem mother cell divides unequally, cutting off a very small cell from the corner of the mother cell The larger cell becomes a sieve tube, the smaller a companion cell Often the companion cell divides again to form two or more companion cells associated with a single sieve tube The cytoplasm of the companion cells remains dense, develops few vacuoles, and always has a well-developed nucleus In the sieve tube, on the contrary, the cytoplasm becomes peripheral, and there is a large central vacuole The nucleus has disappeared in the mature sieve tube The walls of the sieve tube are characterized by the presence of porous places called sieve plates The pores of these sieve plates result from the enlargement or fusion of the photoplasmic strands, known as plasmodesma strands, which connect the protoplasts of adjoining cells The enlargement of these strands causes an enlargement of the pores through which they pass, so that conspicuous openings are formed between adjacent cells The development of sieve tubes in Gymnosperms is very similar to that in angiosperms, but no companion cells are formed, and the pores in the sieve plates are much smaller The development of phloem fibers is like that of xylem fibers

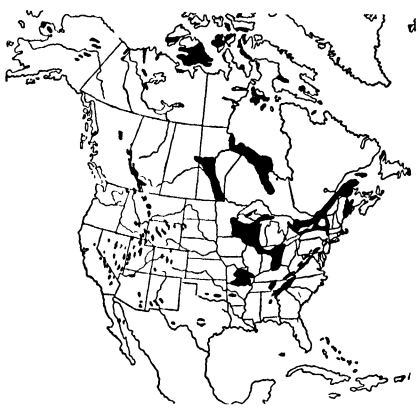
It is obvious that with continued formation of xylem cells inside the cambium and consequent increase in stem diameter, the cambium is constantly being pushed outward and stretched Gliding growth of cambium cells and those cut off from them causes increase in circumference of the cambium cylinder and so prevents any breaking of the same For a time the phloem cells maintain their shape against the pressure of the enlarging stem within In time, however, the phloem cells become crushed and distorted beyond recognition

The isodiametric cambium cells divide to form either

xylem or wood ray cells inside, or phloem ray cells outside the cambium These cells differentiate directly into ray cells

All tissues derived from the divisions of the cambium cells are known as secondary tissues, in contrast to the primary tissues, which are formed by differentiation of the cells of the procambial strands (R M W)

CAMBRIAN PERIOD. The earliest subdivision of the **Paleozoic Era** Type locality, North Wales The formations of this system were first studied and named by Adam Sedgwick in 1853 The Cambrian period began some 500 million years ago, and lasted for 70–80



Map showing known areas of outcrops (surface distribution) of Cambrian, Ordovician, and Silurian strata in North America

million years Cambrian formations are well exposed in North America in the Appalachians and Rocky Mountains Important lower Cambrian beds containing the oldest known faunas occur in British Columbia Other countries in which the Cambrian is well exposed are Sweden, Britain, Spain, Scandinavia, France, Germany, eastern China, northeastern Siberia, India (Himalayas and Salt Range), Morocco, Australia, Argentina and Antartica Cambrian sediments represent the earliest evidence of deposition in well defined **geosynclines,** the principal types being **sandstones, shales** and **limestones. Tillites** indicate continental glaciation The maximum thickness of 40,000 feet of Cambrian strata occurs in North America The oldest known invertebrate fossils occur in this period, the principal types being **trilobites, chitinous brachiopods,** and primitive **graptolites;** all of which had a marine habitat It is interesting to note that the paleontological record begins with such highly developed organisms as trilobites, whose ancestors are entirely unknown in the pre-cambrian formations The "father" of American Cambrian stratigraphy and paleontology is Charles D Walcott The base of the Cambrian has not been clearly defined and in some places it probably passes without hiatus into the lower **Proterozoic.** In eastern North America the top of the Cambrian is also under debate, the upper beds forming the base of a new system called the Ozarkian by E O Ulrich (R M F)

CAMEL. Mammalia, Artiodactyla Animals with long legs and necks and a conspicuously humped back They are adapted for life in arid regions, including sand deserts, by the broad feet and slit-like nostrils, internally the development of cells for the retention of water in one part of the stomach is especially important for life in such regions

The two existing species of camels, the Arabian, *Camelus dromedarius,* with one hump and the Bactrian, *C bactrianus,* with two, are found in the Old World The arabian camel is found both in Africa and Asia and the Bactrian in the desert regions of central Asia Both species have been domesticated They are used for riding and as beasts of burden, and also supply foods in the form of milk and flesh Their hair is used in making fabrics

The Arabian camel was introduced into the southwestern states by the United States government in 1856 but after many years of apparent success the experiment was abandoned The animals which were freed died out after persisting for some years (A W L)

CAMEL-CRICKET. Insecta, Orthoptera Wingless insects related to the **katydids** They live in dark moist places and are dull colored These facts together with the strongly humped back give them their name They are also called cave-crickets (A W L)

CAMERA. The ordinary photographic camera consists essentially of a positive or converging objective **lens** mounted at one end of a light proof enclosure, at the opposite end of which a sensitized film or plate may be exposed to receive and record the real, inverted image formed by the objective

The details of design of photographic objectives are far too technical to be discussed in detail here In addition to the elimination of **spherical** and **chromatic aberration** the ends to be secured are speed, wide angle, absence of distortion, and flatness of field The speed of an objective for plates of given sensitiveness, that is, the rate at which the photographic image is produced, is dependent upon the mean illumination over the image area This is proportional to the square of the ratio of the diameter, D, of the objective aperture to the focal length, L, of the objective The size of the aperture is controlled by a diaphragm ("stop"), so that the speed may be adapted to circumstances such as available light or motion of the object Camera makers and photographers call the ratio L/D the "F-number" or stop of the objective Thus for an "$F/8$" objective, $L = 8D$ In geometrical optics the same ratio, L/D is called the relative aperture To obtain wide angle without distortion ordinarily requires much care in figuring the lens The "panoramic" camera secures this end by slowly rotating the camera about a vertical axis and exposing at one time only that part of the film which is near the optical axis A "flat" field means that objects at a considerable range of distance are approximately focused in one plane The simplest condition favoring this is short focal length, and this accounts for the success achieved in using the cheap "box" type camera

An astrographic camera is merely a **telescope** with a plate holder replacing the eyepiece If the telescope is of the refracting type the **chromatic aberration** must be treated in such a manner that the photographically active radiation (greens and blues) are all brought to the same focus with the other colors thrown well out of this position In microphotographic cameras a greatly enlarged image of the object is produced by the optical system of the microscope The "telephoto" camera has an additional lens system to magnify the images of distant objects The special features of motion picture cameras concern only the mechanism for securing intermittent exposure and for shifting the film in synchronism with the interval between exposures In such cameras the "F-number" must be very small to obtain the speed necessary for the short exposures and the focal length must be short to make the individual pictures small (L D W)

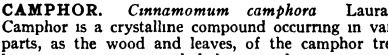
CAMPANULARIAE. Coelenterata, Hydrozoa. An order made up of colonial species with two forms of **polyps,** one nutritive and the other reproductive, known respectively as hydranths and blastostyles, and both en-

veloped partially in a cupped extension of the sheath of the colony The common and widely distributed genus *Obelia* is an example (A W L)

CAMPHOR. *Cinnamomum camphora* Lauraceae Camphor is a crystalline compound occurring in various parts, as the wood and leaves, of the camphor tree, a large evergreen tree with light green leaves, growing in many warm regions of southeastern Asia, but particularly on the Island of Formosa It has been introduced into California, Florida and other warm parts of the United States as an ornamental tree Its abundance in Japanese-owned Formosa gives that country virtual control of the natural supply of camphor

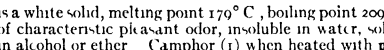
The old method of extracting camphor involved chopping down the tree and cutting it up into small chips which were distilled by primitive means The crude product thus obtained was redistilled to remove the oil of camphor present and the crystalline camphor obtained At present such crude and destructive processes of manufacture are prohibited by the Japanese, and steps are being taken to plant trees to ensure an adequate future supply

Camphor

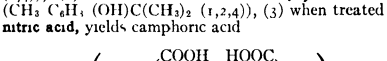


is a white solid, melting point 179° C , boiling point 209° C , of characteristic pleasant odor, insoluble in water, soluble in alcohol or ether Camphor (1) when heated with **phosphorus** pentoxide, yields cymene ($CH_3\,C_6H_4\,C(CH_3)_2$ (1,4)), (2) when heated with **iodine**, yields carvacrol ($CH_3\,C_6H_3\,(OH)C(CH_3)_2$ (1,2,4)), (3) when treated with **nitric acid**, yields camphoric acid

and then, by further oxidation, camphoronic acid



(4), when treated with **hydroxylamine**, yields camphoroxime ($C_9H_{16}\,C{=}NOH$), solid, melting point 120° C , (5) when treated with **nitrous acid** (amyl nitrite plus sodium alcoholate), yields isonitrosocamphor



solid, melting point 153° C Camphor may be made synthetically by converting pinene into bornyl chloride with hydrogen chloride, thence to isobornyl acetate, thence to isoborneol, and finally oxidizing borneol to camphor

Camphor is detected by formation of the **oxime** and determination of its melting point Camphor is used (1) in medicine as a heart stimulant and for other purposes, (2) in celluloid and lacquers, (3) in insecticides and moth preventives Camphorated oil is a solution of camphor in cotton-seed oil See **Aldehydes, Ketones, and Related Compounds.** (R K S, R M W)

CAMPTONITE. A dark **basaltic dike** rock of the essential mineralogical composition of a **diorite**, requiring, however, microscopical examination for proper identification It was named from the type locality, Campton, New Hampshire (E S C S)

CANADA BALSAM. A slightly yellow, transparent, fluid **resin** procured from a North American species of silver fir tree Used for mounting thin sections of rocks, and of tissues of plants and animals for microscopic examination, between glass slides, and for cementing glass in optical instruments The **refractive index** of Canada balsam after it has been heated varies between 1 534 and 1 540, according to A Johannsen (R M F)

CANADIAN. For the geological significance of this term, see **Ordovician.**

CANAL. In zoology, a canal is a tubular structure or passage, with specific applications in many groups of animals among which are the following 1 The passages in the wall of a **sponge.** 2 Slender diverticula of the enteric cavity in **coelenterates** and **ctenophores.** 3 The stone canal, ring canal, and other parts of the water vascular system in **echinoderms.** 4 The inguinal canal through which the testis descends from the abdomen into the scrotum in **mammals.**

In engineering, a canal is an artificial channel conveying or holding water There are canals built primarily for navigation, and canals whose purpose is to convey water from one point to another Examples of the former type are to be found in some of the famous ship canals of the world, and examples of the latter type in hydraulic power canals and irrigation canals

Navigable canals may be classified according to the relative levels of the two bodies of water which they connect The Suez Canal is a simple channel connecting the Mediterranean and the Red Sea at practically the same level The New Orleans Industrial Canal connects a higher and a lower body of water by a simple gradient, but the Panama Canal crosses a continental divide, making the middle some 85 feet above the ends which have about the same elevation A canal such as the Sault Ste Marie follows a river valley and by-passes the portions of the river which cannot be navigated The Barge canal is a hybrid type composed partly of artificial canal and partly of canalized river

Where the profile of a navigable canal is on a gradient, locks must be employed to divide the waterway up into a number of adjacent steps The lock is a short section of the waterway just large enough to accommodate the longest boat By means of gates the lock section may be shut off from both adjoining sections of the canal Valves control the inlet of water to the lock, the operation of which is as follows A boat proceeding upstream in the canal approaches a lock The water level in the lock is the same as that in the section containing the boat, so the gates between the boat and the lock are opened, permitting the boat to enter the lock at the lower water level The gates are then closed, and water is admitted from the higher level As the water rises in the lock it carries the boat with it When the water level in the lock equals that in the adjacent canal section, the gates are opened on that end, and the boat is then free to proceed along the canal at the higher level

Canals built for the purpose of transporting water from one point to another must, for economy, convey the water as rapidly as possible, but not with a velocity great enough to cause erosion While navigable canals are usually simply excavated in earth and rock, and have little or no water movement within them, water conveying canals may be eroded if the water exceeds a certain critical velocity On the other hand, if the water flows too slowly, in some cases there may be a silting up of the canal by earth material released from suspension There is a critical velocity, however, at which neither silting nor erosion will occur Many canals having a flow of water are lined with concrete or rock The rate of flow of water in a canal depends upon the cross-section of the canal, the character of the wetted surface, and the gradient of the bottom The friction loss in a canal or natural channel is equal to the fall of the surface level of the stream, provided the velocity remains constant The velocity of water can be found by a number of empirical formulae Probably the most widely accepted of these is the Kutter-Chezy formula,

$$v = C\sqrt{RS}$$

v is the mean velocity, feet per second, S is the slope, fractional fall per foot of length, C is a coefficient in-

volving the channel roughness and the hydraulic radius, as well as the slope, R is the hydraulic radius of the cross-section of the canal, and is equal to the cross-sectional area of flow divided by the wetted perimeter A canal cross-section in the shape of a semicircle is ideal from the standpoint of minimum friction, and concrete lined canals are often so built However, canals excavated in earth or rock are ordinarily trapezoidal in shape, and velocities of from one to four feet per second are employed, depending upon the nature of the soil (F T M)

CANAL RAYS. This term is a bad translation of the German *Kanalstrahlen* A more accurate designation would be "tunnel rays" or "perforation rays" They consist of positive particles in a vacuum tube which escape through tunnels or holes bored in the cathode Positive ions originating in the gas near the cathode move toward it with great speed, ordinarily striking it and causing the surface disintegration and **sputtering** of the metal soon observable, also doubtless releasing **cathode-ray** electrons But if the cathode is perforated with holes so placed that the positive rays can enter them, some of the particles pass through into the space behind the cathode In especially constructed canal-ray tubes, this space is elongated so that the positive rays, now isolated from the cathode rays, can be studied separately (L D W)

CANANGA OIL. Volatile oils.

CANARY. Aves, Passeriformes A **finch,** *Serinus canarius,* native to the Canary Islands, which has been extensively used as a cage bird The wild species is brownish with yellow markings but in captivity pure yellow strains have been developed

The goldfinch of North America and to a lesser extent the yellow warbler are called wild canaries from their similar yellow color (A W L)

CANCER. This is the name of a constellation and a disease These topics will be discussed in that order

Cancer (The crab) (Map, page 306) is a small and poorly marked **constellation** of faint stars that is of importance principally because it is the fourth sign of the **zodiac.** In this constellation is to be found the fine **cluster** as Praesepe (or the Beehive) The stars are not so numerous as in some other star clusters, but are of sufficient brightness to make this an interesting object in a small telescope Galileo counted 36 stars with his telescope but observers using modern equipment have counted over 300 On a clear moonless night the object appears as a faint glow of light, and is frequently used by astronomers as a test of the transparency of the **atmosphere.**

Cancer, the disease, is a term, which in its broad sense, includes every type of malignant **tumor,** regardless of its origin, or in what part of the body it originates

Hippocrates, in the fifth century B C, probably first used the Greek word crab to describe a spreading cancerous growth From the Romans the word cancer comes meaning crab

Cancer is one of the most ancient of diseases and its occurrence appears in the earliest records of man Cancer is the most universal and common of all diseases and not only attacks man but all forms of life, including plant life where growths of a similar nature are found

No age group is exempt New born babies have been known to have it The majority of cases, however, occur in the age group between forty and fifty

The total deaths from cancer in the United States have been estimated to be around 150,000 annually (one out of every eight deaths)—a rate of 125 per hundred thousand No accurate figures can be given as only about one percent of those dying in this country are autopsied and many die from unrecognized cancer, the deaths being attributed to terminal disease such as pneumonia and various circulatory diseases

In 1900 cancer rated sixth as a cause of death This increase to second and almost first place is accounted probably by (1) more accurate diagnosis of cancer as a cause of death and increase in the average life expectancy In other words, more people live longer than previously so that they reach an age when cancer is more likely to develop

Cancer begins as a single body cell or group of cells which suddenly start to multiply without restraint, growing independently of the rest of the body, not serving any useful purpose, invading the surrounding tissues or organs by direct spread or spreading throughout the body by means of **metastasis** (small groups of cells breaking off from the primary growth and being carried by the blood or lymph channels to far distant tissues where they in turn produce growths similar to the original or primary tumor) It is this characteristic of spread or metastasis that distinguishes a malignant from a benign tumor Benign tumors are usually harmless and resemble malignant tumors in that they represent growth without restraint and do not usefully serve the body They differ from malignant tumors in that (1) They do not metastasize or invade tissue, (2) They usually (but not always) grow slowly, (3) They only interfere with function through pressure, obstruction of surrounding structures and usually only threaten life when they compress through increase in size some vital structure This is especially true when they grow in a confined or closed space (A benign tumor of the brain unless removed or destroyed, will cause death simply from pressure on surrounding brain tissue)

With some tumors it is easy to distinguish between benign and malignant tumors Other tumors may be borderline between the two classifications and in a few cases may even be difficult for an expert to distinguish between the two In this borderline group an accurate diagnosis cannot be made by physical examination of the patient or any other method except surgical **biopsy** and microscopic examination of the tissue removed

In spite of observations and theorizing for the past two thousand years the cause of cancer is still unknown The Greeks and Romans attributed cancer to a disturbance of the humoral balance of the body, and to-day various theories are similar, in that they presuppose alterations in the secretions of the endocrine glands as a partial cause for the abnormal cell growth Modern research has demonstrated that chemical irritation and the irritation of chronic inflammation often is a starting point for at least some malignant tumors

One theory of long standing is that of Cohenheim, assuming that tumors start from misplaced embryonic **cells** which may remain dormant for years With some stimulus that is unknown, these **embryonic** cells start their unrestrained growth and become a malignant tumor Such embryonal displacement of cells is not uncommon and may well account for the start of some tumors A serious objection to this hypothesis is the fact that tumor formation can be caused in almost any portion of the body by chronic irritation

Another theory assumes that cancer is due to the action of some unknown parasite, a **virus** which causes irritation of tissues or invades the cell and causes it to proliferate abnormally It is true that in experimental animals certain tumor forms have been produced by a parasite and a filterable virus

The most recent theory, that of Gye, is that an ultramicroscopic virus plus some unknown factor combining with it, is necessary to produce tumor growth This is an ingenious theory and one that has not been proved or disproved

It is impossible to deny that some infectious agent is responsible for cancer If this is so and it well may be, it must be of a type of infectious agent that is unknown at the present time Certainly it is well established that cancer is not contagious.

The occurrence of cancer in man seems to be influenced by hereditary factors in some instances. Cancer

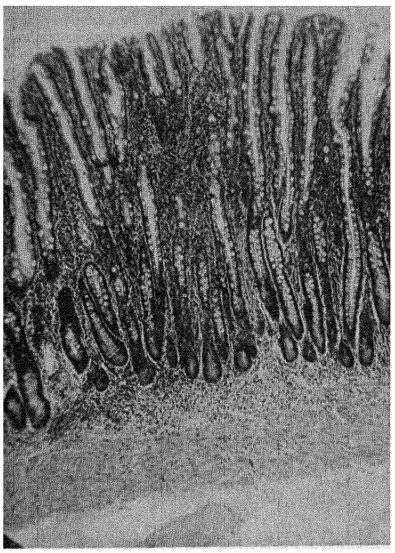


Figure 1. Photomicrograph of normal stomach wall magnified eighty times. The portion at the top represents stomach cavity. The strand-like processes projecting upward represent the glands and their ducts which secrete the gastric juice. The lighter area below the glands is the muscular wall of the stomach. (Courtesy of *Fortune Magazine.*)

is not directly inherited but there are families which show a high susceptibility to cancer. Considerable work has been done on inheritance of cancer in mice by Maud Slye.

The relationship between injury and the occurrence of cancer is usually based on faulty or superficial observation or accidental coincidence. A single injury practically never causes cancer formation but it will in some instances cause a tumor either to increase or decrease its rate of growth.

In a very small proportion of malignant tumors there has occurred spontaneous disappearance of malignant growths. This has been estimated to occur not oftener than one in 100,000 cases. Many such cases have recurred after five years or so.

Most of these spontaneous cures have followed partial surgical removal, infection about the tumor, some acute infectious systemic disease accompanied by high fever, and interference of the blood supply of the tumor.

Tumors are classified according to cellular structure, the tumor being named according to the tissue from which it originates.

The classification is difficult and too complex to be given in full detail here. A simple classification for the more common tumors is given below.

I. Connective Tissue Tumors

A. Benign Tumors
   (a) Fibroma—composed of fibrous tissue.
   (b) Chondroma—composed of cartilaginous tissue.
   (c) Osteoma—composed of osseous or bone tissue.
   (d) Lipoma—composed of fatty tissue.

B. Malignant Tumors
   Sarcoma. One of the large groups of tumors composed of any one of the varieties of connective tissue.

II. Muscle Tissue Tumors

A. Benign Myoma—composed of smooth muscle tissue.

III. Epithelial Tumors

A. Benign
   (a) Papilloma—made up of surface epithelium.
   (b) Adenoma—made up of glandular epithelium.

B. Malignant
   (a) Epithelioma—composed of flat, scale-like epithelial cells.
   (b) Carcinoma—a large group of malignant tumors composed of glandular epithelial cells.

IV. Endothelial Tumors

Composed of cells that line blood vessels, lymph vessels, joints, lymphatic cavities and other closed cavities of the body.

A. Benign
   (a) Hemangioma—a tumor made up of blood vessels.
   (b) Lymphangioma—a tumor made up of lymph vessels.

V. Pigmental Tumors

A. Benign
   Pigmental moles (may become malignant from chronic irritation).

B. Malignant
   Melanoma. A tumor derived from pigmental moles or cells that have developed malignant characteristics.

The onset of cancer is insidious and the growth may be quite large before any symptoms are noticed by the patient. Pain is seldom noticed in cancer unless the growth is well advanced, causing pressure on nearby structures or when metastases have developed.

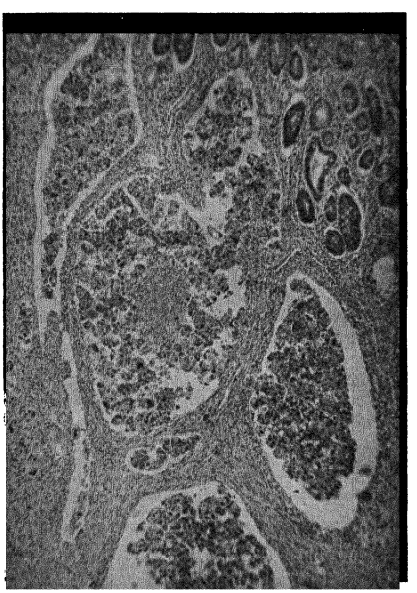


Figure 2. Section through a cancerous tumor of the stomach, magnified one hundred times. Remnants of normal gland tissue similar to Figure 1 may be seen in upper right hand corner. The remainder of the illustration shows nests of cancer cells invading the muscular layer of the stomach wall. (Courtesy of *Fortune Magazine*).

The first sign of cancer on the body surface or in the breast, tongue, or lip is a lump or slight thickening of the tissue

Internal cancer is particularly difficult of early diagnosis Pain is an extremely late symptom In intestinal, stomach, or rectal cancer the first symptom may be persistent indigestion or abdominal distress which is treated by the patient by frequent doses of soda and other alkalies until it is too late to do anything Lack of appetite and disturbances of taste may be other signs

Cancer in other parts of the body may be first marked by unusual discharges or slight bleeding Sores or ulcers that refuse to heal may have undergone malignant change Bleeding from the nipple or the rectum or unusual discharge of bleeding from the female genital organs are suggestive of cancer as well as other diseased conditions Diagnosis can be made by a competent physician or surgeon Cancer of the rectum is often treated as hemorrhoids or constipation—X-ray and proctoscopic examination can easily prove the absence or presence of cancer Cancer of the bone may cause vague aching pain early, and is often treated as "rheumatism" X-ray is of utmost value in diagnosis of bone cancer

Diagnosis of cancer requires a complete physical examination and depending on the location of the cancer, X-ray or other special diagnostic procedures When a positive diagnosis cannot be made, as is sometimes the case, it is necessary to do a **biopsy**. By this means an exceedingly small piece of tissue is removed, cut and stained and then examined under the microscope by an expert pathologist

The earlier cancer is found, the more difficult it is to recognize When diagnosis is easy the disease often is far advanced

Often the doctor is at fault, through not noticing salient points in the history of a case, not doing a thorough examination or making use of special examinations But more often it is the patient who is at fault, either through ignorance, fear, or use of home remedies or remedies advertised for constipation, piles, indigestion, etc

Treatment of cancer involves surgery, radium or X-ray or a combination of surgery and radiation Different forms and location of cancer may require one or the other or both

Cancer of the skin, the **cervix** of the uterus is often best treated by radium Palliative treatment of certain foci of inoperable cancer is done by use of X-ray or radium

In general cancer of the breast, stomach, intestine, uterus, prostate, kidneys, brain and most internal forms of cancer are best treated by surgery Radiation by X-ray or radium in some cases is used before operation and after operation Cancer is curable but only when it exists as a primary localized growth When it has begun to spread over the body death usually results.

In certain forms of cancer electro-surgery is used making use of the endotherm knife (radio knife) for coagulation and removal of tumors It is particularly used in less accessible growths as in the larynx, brain, chest, and bladder (W K G, R S M)

CANCRINITE. The mineral cancrinite is a complex orthosilicate (see **Silicon**) corresponding approximately to the formula $3H_2O\ 4Na_2O\ CaO\ 4Al_2O_3\ 9SiO_2\ 2CO_2$ It is **hexagonal**, with prismatic cleavage, hardness, 5–6, specific gravity, 2 42–2 50, color, white to gray or may be greenish, bluish, yellow, or flesh red, colorless streak, luster, subvitreous to greasy, transparent to translucent Cancrinite is found only in the **nephelite-syenites** and related rock types and commonly associated with **sodalite.** Cancrinite is believed to be in part primary, having crystallized direct from the **magma,** and in part secondary as a result of alteration of nephelite by solutions of calcium carbonate Cancrinite is found in the Ilmen Mts of Russia, in Rumania, in Norway and in Canada in Hastings County, Ontario, and in the United States in Kennebec County This mineral was named for Count Georg Cancrin, a Russian statesman who died in 1845 (E S C S)

CANDLEFISH. Pisces, Teleostei An oily **fish,** *Thaleichthys pacificus,* belonging to the **smelt** family It is found from Oregon to Alaska and ascends the coastal streams It is an important food fish and takes its name from the fact that it can be burned as a candle when dried (A W L)

CANDLE-FLY. A southern name for **moth,** equivalent to the northern miller or moth-miller (A W L)

CANDLE POWER. Chief among the problems of **photometry** has been the development of a suitable standard of luminous intensity In the earlier stages of the science it was sufficient to rate a lamp as equivalent to so many ordinary candles Later it became necessary, in the interest of accuracy, to agree upon specifications for the English standard candle, as to its composition, wick structure, rate of burning, etc At best such a standard could be only approximately uniform The pentane lamp (approximately one candle power), the French Carcel lamp, burning colza oil, and the German Hefner lamp, burning amyl acetate, as well as standardized gas flames, were subject in less degree to the same limitations

The present standard United States candle is based upon and defined in terms of the mean horizontal luminous intensity of a set of forty-five carbon-filament incandescent lamps at the Bureau of Standards When operated at definite, constant voltage (an essential condition), such lamps give a very steady output The international candle, adopted by Great Britain, France, and the United States in 1909 and by the International Commission on Illumination in 1921, is practically identical with the Bureau of Standards candle (L D W)

CANE CUTTER Cottontail.

CANE-RAT. Mammalia, Rodentia An African burrowing species more closely related to the **porcupines** than to the true rats (A W L)

CANGA A Brazilian term for an iron-rich conglomerate or breccia in which the pebbles or **anguclasts** are **hematite** and itaberite cemented by hematite or **limonite.** (R M F)

CANINE 1 Pertaining to dogs 2 An elongate conical tooth between the incisors and premolars of each half-jaw The eye-teeth of man in the vernacular. (A W I)

CANIS MAJOR. (The great dog) (Map, page 306) Both this **constellation** and its companion Canis Minor, or the little dog, have been named from remote antiquity as the dogs of **Orion Sirius** in Canis Major and **Procyon** in Canis Minor are both well known stars, Sirius being the brightest observable in the northern sky Reference to these stars are to be found in nearly all ancient classical literature Sirius, in particular, was of great importance to the Egyptians because it rose with the sun at the period when the waters of the Nile were due to rise and was considered as a herald of the returning fertility of the valley Sirius is not only the brightest, but also the closest star visible to the naked eye which can be observed in the **latitudes** of Europe or North America Intrinsically Sirius has a brightness more than 20 times that of our sun Both Sirius and Procyon have faint companions, that of Sirius being particularly famous as the first of the **white dwarfs** discovered (W K G)

CANKER-WORM Insecta, Lepidoptera **Insects** of two chief species, the spring canker-worm, *Paleacrita vernata,* and fall canker-worm, *Alsophila pometaria,* respectively, which attack apple trees and are sometimes

important pests The spring canker-worm is found throughout the United States and the fall canker-worm in the northeastern quarter of the country

The caterpillars eat leaves and so can be destroyed by spraying with arsenate of lead Since the females are wingless, bands of tanglefoot around the tree trunks prevent their ascending the trees to deposit their eggs

Canker-worms of three other species occur in North America (A W L)

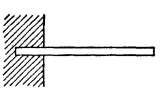
CANNABIS INDICA. A variety of common **hemp** from which is procured the so-called hashish and marijuana, etc—habit-forming narcotic **drugs** They are not commonly used in medical practice (R S M)

CANNEL COAL. A form of bituminous or soft **coal** which ignites easily and burns with a hot "candle-like" flame, due to its high percentage of volatile matter Especially desirable for open fires and metallurgical processes Most cannel coals owe their desirable peculiarities to their large content of paraffine-like fossil spore cases which are highly volatile The peculiar chemical and organic composition of this type of coal strongly suggests that it originated as a lake muck (sapropel) under open water rather than typical peat bog conditions (R M F)

CANTALOUP Gourd Family.

CANTHARIDES Spanish fly.

CANTILEVER BEAM A beam which is rigidly connected at one end to a fixed support and free to move at the other end is called a cantilever beam This theoretically fixed condition rarely occurs because of deformation of the supporting material The maximum **bending moment** and maximum **shear** occur simultaneously at the face of the support The usefulness of this type of beam is demonstrated in structures such as canopies, unbraced airplane wings and cantilever **retaining walls** (C W C)


Cantilever Beam

CANVAS-BACK Aves, Anseriformes A large North American **duck**, *Nyroca valisneria*, similar to the redhead but with a dusky crown and face Its flesh at the proper season is superior to that of other ducks (A W L)

CAPACITANCE Formerly called "electrical capacity," the capacitance of an electrically conducting body is the ratio of the quantity of electricity imparted to the body to the resulting change in its electric potential It is usually expressed in coulombs of charge per volt of potential change, that is, in terms of the **farad**, or its submultiples, the fundamental c g s electromagnetic unit being, however, the "abfarad" (See **Electrical and Magnetic Units**)

If a conductor is completely isolated, that is, far removed from other conductors, including the earth, and is surrounded by a homogeneous, perfectly insulating **dielectric**, its capacitance depends only upon the size and shape of its external surface and upon the **dielectric constant** of the surrounding medium For some bodies of definite goemetrical form, the capacitance may be calculated For example, the capacitance of an isolated sphere, in farads, is equal to $kr/(9 \times 10^{11})$, in which r is the radius in centimeters and k is the dielectric constant of the surrounding medium The capacitance of a conductor may be greatly increased by bringing it near to other conductors (in which case it forms part of a **condenser**)

Very long electric circuits, especially when the wire is surrounded by a conducting sheath, as an ocean cable, have considerable capacitance because of the condenser-like action of wire and sheath with the insulation between them acting as dielectric The same is true of insulated wire wound in a close coil, adjacent turns of which, being at slightly different potential, act as the conductors of a condenser, an effect which may be partially avoided by a criss-cross or "honeycomb" winding or by a "banked" winding (in flat spirals) The capacitance of a circuit, whether thus "distributed" or intentionally introduced by means of condensers, may have marked effect upon alternating or variable currents traversing it See **Electric Circuits** and **Alternating Currents** (L D W)

CAPACITIVE LOAD. An **alternating current circuit** in which the current drawn has a slight lead over the voltage is said to provide a capacitive load Capacitive loading may be the result of actual **condensers**, or of virtual condensers in the form of long overhead transmission lines, or over-excited synchronous rotating equipment Most electrical apparatus, such as motors, heaters, coils, etc, draws from the line a current which lags the voltage, and the use of some capacitive load is desirable in order to bring the current and voltage more nearly in phase, and thus raise the **power factor.** (F T M)

CAPE POLECAT. Mammalia, Carnivora A South African animal resembling the **skunks** and apparently intermediate between them and the true **polecats.** Like these relatives they have a foul odor (A W L,)

CAPELLA. Capella (**α Aurigae**) is the third brightest star visible in the northern latitudes, and the fifth brightest star on the celestial sphere It is closer to the pole than any of the other bright stars and July is the only month in which it cannot be observed from the latitude of New York Capella has always played an important part in mythological writings and we find it referred to on an old tablet dating back to 2000 B C **Astrologically,** Capella portended civic and military honors and wealth

Astronomically, Capella is particularly interesting for it is a star which is a **spectroscopic binary** with a period of 104 days, and the angular distance between the components has been measured with the interferometer From the complete solution of the **orbit,** the physical characteristics of the object may be found It is a **giant** star of the same **spectral class** as our sun (W K G)

CAPERCAILLIE. Aves, Galliformes A large woodland **grouse** of northern and central Europe and Asia The species is also known as the capercally, capercailzie, wood-grouse and cock-of-the-wood *Tetrao urogallus* (A W L)

CAPILLARITY The name given to a class of phenomena, of which the elevating or depression of liquids in fine tubes is representative When the inter-

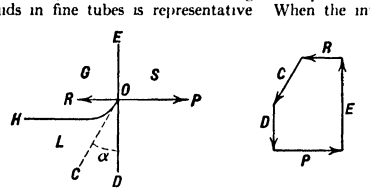


Figure 1 Capillary force, large adhesion

face between a liquid and a gas, or between two liquids, is intercepted by a solid surface, an equilibrium is established at the junction among the forces acting along the three surfaces of contact For example, let a plate of solid S be dipped into a liquid L having gas G above it (see Figs 1 and 2) A molecule at the junction O is acted upon by the adhesive attraction OP, by the forces which give rise to the three **surface tensions** along the interfaces OH, OE, and OD, and

by the reaction *OR* of the plate *S* against which it is drawn by the adhesion (Its weight may be considered negligible) The flexible interface *OH* adjusts itself

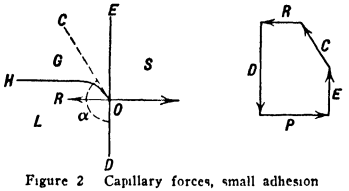


Figure 2 Capillary forces, small adhesion

so that these forces come into equilibrium, unless, indeed, one of them, *OE*, exceeds the resultant of the others, in which case the liquid "creeps" indefinitely along the surface as oil does over a glass or tin container The equilibrium polygon at the right is labeled in each case to correspond with the figure representing the surfaces The "angle of contact" α, between the liquid surface at *O* and the solid surface *OD*, is determined by the aforesaid forces acting at *O* For most liquids against glass it is acute, for mercury against glass it is obtuse In special cases it may be 90°, and in others it reduces to zero, *ED* being asymptotic to *OH*

If the interface between two media *A* and *B* (Fig 3) is curved, *A* being on the concave side, the pressure in *A* is greater than in *B* on account of the surface tension, much as the pressure inside a rubber balloon is greater than outside We can now understand why water rises in a capillary tube For, to secure equilibrium, the liquid must rise until the pressure inside the surface at *B*, plus the pressure due to gravity at depth *h*, makes the pressure at *L* equal to that at the surface level outside, that is, to the atmospheric pressure Similar reasoning applies to the depression of mercury in a glass tube See also **Electrocapillarity** (L D W)

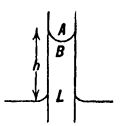


Figure 3 Rise of liquid in capillary tube

CAPILLARY. 1 Hair-like, especially in application to fine tubes 2 A minute blood vessel intervening between the arteries and veins See **Circulatory system.** (A W L)

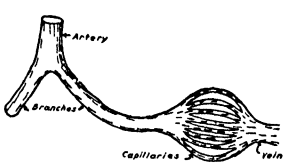


Diagram to illustrate variations in velocity of bloodflow If a vessel divides into two branches, these will be individually of less cross section than the main trunk, but united they will exceed it Linear velocity will be lower in the branches than in the parent stock The sum of the cross sectional areas of the capillaries is greater than that of the artery or vein (From Kimber and Gray, *Textbook of Anatomy and Physiology*, Macmillan & Co)

CAPILLARY ELECTROMETER. Electrocapillarity.

CAPILLARY FRINGE Above the zone of saturation, capillary pores may exist which, if filled with water, form a zone or fringe of moisture higher than the true **water table.** This is the capillary fringe or zone of capillarity (E S C S)

CAPITULUM 1 A protuberance on mites and ticks which appears to be a small head but is formed only of the mouth parts 2. Any small head, or small, bony, articular eminence, such as the capitulum of a rib. (A W L)

CAPRICORNUS. (The sea-goat) (Map, page 306) This is a **constellation** of small stars, not at all striking in appearance, but important because it is the tenth of the **zodiac** The star Alpha (named Giedi) is one of the more remarkable stars, it being actually made up of six components The two larger can be seen by some keen-eyed persons as separate, but it is easily resolved by means of an opera glass Each of these two components may be still further resolved into three component parts (W K G)

CAPRIMULGIFORMES. An order of nocturnal birds (**Aves**) with very wide mouths The **nightjars,** including the **whip-poor-will** and **nighthawk,** the **goat-suckers,** and the **oil birds** (A W L)

CAPSAICIN. Potato Family.

CAPSTAN. A capstan is a machine, usually rotary, used chiefly in connection with shipping for hoisting heavy weights Although formerly turned by hand with a capstan bar, the capstan is now frequently operated by a steam engine or electric motor The capstan may have a reduction gear so that it can be operated at two different speeds, and thus be suited to the loads to be hoisted (F T M)

CAPSULE Fruit.

CAPTACULA. Filaments with suckers at the tips, found on the dorsal surface of the head in the tooth-shells, marine **molluscs** of the class Scaphopoda (A W L)

CAPUCHIN MONKEY. Mammalia, Primates Any of several species of South American **monkeys** of the genus *Cebus*, which are characterized by the moderately long prehensile tail They differ from the other species with prehensile tails in having this organ fully covered with hair and not bare on the lower surface near the tip Also called sapajous (A W L)

CAPYBARA Mammalia, Rodentia A large South American species, *Hydrochoerus capybara,* of the **cavy** family These animals attain a length of four feet and a weight of almost one hundred pounds They are semi-aquatic in habits and while their food usually consists of water plants and other vegetation they sometimes make inroads on cultivated crops They are also called capivara and carpincho (A W L)

CARABAO. Buffalo.

CARACAL. Mammalia, Carnivora A member of the **cat** family found in India and thence into Africa where it is widely distributed It is related to the **lynxes** and like them is marked by tufted ears Sometimes known as the Persian lynx *Lynx caracal* (A W L)

CARACARA. Aves Falconiformes South American birds (**Aves**) of several species related to the **hawks** They eat carrion but also catch living prey and sometimes rob other birds of their prey One species, Audobon's caracara, *Polyborus cheriway,* occurs in the extreme southern parts of the United States (A W L)

CARACUL. Karakul

CARAPACE. A shield-like covering of the upper part of the body In the crustaceans it is the body wall of the thorax and in the **turtles** and **tortoises** it is a complex structure made up of bony plates, including flattened ribs and vertebrae, covered with thin horny plates The armor of the **armadillo,** composed of many bony plates developed from the skin and covered with horny plates, is also called a carapace (A W L)

CARAPATO. Arachnida, Acarina **Ticks** of two species, found in tropical Africa and Central America, respectively The African species is also called the tampan

The wounds produced by these creatures are severe in themselves but their transmission of the germs of **relapsing fever** is a much greater danger. (A.W L.)

CARAWAY Carrot Family.

CARAWILA. Halys, pit viper.

CARBAMIC ACID. Amines and Amides.

CARBAZOLE. See Pyrrole and Related Compounds.

CARBIDES. Carbon.

CARBINOLS. Alcohols.

CARBOHYDRATES. Carbohydrates are polyhydroxy **aldehydes** or **ketones**, or those products which are chemically related to such simple units by combination of two or more of these units through the loss of water These higher units are thus **anhydrides.** They yield the simple units, referred to above, by treatment with acids, such as **hydrochloric** or **sulfuric**, or particular **enzymes.**

Carbohydrates respond to the alpha-naphthol test as given under glucose, reaction number (12) below, when heated (1) in air, carbohydrates burn to form **carbon dioxide** plus water, evolving heat, (2) in the absence of air, combustible gases, watery and tarry distillates, and charcoal residue

Carbohydrates may be classified as follows

Monosaccharides (sugars)

Crystalline solids, insoluble in water, sweet taste Those that occur in nature are fermentable by certain enzymes

Tetrose $C_4H_8O_4$

1 Erythrose

Pentoses $C_5H_{10}O_5$

2 Arabinose
By boiling gum arabic, cherry gum, corn pith, elder pith with dilute sulfuric acid

3 Xylose
By boiling substances mentioned under arabinose above

4 Ribose

5 Lyxose

Hexoses $C_6H_{12}O_6$

Aldohexoses

6 Glucose, dextrose ("grape sugar"), melting point 146° C (anhydrous) With the **enzyme** zymase (of yeast) yields ethyl **alcohol** plus **carbon dioxide.** Specific rotatory power—see glucose below.

7 Galactose
Specific rotatory power + 83 9°

8 Mannose
Specific rotatory power + 14 1°

9 Gulose

10 Idose

11 Talose

12 Altrose

13 Allose

Ketohexoses

14 Fructose, laevulose ("fruit sugar"), melting point 95° C Specific rotatory power −88 5°

15 Sorbose

16 Tagatose

Disaccharides (sugars) $C_{12}H_{22}O_{11}$

Crystalline solids, soluble in water, sweet taste.

17 Sucrose ("cane sugar," "beet sugar"), melting point 170–186° C (decomposes) With the enzyme invertase, yields glucose plus fructose Specific rotatory power + 66.4°

18. Lactose ("milk sugar"), melting point 202° C (anhydrous) With the enzyme lactase yields glucose plus galactose Specific rotatory power + 52 4°

19. Maltose ("malt sugar"), melting point of $C_{12}H_{22}O_{11}H_2O$ 100° C With the enzyme maltase yields glucose plus glucose Specific rotatory power + 138 5°

20 Melibiose
With enzymes or dilute acid yields glucose plus galactose

21 Cellobiose
With the enzymes maltase, or cellase, yields glucose plus glucose

22 Trehalose

Trisaccharide $C_{18}H_{32}O_{16}$

Crystalline solid, soluble in water, tasteless

23 Raffinose, melitose, melting point 118° C (anhydrous) With the enzyme invertase, yields fructose plus melibiose With the enzyme emulsin, yields sucrose plus galactose

Polysaccharides (non-sugars) $(C_6H_{10}O_5)_n$

Non-crystalline solids, insoluble in water, tasteless

24. Starches
With the enzyme diastase yield maltose

25 Celluloses
With hydrochloric acid, heated, yields glucose
With acetic anhydride plus concentrated sulfuric acid, yield cellobiose

26. Dextrin
With the enzyme diatase yields maltose
With the enzyme maltase or with acids yields glucose

27 Inulin, melting point 178° C (decom) $(C_6H_{10}O_5)_n$
With the enzyme inulase (but not with diastase) yields fructose

28. Glycogen, melting point 240° C
With the enzyme diastase (or ptyalin), yields glucose plus maltose

29. Pentosans

Glucose may be called the key carbohydrate, since it is the leading member of the aldohexose group, and is formed as one of the products or the only product when the following carbohydrates are hydrolyzed, sucrose, lactose, maltose, cellulose, glycogen Glucose is a colorless solid, $(C_6H_{12}O_6)$, less sweet than sucrose, soluble in water from which it may be crystallized $(C_6H_{12}O_6 H_2O)$, melting point 86° C, slightly soluble in alcohol from which it may be crystallized anhydrous of melting point 146° C Either of these crystalline forms, upon examination of the solution in the polariscope, shows a specific rotary power of +110° when the solution is freshly prepared, but the solution changes, gradually upon standing or rapidly upon heating, to a constant value of +52 5°, a phenomenon known as mutarotation Glucose reacts (1) with alkaline **cupric** salt solution (Fehling's solution) to form **cuprous** oxide, (2) with ammonio-silver salt solution (Tollen's solution) to form finely divided or mirror film of silver, (3) with **phenylhydrazine** in acetic acid, to form glucose phenylhydrazone $(CH_2OH(CHOH)_4CH\ NNHC_6H_5)$, white solid, melting point alpha 159–160° C, beta 140–141° C, with excess phenylhydrazine to form glucosazone $(CH_2OH(CHOH)_3C\ NNHC_6H_5\ CH\ NNHC_6H_5)$ yellow solid, melting point 205° C decom, (4) with acetic **anhydride,** to form glucose pentacetate $(C_6H_7(OOCCH_3)_5CHO)$, melting point alpha 112 to 113° C, beta 131 to 134° C, (5) with **sodium** amalgam, to form sorbitol $(CH_2OH(CHOH)_4CH_2OH)$, (6) with **hydriodic acid,** to form 2-iodo-normal-hexane $(CH_3(CH_2)_3CHICH_3)$, (7) with **sodium** hydroxide solution, to form yellowish-brown solutions upon warming, (8) with **calcium** hydroxide solution, to form calcium glucosate $(CH_2OH(CHOH)_4COCa(OH))$, slightly soluble solid from which glucose is recoverable by action of **carbon dioxide** (calcium carbonate formed simultaneously). **Strontium** hy-

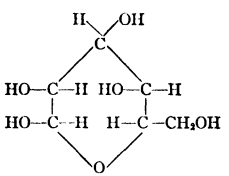
droxide and **barium** hydroxide react similarly. Any of these three reactions may be utilized to recover glucose, with the limitation that barium soluble compounds are poisonous, (9) with **hydroxylamine** hydrochloride, to form glucoseoxime ($CH_2OH(CHOH)_4CH\ NOH$), melting point 138° C, (10) with hydrocyanic acid, to form glucosecyanhydrin ($CH_2OH(CHOH)_4CHOHCN$), (11) by oxidation, to yield with **bromine** gluconic acid ($CH_2OH(CHOH)_4COOH$), and with **nitric acid** saccharic acid ($COOH(CHOH)_4COOH$), (12) with alpha-naphthol dissolved in chloroform and then forming a layer of concentrated sulfuric acid beneath the mixture, to form a red coloration at the junction of the two liquid layers (Molisch's test for carbohydrates) Upon standing, the color changes to purple (13) With methyl **alcohol** in the presence of **hydrogen chloride**, to form methyl glucoside (methyl ether of glucose)

$$(CH_2OH\ CH(CHOH)_3CH(OCH_3)),$$
$$\text{└——O——┘}$$

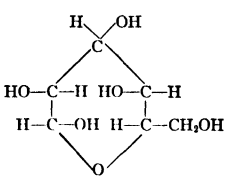
specific rotatory power, alpha $+158°$, beta $-34°$ Alpha and beta methyl glucoside (an ether) correspond to alpha and beta forms of glucose

$$(CH_2OH\ CH(CHOH)_3CH(OH)),$$
$$\text{└——O——┘}$$

specific rotatory power, alpha $+110°$, beta $+17.5°$ Alpha-glucose may be prepared by crystallization of glucose from acetic acid plus water solution at ordinary temperatures, and beta-glucose from glacial acetic acid at higher temperatures Ordinary glucose is chiefly the alpha form Haworth suggests the formulas.



Alpha-glucose



Beta-glucose

The following methylglucosides have been prepared and used in the study of the structure of glucose, namely, 2,3,4,6-tetramethylglucose or galactose

$$(CH_2OCH_3\cdot CH(CHOCH_3)_3CHOH),$$
$$\text{└——O——┘}$$

2,3,6-trimethylglucose

$$(CH_2OCH_3\cdot CH\ CHOH(CHOCH_3)_3CHOH),$$
$$\text{└————O————┘}$$

2,3,4-trimethylglucose

$$(CH_2OH\ CH(CHOCH_3)_3CHOH),$$
$$\text{└——O——┘}$$

1,3,4,6,-tetramethylfructose

$$(CH_2OCH_3\ CH(CHOCH_3)_2C(OH)\ CH_2OCH_3).$$
$$\text{└——O——┘}$$

Glucose possesses four asymmetric carbon atoms (2, 3, 4, 5), making possible 16 different stereoisomerides. These are represented by the two forms (dextro and laevo) of each of the 8 aldohexoses listed (all but two of the 16 have been prepared and identified) In structure these differ solely in the arrangement of the groups —H and —OH about the four asymmetric carbon atoms Similarly, the aldopentoses consist of 4 pairs, or 8 in all, stereoisomerides, namely, dextro- and laevo-arabinose and the pairs of each of the three sugars, which follow in the list

Glucose and fructose are present in sweet fruits, such as grapes and figs, and in honey These two are the only hexoses found in nature in the free state Glucose is normally present in human urine to the extent of about 0 1 per cent, but in the case of those suffering from **diabetes** glucose is secreted in large amount Glucose is formed, as previously mentioned, by the reaction of polysaccharides and water, the reaction with starch in the presence of very dilute hydrochloric acid serving as the industrial source (the hydrochloric acid acts as a catalyzer, and the small percentage present is later neutralized to form sodium chloride) The solution is evaporated to a syrup or to crystallization, and is used in the manufacture of sweets, and (usually) alcohol, and in foods The reaction of glucosides with water, by enzymes or acids, produces glucose as one of the products With **sodium** hydroxide, under carefully defined conditions, glucose forms **lactic acid** Glucose is used as food and for the production of alcohol of wines from fruit juices Glucose may be detected by formation of glucosazone, and determination of its melting point

Fructose is present with glucose in sweet fruits and honey, may be obtained free by reaction of inulin of dahlia tubers or artichokes with water, and with glucose by reaction of sucrose with water, the product being known as invert sugar Fructose differs from glucose in structure in being a pentahydroxy-2-ketone, $CH_2OH(CHOH)_3COCH_2OH$ instead of aldehyde The specific rotatory power of fructose is $-88.5°$ Fructose forms the same identical osazone as glucose, and the same alcohol (sorbitol plus mannitol) by reduction Fructose may be used as sugar by diabetic patients to advantage instead of glucose or sucrose Fructose is detected by the violet color its alkaline solution gives with meta dinitrobenzene

Sucrose is a colorless solid, when heated melts at 170° to 186° C, and on cooling forms barley sugar which gradually crystallizes, upon heating above the melting point forms caramel, a brown liquid, with decomposition Caramel is used in confectionery, and in coloring beverages and foods At higher temperatures decomposition into gaseous and tarry substances occurs, finally leaving a residue of carbon ("sugar charcoal") Other sugars behave similarly Sugars are also carbonized by concentrated sulfuric acid Sucrose is very soluble in water, and is obtained from solution by crystallization, usually by vacuum evaporation The solution has a specific rotatory power of $+66.4°$, does not exhibit mutarotation, but is converted by acids or invertase into invert sugar (glucose plus fructose), specific rotatory power $-19.7°$ Sucrose forms with calcium hydroxide calcium sucrosate, a 1 per cent solution of sugar dissolves about 18 times as much calcium hydroxide as does pure water This behavior is utilized to recover sugar from solutions, as in the case of glucose, and also to determine free calcium oxide in burnt lime, due to the reactivity of calcium hydroxide and non-reactivity of calcium carbonate Sucrose is non-reactive with dilute sodium hydroxide, with phenylhydrazine, with ammonio-silver salt solution, but, when inverted to glucose plus fructose, these reactions may be obtained Sucrose forms with acetic anhydride sucrose octaacetate. The suggested structural formula is

$$CH_2OH\quad CH_2OH$$
$$CH_2OHCHOHCH(CHOH)_3CH—O—C\ (CHOH)_2CH$$
$$\text{└——O——┘}\qquad\qquad\text{└——O——┘}$$

Glucose residue Fructose residue

Sucrose is an important food preservative, food flavor, and a raw material for confectionery and for industrial alcohol

Sucrose is extensively distributed in the seeds and leaves of plants, and is the most abundant of the sugars The commercial sources of sucrose are the stems of sugar-cane (11 to 16% sucrose, average 13%), the root of the sugar beet (average 16% sucrose, selection having raised the sucrose content from 5% to a maximum of 20%), the sap of the sugar maple, and the stems of sorghum-cane Sucrose is pressed from the stems of sugar-cane or sorghum-cane, and extracted with the water from the sliced roots of sugar-beets The solutions are purified, evaporated and crystallized to such a degree that commercial sucrose is practically chemically pure (about 99 8% sucrose) The purity of sugar and the concentration or strength of sugar solutions is determined by the rotatory power of the solution, the special polariscope usually used being called a saccharimeter Sucrose is reduced with Fehling's solution only after inversion

The sugar content of some common fruits have been reported by Kulisch:

	Sucrose	Hexoses
Apple	1 0–5 4	7 0–13 0
Apricot	6 0	2 7
Banana, ripe	5 0	10 0
Pineapple	11 3	2 0
Strawberry	6 3	5 0

Lactose is obtained from the residual water solution ("whey") of milk after removal of fat and casein for butter and cheese Milk contains about 4 5% of lactose Lactose forms hard gritty crystals ("sand sugar") ($C_{12}H_{22}O_{11}$ H_2O), loses water at 140° C , melting point 202° C (anhydrous) with decomposition, is less sweet than sucrose, reduces ammonio-cupric salt solution, ammonio-silver salt solution, forms osazone, melting point 200° C , turns yellow when warmed with sodium hydroxide solution Lactose is the source of galactose, and undergoes, with the proper **enzymes**, fermentation into **lactic acid** and **butyric** acid

Maltose is found in soy bean, and is produced by the action of the enzyme diastase of germinated barley (malt) on starch at 50° C , and is thus an intermediate product in the transformation of starch into alcohol Maltose ($C_{12}H_{22}O_{11}$ H_2O), melting point 100° C , when rapidly heated, may be crystallized from the concentrated malt syrup after removal of proteins and insoluble material Maltose reduces ammonio-cupric salt solution, and forms osazone

Starch is a white powder, odorless and tasteless, insoluble in cold water, forming an emulsion ("starch paste") or gel with hot water, the consistency of which depends upon the ratio of starch to water used When boiled starch emulsion is cooled and treated with a solution of **iodine** in alcohol or **potassium** iodide, a blue coloration is produced, which is a sensitive and characteristic test The blue color is associated with the adsorption of iodine on the surface of the starch, and disappears in the presence of alkalis When boiled with dilute acid, starch is first changed into a soluble gummy mixture known as dextrin, and finally into glucose When starch, either alone or in the presence of a slight amount of nitric acid, is heated to 120° to 200° C , dextrin is formed, at higher temperatures starch behaves similarly to sucrose With concentrated nitric acid, starch forms esters, similar to cellulose nitrates By the action of the **enzyme** diastase, starch is converted into maltose, which with the enzyme maltase yields glucose Starch is non-reactive with ammonio-**cupric** salt solution, and with **phenylhydrazine** Starch is extensively distributed as granules in many plants Those that serve as important reserves of starch are the seeds of wheat, corn, barley, rye, rice, the tubers of potato, cassava (tapioca starch), the pith of the sago palm The form and size of the starch granules are characteristic of the plant in which it is found. When viewed in the microscope, the grains are seen to be cells made up of an inner nucleus, surrounded by concentric layers True starch or amylose is present in the interior of the starch cell, while pseudo-starch or amylopectin is contained in the walls of the cell The formation of starch paste is associated with the presence of the latter substance, which appears to contain a small proportion of combined phosphoric acid

Starch is obtained by coarsely crushing the raw material, e g , corn kernels or potatoes, the starch grains are washed free from cellulose and other materials by water The suspension of starch is allowed to settle and the water drawn off In the case of corn kernels, the oily germs float on the surface of the suspension and are separated for subsequent extraction of oil It has been suggested that starch consists of a number of glucose units attached to each other by oxygen linkages to the 3 6 carbons Starch is an important food material commonly consumed with the **proteins** of cereal grains, rice and potatoes Starch is a raw material for the brewing industry, for industrial alcohol, for dextrin, and is used in laundering textile goods as a stiffening agent and finish, in sizing paper, and as a thickening agent and adhesive

Cellulose is a white solid, odorless and tasteless, insoluble in cold or hot water, chemically non-reactive except when drastically treated Cellulose (1) when heated with water at 260° C under pressure, dissolves completely with decomposition, (2) when treated with concentrated **sulfuric acid** dissolves, the solution upon dilution and boiling yielding glucose, (3) when treated with **sodium** hydroxide (15% to 25% NaOH) the fibers swell up and upon washing and drying possess a lustrous appearance, (4) with **iodine** in **potassium** iodide solution plus **zinc** chloride (Schulze's solution) produces a dark blue color, (5) with 80% **sulfuric acid** and rapidly washed and dried yields parchment surface Simple cellulose is represented in nature by the cottonseed hair Compound celluloses are widely distributed in plants, the two principal types being

(a) Lignocelluloses, of woods, cereal straws, jute These cellulose materials yield lignin by treatment (1) with 43% **hydrochloric acid**, cold for 12 hours, (2) with 8% to 12% sodium hydroxide at 140° to 160° C for 6 to 10 hours, (3) with 72% sulfuric acid at ordinary temperature for 18 hours (the common method) Wood yields about 25% of lignin by the last treatment The composition of lignin is not known

(b) Pectocelluloses, of flax, hemp, ramie These cellulose materials yield pectic substances by treatment with oxalic acid or ammonium oxalate at 85° C for 24 hours, followed by carefully defined treatment with **alcohol, acetic acid** and **calcium** chloride Pectic substances are most abundant in leaves, e g , ivy, sycamore, and in apples or oranges, especially the white peel of the latter

Cellulose of cotton fiber is supplemented industrially by that made from wood of **coniferous** trees, e g , spruce, hemlock, into pulp, mainly for paper, by treatment (1) with **calcium** hydrogen sulfite plus sulfurous acid solution—the sulfite process—heated under pressure for several hours, (2) with **sodium** hydroxide solution—the soda process—under similar conditions, (3) with **sodium** sulfide plus **sodium** hydroxide solution—the sulfate process—under similar conditions Other industrial sources of cellulose are flax, hemp, ramie, jute, Manila hemp, cereal straw, used mainly for textiles, and cordage.

Cotton cellulose is an important textile fiber. Cotton and wood cellulose may be transformed into esters, three of which are of outstanding importance (1) Cellulose nitrates (See Figure 1), for explosives, plastics, photographic films, lacquers, collodion, rayon (made non-inflammable by denitrifying with ammonium sulfide solution), (2) cellulose acetate, for plastics, photographic films, rayon, lacquers, (3) cellulose xanthate, used in making synthetic textile fiber or translucent wrapping paper called viscose Viscose is made by impregnation of cellulose with sodium hydroxide (17 5% NaOH) solution, sodium cellulose ($C_6H_{10}O_5 \cdot 2NaOH$) approximately being formed (See Figure 2) Addition of **carbon disulfide** (one mol CS_2 to one mol $C_6H_{10}O_5$, ap-

proximately) results in the formation of yellow sodium xanthate (possibly $C_6H_9(ONa) \cdot O \cdot CS \cdot SNa$), which after ripening and purifying is exuded as

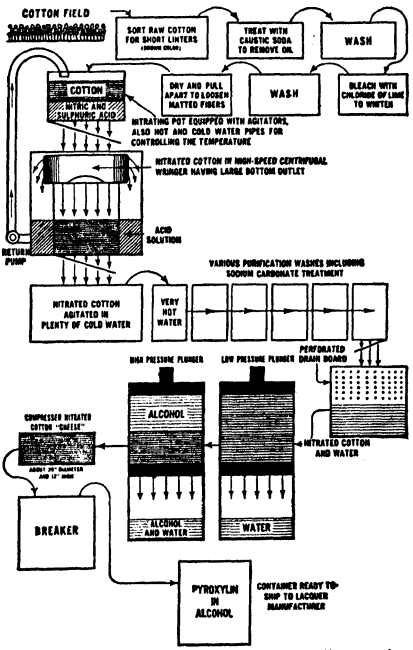


Figure 1. Flow sheet of nitrocellulose or pyroxlin manufacture from cotton and nitric-sulfuric acid mixture.

fibers or sheets into a bath consisting of dilute sulfuric acid plus sodium hydrogen sulfate plus sugar (many recipes for bath liquor are known) at 30° C. The precipitated material is desulfurized by treatment with very dilute **sodium** sulfide solution at 40° to 50° C., or by exposure to air leaving the fiber or sheet as translucent cellulose. Mixed with metallic dust and coloring matter, viscose is made into artificial leather.

Cellulose, when treated with ammonio-**cupric** hydroxide solution (Schweitzer's solution), dissolves, and, when the resulting solution is acidified, translucent flocculent cellulose is precipitated. By exuding the ammonio cupric cellulose solution through fine orifices into a bath of acid artificial fibers of cellulose are produced—cupra-ammonium process.

Ground wood pulp or paper turns yellow on exposure to sunlight, and with phloroglucinol dissolved in alcohol produces a red color. Lignin complexes of wood are destroyed by treatment with **chlorine** or **bromine** at ordinary temperatures, leaving cellulose residue. Wood powder ("sawdust") when heated at 220° C. with sodium hydroxide plus potassium hydroxide yields sodium potassium oxalate, from which oxalic acid may be obtained. Destructive distillation of wood yields gases, watery distillate—containing **acetic acid**, methyl **alcohol**, **acetone**, tar distillate, and charcoal residue.

Dextrin is a white to yellow solid, forming an adhesive with water, non-reactive with ammonio-cupric salt solution, reactive with iodine in alcohol or potassium iodide, usually forming red, brown, or blue color. Formed when starch is (1) heated to 120° to 200° C. either alone or in the presence of a slight amount of nitric acid. Dextrin is formed when bread is toasted and is present in well-baked bread crust, and on the surface of starched goods that have been ironed hot. Dextrin is used in adhesives.

Inulin is a white solid, soluble in warm water, specific rotatory power −40°, with iodine in alcohol or potassium iodide gives yellow color. Inulin is present in tubers of dahlia to the extent of about 10%. Inulin reacts

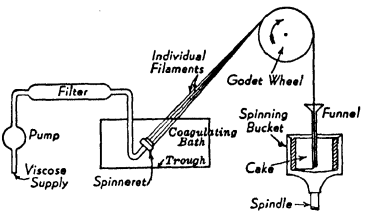


Figure 2. Diagram showing the formation of rayon filaments and thread. (Courtesy *duPont Rayon Co.*)

with water in the presence of the enzyme inulase or of acids to form fructose. The enzyme diastase does not produce this change.

Glycogen, or animal starch, is a white solid, soluble in water, specific rotatory power +197°, with iodine in alcohol or potassium iodide solution, forming brown color. Glycogen is found as reserve carbohydrates in the animal body, more particularly in the liver. Horseflesh, oysters and beef are sources of glycogen.

Pentosans are polysaccharides which may be considered as anhydrides of pentose sugars, after the manner of the hexosans, sucrose, starch, from glucose, fructose. When pentosans or pentoses are heated with hydrochloric or sulfuric acid, furfural ($C_4H_3O \cdot CHO$) is formed, and addition of aniline produces a red color. Pentosans are present in gummy carbohydrates, in bran of wheat seed, and in woods.

By means of the cyanhydrin reaction higher sugars of the heptose, octose and nonose types have been prepared. A monosaccharide such as an aldohexose may be converted into the next lower monosaccharide, such as an aldopentose, by oxidation to the acid, which corresponds to the aldohexose, then treating the calcium salt solution of this acid with a solution of ferric acetate plus hydrogen peroxide. Carbon dioxide is evolved and aldopentose formed. (R.K.S.)

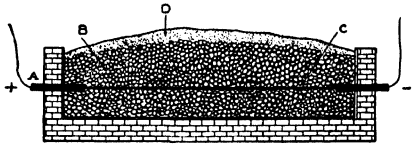
CARBON. Symbol: C. Atomic number: 6. Atomic weight: 12.010. Density: (1) Diamond, 3.52, (2) Graphite, 2.25, (3) Amorphous, 1.88. Hardness: (1) Diamond, 10, (2) Graphite, 0.5 to 1.0. Melting point: >3500° C. Boiling point: 4200° C.

The chemical element carbon is known in three forms, namely, (1) diamond, (2) graphite, (3) amorphous, such as charcoal, coke. When heated in excess air or **oxygen**, carbon burns to form carbon dioxide with the evolution of a definite amount of heat from each form. See **Chemical Composition, Allotropic Elements.** Discovery prehistoric. Isotopes: 12 (99.3%), 13 (0.7%). The uses of carbon are dependent upon the form and variety, diamonds for jewels and as abrasive, graphite in lubricants and as an electrical conductor, cocoanut charcoal for adsorbing gases at low temperature in an enclosed space to produce a high vacuum, activated carbon to absorb color from solutions and to remove odor from water, coke and wood charcoal as fuels.

Carbon occurs (1) Free, as **diamond** and graphite of local distribution, e.g., diamonds in South Africa, **graphite** in Ceylon, and (2) Combined, as carbonate rocks, such as **limestone** and **dolomite**, as **hydrocarbons** in petroleum, natural gas, coal, and as plant and animal constituents generally distributed.

Microscopic diamonds have been made by crystallization of carbon dissolved in iron under high pressure of

the solidifying iron. Graphite is made artificially from anthracite coal by heating to the temperature of the electric furnace. Various varieties of carbon are prepared by heating certain organic materials, e.g., cocoanut charcoal for gas adsorption, bone charcoal and activated carbon for decolorizing solutions of organic substances, lamp



Graphite production in electric resistance furnace by Acheson process. A, Electrodes of graphite; B, Charge of coarse grains of coke; C, Core of carbon rod; D, Covering of sand and coke mixture.

black or soot for paint pigment by incomplete combustion of natural gas or petroleum, gas carbon by coking the residue in the distillation of petroleum, coke and wood charcoal by the destructive distillation of coal and wood, respectively. See **Destructive Distillation.**

The behavior of different forms of carbon towards strong oxidizing agents, e.g., **nitric-sulfuric acid** mixture or sulfuric acid plus **potassium** chlorate, serves to distinguish them. Diamond is unacted upon by these reagents, graphite upon prolonged treatment and heating yields graphitic acid, yellow, of the original external form of the graphite, and amorphous carbon forms are dissolved yielding humic acid and finally mellitic acid ($C_6(COOH)_6$), melting point 286° C.

Acids, carboxylic.

Carbides. **Calcium** carbide (CaC_2) and **sodium** carbide (Na_2C_2) yields **acetylene** with water; **aluminum** carbide (Al_4C) yields **methane** with water; **silicon** carbide (SiC) and **titanium** carbide (TiC) do not react with water; silicon carbide and **tungsten** carbide are used in machining operations on account of their hardness; carbides of **iron** (Fe_3C), **manganese** (Mn_3C), and **chromium** (Cr_4C, Cr_3C_2), and many other metals, also of **boron** (B_4C) have been reported.

Chlorides. See **Chlorine.**

Hydrides. See **Hydrocarbons.**

Oxides. Carbon dioxide, carbonic acid anhydride, "carbonic acid gas" (CO_2) is a colorless gas, density 1.9769 grams per liter, 0° C., 760 mm. or 1.53 when air equals 1.00, melting point — 56.6° C. at 5.2 atmospheres, solid sublimes at — 79° C. at 1 atmosphere, critical temperative 31° C., critical pressure 73 atmospheres, soluble about one volume in one volume of water at 15° C. and 1 atmosphere. Carbon dioxide is used in solution under pressure for carbonated beverages, as a liquid for extinguishing fires and making solid carbon dioxide, and as a solid ("carbon dioxide snow," "dry ice") in the maintenance of low temperatures, and as a gas quickly generated, for extinguishing fires and making carbonates, and is the source of carbon (in the atmosphere) for plant life. Carbon dioxide is chemically a remarkably permanent gas, requiring such treatment as burning magnesium to separate carbon (plus magnesium oxide); it is, however, reduced to carbon monoxide at a red heat by carbon or iron; and dissociates into carbon monoxide plus oxygen above 1300° C. (69% unchanged at 2400° C.). Carbon dioxide is formed (1) in the combustion of fuels when burned with excess air, (2) in the respiration of animals by oxidation of foods, (3) by the action of acids on carbonates, (4) by heating carbonates, such as sodium hydrogen carbonate (not sodium carbonate), **calcium** carbonate, or **magnesium** carbonate; and is recovered from (5) **fermentation** processes, and (6) many gas wells. The atmosphere contains about three parts by volume of carbon dioxide in 10,000 volumes of air.

Carbon dioxide is estimated by absorption in **sodium** or **potassium** hydroxide solution and measuring the volume of the gas before and after absorption; by absorption with solid sodium hydroxide or soda-lime and weighing before and after absorption; or by passage through **barium** hydroxide solution and titration of the alkali before and after passage. During rest, the human body maintains a constant pressure of carbon dioxide in the lungs (5.6% CO_2), a rise in the percentage of carbon dioxide increases the rate of breathing (even 0.2% increase in carbon dioxide doubles the rate of breathing), and a fall in the percentage decreases the rate of breathing with danger of cessation.

Carbon monoxide, carbonic oxide (CO) is a colorless, odorless gas, density 1.2504 grams per liter, 0° C., 760 mm. or 0.98 when air equals 1.00. Melting point — 207° C., boiling point — 192° C., insoluble. Carbon monoxide has marked physiological effect through its combination with the blood, probably forming purple carboxyhemoglobin more stable than oxyhemoglobin which oxygen forms, thus poisoning by oxygen starvation of the blood. Its presence in blood may be recognized by the characteristic absorption spectrum and the behavior of the spectrum with certain chemicals. Poisoning by inhalation of carbon monoxide, which is odorless, is a serious hazard where there are present exhaust gases from internal combustion engines or gases from the incomplete combustion of fuels from stoves and furnaces. (See **Carbon Monoxide Poisoning.**) Chemically, carbon monoxide is (1) combustible to form carbon dioxide, accompanied by a transparent blue flame and the evolution of heat, but the fuel value is low (320 British thermal units per cubic foot), (2) reactive with **chlorine,** forming carbonyl chloride ($COCl_2$) in the presence of light and a **catalyzer,** (3) reactive with **sulfur** vapor at a red heat, forming carbonyl sulfide (COS), (4) reactive with **hydrogen,** forming methyl **alcohol** (CH_3OH) or **methane** (CH_4) in the presence of a catalyzer, (5) reactive with **nickel** (also **iron, cobalt, molybdenum, ruthenium**) to form nickel carbonyl ($Ni(CO)_4$) (and carbonyls of the other metals named), (6) reactive with fused **sodium** hydroxide, forming sodium formate (HCOONa), (7) reactive with **cuprous** salt dissolved in either **ammonium** hydroxide or concentrated **hydrochloric acid,** which solutions are utilized in the estimation of carbon monoxide in mixtures of gases, e.g., flue gases of combustion, coal gas, exhaust gases of internal combustion engines, (8) reactive with **iodine** pentoxide at 150° C. For the reaction of carbon monoxide with oxygen to form carbon dioxide—finely divided **iron,** or **palladium** wire is a catalyzer; for the reaction of carbon monoxide with water vapor to form carbon dioxide plus hydrogen ("water gas reaction") important studies have been made of the conditions; and for the reaction of carbon dioxide plus carbon heated similar important studies have been made (at 675° C., 50% CO_2 plus 50% CO; at 900° C., 5% CO_2 plus 95% CO). Carbon monoxide is formed by the incomplete combustion of **fuels.** The reaction of carbon plus oxygen at such a temperature as produces carbon monoxide (say 900° C., 95% CO plus 5% CO_2) evolves heat, while the reaction of carbon plus carbon dioxide, producing carbon monoxide at the same temperature absorbs heat. Accordingly, it is possible to arrange the oxygen (free or as air) and carbon dioxide supply ratio in such a way that the desired temperature may be continuously maintained. The reduction of carbon dioxide by iron forms carbon monoxide plus ferrous oxide.

Carbon suboxide (C_3O_2) is a colorless gas, of unpleasant odor, poisonous, boiling point 7° C., burns with a blue smoky flame producing carbon dioxide. When condensed to liquid, carbon suboxide slowly changes at ordinary temperature to a dark red solid, soluble in water to a red solution. Reacts with water to form malonic acid, with **hydrogen chloride** to form malonyl chloride, with **ammonia** to form manolamide. Made by heating malonic acid or its ester at 300° C. under diminished pressure, and separation from simultaneously formed

SCHEME SHOWING THE INTERRELATIONSHIPS OF SOME CARBON-CONTAINING SUBSTANCES

Hydrocarbons Natural gas, petroleum, coal, lignite, shales in nature	CARBON Diamond, graphite in nature Graphite, charcoals, coke artificially	Carbon monoxide Formic acid Acetic acid Metallic acetates	Carbon suboxide Malonic acid Oxalic acid Metallic oxalates Insoluble Except sodium, potassium ammonium.	Carbon dioxide Carbonic acid Metallic carbonates Calcite, dolomite, magnesite, strontianite, witherite, malachite, azurite in nature. Insoluble Except sodium, potassium, ammonium
	Formaldehyde Acetaldehyde Acetone			
Methyl alcohol Ethyl alcohol Glycol Glycerol		Organic acetates	Organic oxalates	Organic carbonates
	Fatty oils, fats, waxes In plant and animal substances			
Carbohydrates In plant and animal substances				
	Proteins In plant and animal substances			

carbon dioxide and ethylene by condensation and fractional distillation

Compounds of carbon are discussed as follows

Antimony-containing See **Antimony, organic compounds**

Arsenic-containing See **Arsenic, organic compounds**

Boron-containing See **Boron, organic compounds**

Bromine-containing See **Bromine, organic compounds**

Chlorine-containing See **Chlorine, organic compounds**

Fluorine-containing See **Fluorine, organic compounds.**

Halogen-containing See **Individual Halogen.**

Hydrocarbons.

Iodine-containing See **Iodine, organic compounds**

Metal-containing See **Individual Metal**

Nitrogen-containing See **Nitrogen, organic compounds,** but first consult key below

Oxygen-containing See **Oxygen, organic compounds,** but first consult key below

Phosphorus-containing. See **Phosphorus, organic compounds**

Silicon-containing See **Silicon, organic compounds**

Sulfur-containing See **Sulfur, organic compounds.**

Organic compounds are discussed as follows

Sulfur-containing organic compounds are listed under **Sulfur**

Phosphorus-containing organic compounds are listed under **Phosphorus**

Chlorine-containing organic compounds are listed under **Chlorine**

Bromine-containing organic compounds are listed under **Bromine.**

Iodine-containing organic compounds are listed under **Iodine.**

Fluorine-containing organic compounds are listed under **Fluorine.**

Nitrogen-containing organic compounds, *except those cited above,* are listed under **Nitrogen**

Organic compounds containing carbon and hydrogen only are listed under **Hydrocarbons**

Organic compounds containing carbon and oxygen only are listed under **Carbon, oxides**

Organic acids containing carbon, hydrogen and oxygen only are listed under **Acids, carboxylic**

Organic compounds containing oxygen, *except those cited above,* are listed under **Oxygen**

Organic compounds are grouped as follows

Division Number	Chemical Elements	Generic Groups	
I	C, H	Hydrocarbons	See **Hydrocarbons**
II	C, O	Oxides, carbon	See **Carbon oxides**
III	C, H, O	Acids, mono, di, tri, basic	See **Acids, carboxylic**
		Aldehydes, mono, di	See **Aldehydes**
		Ketones, mono, di	See **Aldehydes**
		Quinones	See **Phenols**
		Alcohols, prim, sec, tert	See **Alcohols**
		Phenols, mono, di, tri	See **Phenols**
		Acid, anhydrides	See **Acids, carboxylic**
		Esters	See **Esters**
		Ethers	See **Alcohols**
		Acetals	See **Aldehydes**
		Carbon-hydrogen oxides	See **Alcohols**
		Lactones	See **Acids, carboxylic**
		Lactides	See **Acids, carboxylic**
		Hydroxy aldehydes	See **Carbohydrates**
		Hydroxy ketones	See **Carbohydrates**
		Hydroxy acids	See **Acids, carboxylic**
		Aldo-acids	See **Acids, carboxylic**
		Keto-acids	See **Acids, carboxylic**

For further reference, see **Oxygen,** for scheme showing interrelationships of oxygen-function organic compounds, and alphabetical list of compounds

Division Number	Chemical Elements	Generic Groups	
IV	C, N With or without H, O Without S	Nitrate	See **Nitric acid**
		Nitro	See **Nitro**
		Nitrite	See **Nitrous acid**
		Nitroso	See **Nitro**
		Nitrosamines	See **Nitro**
		Hydroxylamines	See **Hydroxylamines**
		Oximes	See **Hydroxylamines**
		Hydrazines	See **Hydrazines**
		Hydrazones	See **Hydrazines**
		Osazones	See **Hydrazines**
		Pyrrole	See **Pyrrole**
		Pyridine	See **Pyridine**
		Amines	See **Amines**
		Quaternary ammonium compounds	See **Amines**
		Cyanides	See **Hydrocyanic acid**
		Isocyanides	See **Hydrocyanic acid**
		Amides	See **Amines**
		Anilides	See **Amines**
		Aminoacids	See **Aminoacids**
		Polypeptides	See **Aminoacids**
		Proteins	See **Aminoacids**
		Cyanates	See **Cyanic acid**
		Isocyanates	See **Cyanic acid**
		Fulminates	See **Cyanic acid**
		Cyanamides	See **Cyanamides**
		Carbamates	See **Amines**
		Ureas	See **Amines**
		Ureides	See **Amines**, and **Purine**
		Purines	See **Purine**
		Semicarbazides	See **Amines**
		Semicarbazones	See **Amines**
		Guanidines	See **Amines**
		Aminoguanidines	See **Amines**
		Hydrazo	See **Hydrazines**, and **Azo**
		Azo	See **Azo**
		Azoxy	See **Azo**
		Diazo (nium)	See **Azo**
		Aminoazo	See **Azo**
		Hydroxyazo	See **Azo**

For further references see **Nitrogen**, for alphabetical list of compounds and scheme showing interrelationships of nitrogen-function organic compounds

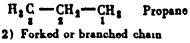
Division Number	Chemical Elements	Generic Groups	
V	C, S With or without H, O, N	Sulfonic acids	See **Thioalcohols**
		Sulfonyl	See **Thioalcohols**
		Sulfones	See **Thioalcohols**
		Sulfinic acids	See **Thioalcohols**
		Sulfinyl	See **Thioalcohols**
		Sulfoxides	See **Thioalcohols**
		Thiophene	See **Thiophene**
		Penthiophene	See **Thiophene**
		Thioalcohols	See **Thioalcohols**
		Thioethers	See **Thioalcohols**
		Tertiary sulfonium compounds	See **Thioalcohols**
		Thiophenols	See **Thioalcohols**
		Thioaldehydes	See **Thioaldehydes**
		Thioketones	See **Thioketones**
		Thioic acids	See **Sulfur, acids**
		Thiocyanates	See **Thiocyanic acid**
		Isothiocyanates	See **Thiocyanic acid**
		Thiocarbonic acid	See **Thiocarbonicacid**

For further references see **Sulfur**, for alphabetical list of compounds, and scheme showing interrelationships of sulfur-function organic compounds.

CARBON SCHEME SHOWING TYPES OF CARBON ARRANGEMENTS

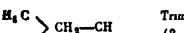
A Carbon Chain Compounds

(1) Straight chain

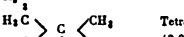


Propane (C_3H_8)

(2) Forked or branched chain



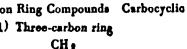
Trimethylmethane (C_4H_{10}) (2-Methylpropane)



Tetramethylmethane (C_5H_{12}) (2,2-Dimethylpropane)

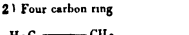
B. Carbon Ring Compounds Carbocyclic

(1) Three-carbon ring



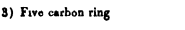
Cyclopropane (C_3H_6)

(2) Four carbon ring



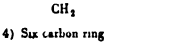
Cyclobutane (C_4H_8)

(3) Five carbon ring



Cyclopentane (C_5H_{10})

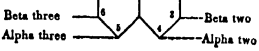
(4) Six carbon ring



Cyclohexane (C_6H_{12})

Benzone (C_6H_6)

Naphthalene ($C_{10}H_8$)



Anthracene ($C_{14}H_{10}$)

Diphenyl ($C_{12}H_{10}$)

(*Continued on next page*)

CARBON SCHEME SHOWING TYPES OF CARBON ARRANGEMENTS —*Continued*

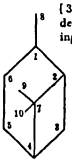
C. Combinations of Carbon Chain and Carbon Ring

(1) Six carbon plug

Carbon skeleton of toluene (C_7H_8 or $C_6H_5\ CH_3$)

Carbon skeleton of limonene ($C_{10}H_{16}$), a terpene hydrocarbon

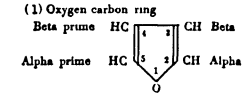
(2) Bridged ring (3 bridges from No 2 to No 4, (1) via No 3, (2) via No 7, (3) via No 1 6 5 Therefore, "bicyclo [3 1 1] heptane" Numbers inside the square brackets denoting the number of carbons in each bridge not counting the piers (No 2,4)



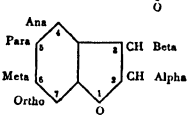
Carbon skeleton of pinene ($C_{10}H_{16}$), a terpene hydrocarbon

D. Heterocyclic Compounds

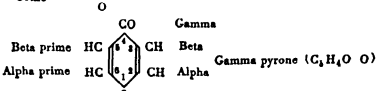
(1) Oxygen carbon ring



Furane (C_4H_4O)

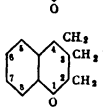


Coumarone (C_8H_6O)



Gamma pyrone ($C_5H_4O\ O$)

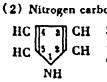
5 8, as for 4-7, respectively of coumarone



2 to 4, alpha, beta, and gamma as of pyrone

Chromane ($C_9H_{10}O$)

(2) Nitrogen carbon ring



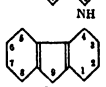
2 to 5, alpha and beta, as of furane

Pyrrole (C_4H_5N)

4 7, as of coumarone

2 to 3, alpha and beta, as of coumarone

Indole (C_8H_7N)

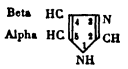


Carbazole ($C_{12}H_9N$)

Pyrazole ($C_3H_4N_2$)

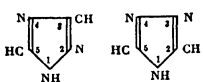
Isindazole ($C_7H_6N_2$)

Indazole ($C_7H_6N_2$)

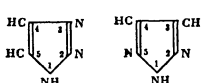


Iminazole ($C_3H_4N_2$)

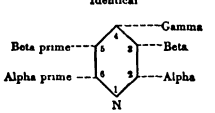
Benziminazole ($C_7H_6N_2$)



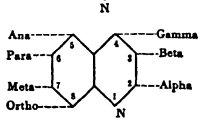
Triazoles ($C_2H_3N_3$)



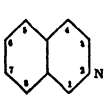
Tetrazole (CH_2N_4)



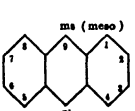
Pyridine (C_5H_5N)



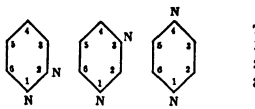
Quinoline (C_9H_7N)



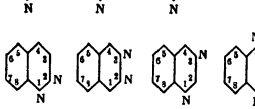
Isoquinoline (C_9H_7N)



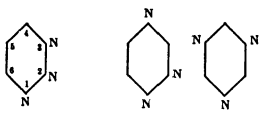
Acridine ($C_{13}H_9N$)



Three diazines ($C_4H_4N_2$)
1. 1,2 (pyridazine)
2 1,3 (pyrimidine)
3. 1,4 (pyrazine)

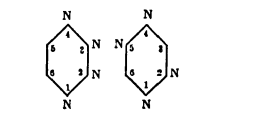


Four benzodiazines
1. 1,2 (cinnoline)
2. 2,3 (phthalazine)
3. 1,3 (quinazoline)
4. 1,4 (quinoxaline)



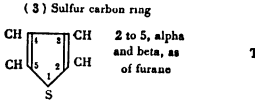
Three triazines
1. 1,2,3
2 1,2,4
3. 1,3,5 (cyanidine)

Vicinal Asymmetrical Symmetrical



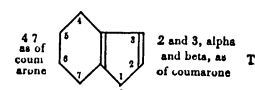
Two tetrazines
1 1,2,3,4
2. 1,2,4,5

(3) Sulfur carbon ring



2 to 5, alpha and beta, as of furane

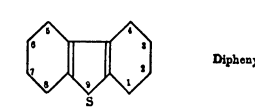
Thiophene (C_4H_4S)



4 7 as of coumarone

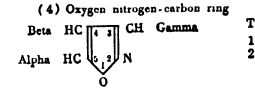
2 and 3, alpha and beta, as of coumarone

Thionaphthene (C_8H_6S)

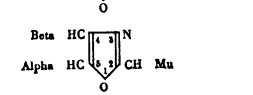


Diphenylene sulfide ($C_{12}H_8S$)

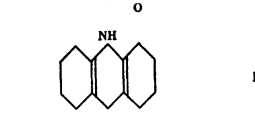
(4) Oxygen nitrogen-carbon ring



Two oxazoles (C_3H_3NO)
1. 1 0 2 N
2 1-0 3 N

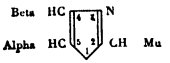


Benzoxazole (C_7H_5NO)

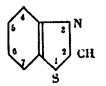


Phenoxazine ($C_{12}H_9NO$)

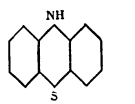
(5) Sulfur nitrogen-carbon ring



Thiazole (C_3H_3NS)



Benzthiazole (C_7H_5NS)



Phenthiazine ($C_{12}H_9NS$)

(R K S)

CARBONADO (BLACK DIAMOND). The mineral carbonado is an opaque massive black variety of **diamond**, often crystalline to granular or compact and without cleavage In thin splinters it appears greenish black by transmitted light It is found chiefly in Bahia, Brazil Carbonado is in demand for rock drilling apparatus (E S C S)

CARBONATE. Carbonic Acid.

CARBONIC ACID AND CARBONATES. Carbonic acid (H_2CO_3) is a solution formed when **carbon dioxide** is dissolved in water The concentration of acid formed is small, and carbon dioxide may be completely expelled upon boiling The solution reacts with alkalis to form carbonates, e g , sodium carbonate, sodium hydrogen carbonate, calcium carbonate, calcium hydrogen carbonate

Metallic carbonates are (1) soluble, e g , **sodium** carbonate, **potassium** carbonate, **ammonium** carbonate, (2) insoluble, e g , **calcium** carbonate, **strontium** carbonate, **barium** carbonate, **magnesium** carbonate, **ferrous** carbonate, **silver** carbonate Metallic bicarbonates are known in solution and on warming are converted into ordinary or normal carbonates, e g , bicarbonates of sodium, potassium, calcium, barium Basic carbonates are important in such cases as lead ("white lead"), **zinc**, **magnesium**, **copper** Carbonates of very weak bases, such as **aluminum**, **ferric**, and **chromic** are not known Found in nature as the carbonates, **calcite**, **Iceland spar**, **limestone** and various forms of impure calcium carbonate ($CaCO_3$), as **magnesite** (**magnesium** carbonate, $MgCO_3$), as dolomite (various compositions of calcium and magnesium carbonates), as **witherite** ($SrCO_3$), as **strontianite** ($SrCO_3$), as **azurite** and **malachite** (various compositions of cupric hydroxycarbonates), in various natural waters as carbonic acid, calcium and magnesium hydrogen carbonates, in blood, as sodium hydrogen carbonate Esters of carbonic acid are diethyl carbonate, ethyl ester of meta-carbonic acid, boiling point 126° C ($(C_2H_5O)_2CO$), made by reaction of ethyl alcohol and carbonyl chloride, dimethyl carbonate ($(CH_3O)_2CO$), boiling point 90° C , methylethyl carbonate ($CH_3O)CO(OC_2H_5$), boiling point 109° C , dipropyl carbonate ($(C_3H_7O)_2CO$), boiling point 168° C , tetraethyl carbonate, ethyl ester of orthocarbonic acid ($(C_2H_5O)_4C$), boiling point 158° C , made by reaction of sodium ethylate and chloropicrin (CCl_3NO_2) Urethanes, ureas, guanidines are carbonic acid derivatives Carbonates may be detected by the fact that dilute sulfuric acid liberates carbon dioxide from the solid The carbon dioxide produces a white precipitate with barium hydroxide The carbon dioxide does not decolorize iodine solutions as sulfur dioxide does (See **Amines and Amides**) (R K S)

CARBONIFEROUS PERIOD. Mississippian and Pennsylvanian.

CARBON MONOXIDE POISONING. Carbon monoxide (which is discussed under **Carbon**) is a colorless and odorless gas, produced when carboniferous materials are burned without sufficient oxygen for complete **combustion** In this mechanical age it is probably the most widely distributed of toxic agents It is not known how many deaths are due to this agent, but the number is great. In various industries, as in the manufacture of steel, mining of coal, the burning of gas and coal, carbon monoxide gas is produced in great quantities The greatest source of this poison, in general, is from the exhaust of motor cars, where its concentration is 7% From this source alone many thousands of persons are to some degree affected daily

Carbon monoxide kills because it combines with the hemoglobin of the blood, thus making it impossible for the hemoglobin to combine with oxygen, which is a necessary life process Carbon monoxide has an affinity for hemoglobin three hundred times that of oxygen The degree of poisoning depends on concentration of the gas and time of exposure If the percentage of the gas in the blood rises to 70% or 80% death is likely to ensue After death the blood is a bright cherry red and hemorrhages and **edema** of the brain are found

A chronic form of poisoning is believed to result in headaches, palpitation, dizziness, anemia, psychoses, and neuritis

The treatment of acute poisoning is immediate artificial respiration, and, as soon as obtainable, the inhalation of a mixture of 93% oxygen and 7% carbon dioxide The carbon dioxide is a direct respiratory stimulant and the pure oxygen hastens the release of carbon monoxide from the hemoglobin Even after recovery, delayed secondary complications such as paralysis and cerebral hemorrhage may occur (R S M)

CARBONYL. Radicals

CARBORUNDUM Carborundum is silicon carbide (SiC), which is used as an abrasive (See **Abrasion**)

CARBOXYL. Radicals.

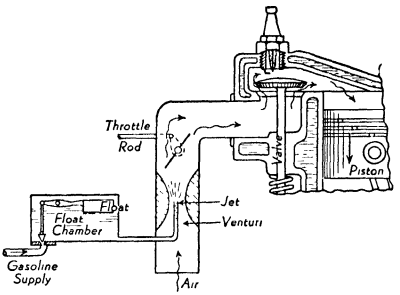
CARBOXYLIC ACID. Acid, Carboxylic.

CARBUNCLE In geology this term is applied to that variety of **garnet, almandine**, which was much used formerly for jewelry, when cut *en cabochon* It is derived from the Latin, *carbunculus*, a small spark, in reference to the glowing effect of that style of cutting In the early part of the Christian Era, the term seems to have been used for red stones of all sorts

In medicine, a carbuncle is a severe localized infection, usually occurring in the **subcutaneous** tissues of the body A carbuncle usually starts in the same way as a boil, but, instead of one, there are several openings A longer time is required for the infection to subside Fever and constitutional symptoms are frequently marked and in some instances death may result from **septicemia** In most cases a cruciate incision, with undermining of the edges, is required The causative organism is usually the **staphylococcus** (E S C S, R S M)

CARBURETION. The fuel for an **internal combustion engine** must be very thoroughly mixed with the air needed for combustion This is very true of the **Otto cycle** engine, since thorough distribution of particles of fuel in the air is essential to the rapid and complete explosive combustion of the fuel in that cycle One of the most effective means of mixing the particles of a liquid fuel with air is by atomization The atomizing and mixing of a liquid fuel with air in the correct proportions is called carburetion, and the device to accomplish this, a carburetor.

The automobile engine offers an instance of applied carburetion, also one of the more difficult carburetive problems, since the automobile engine is expected to operate smoothly and economically with wide variation of power, using fuels of varying quality The **Venturi** tube principle forms the basis of most commercial carburetors In its simplest form it consists of a Venturi tube in the passage leading from the atmosphere to the



Induction system of the gasoline engine showing elementary form of carburetor

cylinder As the air passes this tube, it is speeded up at the throat due to the construction in flow area, and the static pressure of the air is reduced A gasoline chamber with a gasoline level which is maintained slightly below that of the level of the throat of the Venturi, supplies gasoline through an interconnecting tube to a jet whose opening is located in the area of reduced pressure at the Venturi throat Since the surface of the gasoline in the float chamber is subject to atmospheric pressure, the pressure difference causing gasoline to be sprayed out of the jet is the same as that which exists between the atmosphere and the throat of the Venturi tube Thus both air and gasoline are subjected to the same driving pressure, and when one increases the other increases, and vice versa If the discharge of gasoline from the jet, and of air through the Venturi increased in the same ratio, this simple carburetor would be successful for automotive service, but unfortunately the rate of increase of gasoline flow with increasing pressure difference exceeds that for air

The mixture delivered by this carburetor is given by the following equation, in pounds of air per pound of gasoline

$$\text{Mixture} = \frac{C_a A_a}{C_g A_g}\sqrt{\frac{d_a}{d_g}}$$

C's are coefficients of discharge
A's are areas of flow
d's are densities of the fluids

With ordinary gasoline this mixture should be maintained at 15 2 pounds of air per pound of gasoline, but the simple Venturi carburetor will not do that, but rather will give an increasingly richer mixture, as the velocity of air through the Venturi increases The principal reason for this characteristic will be found in the variability of the coefficients of discharge The coefficient of discharge for air through a Venturi tube is approximately constant, but that of gasoline from a jet increases with increasing pressure differential across the jet

The commercial Venturi-type carburetor contains modifications which offset this basic undesirable characteristic so that a uniform mixture will be maintained at all loads The simplest method of offsetting enrichment of mixture was to provide an auxiliary valve admitting air to the mixture before it reached the cylinder This auxiliary air valve opening was closed by a spring loaded valve which was held partially open by the suction in the manifold,

and admitted fresh air to dilute the overrich mixture. The carburetion obtained by the auxiliary air valve principle was inferior to other methods, and has been abandoned

If the gasoline supply tube is constricted between the float chamber and the jet, the pressure drop across the constriction will increase at increasing rates of flow, and the result will be a tendency for starvation of the jet, and weakening of the mixture at high air velocities By combining properly a jet of this type with one of the unrestricted type, a compensated jet arrangement may be designed which will give fairly uniform mixture at varying loads The use of a restricted jet, together with extra high speed jets that come into play when the air speed through the Venturi exceeds a certain value, is another modification of the simple Venturi carburetor Some carburetors have a variable orifice on the gasoline jet created by the use of a throttle operated metering pin, others have a Venturi tube with variable opening

In one type of carburetor the density of the gasoline issuing from the jet is, in effect, varied by bleeding air bubbles into the vertical stem of the jet in such a way that the amount of air mixed with the gasoline increases with increasing load, thus tending to offset the enriching tendency of a plain Venturi-jet carburetor This air bleeding of the jet is called the plain-tube principle of carburetion

The desirability of having a carburetor which will function under inexpert handling, which will deliver an extra rich mixture for acceleration periods, and which will produce a smoothly idling mixture, has made it necessary for carburetor manufacturers to add such auxiliaries as acceleration wells, idling jets, etc, all of which tend to make of a device fundamentally simple in principle, a rather complicated and sensitive piece of apparatus (F T M)

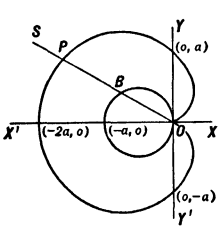
CARCINOMA. Cancer.

CARDAMOMS *Elettaria cardamomum* Zingiberaceae Cardamoms are the seeds of a leafy-stemmed perennial **monocotyledon** growing from five to nine feet in height The flowers, white with purple-striped perianth parts, are borne on leafless stems which rise from the thick fleshy **rhizomes** apart from the leafy stems The angular seeds are borne in three-celled fruits The dried seeds are used in India and elsewhere in tropical Asia as a highly flavored spice (R M W)

CARDIAC Pertaining to the heart A popular term for one who has a chronic heart disease (R S M)

CARDINAL TEETH. In the shells of some **bivalve** mollusks, the interlocking prominences of the two valves just below the umbo (A W L)

CARDIOID. The cardioid is a type of mathematical curve which received its name from its heart-shaped form



Cardioid

The cardioid may be defined geometrically as follows From any point O on a circle of diameter a draw any secant OS cutting the circle at B, and extend OB to P so that $BP = a$, as this secant line rotates about O, the point P describes the cardioid

If we take O as the pole, and OX through the center of the circle as polar axis and the circle to the left of O, the polar equation of the cardioid is $r = a(1 - \cos\theta)$

The cardioid may also be defined as the locus of a point on a circle which rolls without slipping on the circumference of an equal fixed circle, this is equivalent to the above definition

The cardioid has an interesting application to the problem of the trisection of an angle (L L S)

CARDIOLOGIST. A physician who specializes in the diagnosis and treatment of **heart** disease (R S M)

CARDO. The basal segment of an insect **maxilla** by which it is attached to the head (A W L)

CAREY-FOSTER BRIDGE. This is a form of **Wheatstone bridge**, adapted to the measurement of the difference between two nearly equal resistances, with the elimination of errors due to the connections The bridge is of the slide-wire type (the ordinary four-gap form is easily adapted to the purpose), the resistance ρ of the slide wire per unit length being accurately known X and S are to be compared (See figure) A balance is first secured with the contact C at a distance a_1 from M Then X and S are interchanged, and another balance obtained with C at distance a_2 from M It may then be shown that

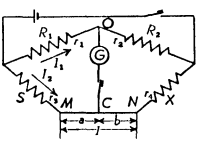


Diagram of Carey Foster bridge circuit

$$X - S = (a_1 - a_2)\rho$$

The Callendar and Griffiths bridge is a special type of Carey-Foster bridge used with **resistance thermometers** (L D W)

CARIBOU. Mammalia, Artiodactyla *Rangifer* **Deer** with partly flattened branching antlers in both sexes, North American relatives of the European reindeer The several species inhabit the more northern parts of the continent, although two come into the United States Caribou are found in northern Maine and in several of the northwestern states (A W L)

CARIES Decay or death of a portion of a bone, due to a chronic inflammatory disease Dental caries is decay of the enamel, dentin or pulp of a tooth Spinal caries is Pott's disease (tuberculosis of the spinal column) (R S M)

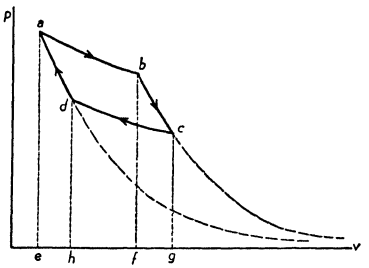
CARINA. 1 A sharp ridge, comparable with the keel of a boat, such as is found on the shells of certain **snails** 2 The median dorsal plate of the shell of a **barnacle** 3 The deep ridge on the breastbone of most birds (**Aves**), more often called by the English equivalent, keel (A W L)

CARINATAE A division of the birds (**Aves**) including all of the flying species which have the breastbone provided with a deep keel for the attachment of the powerful flight muscles The division includes a few species which do not fly and which have only a rudimentary keel The classification of birds as Carinatae and Ratitae is now rather generally abandoned in favor of subdivision into orders without such grouping (A W L)

CARNELIAN. The mineral carnelian is a red or reddish brown **chalcedony**, the word is derived from the Latin word meaning flesh, in reference to the flesh color sometimes exhibited (E S C S)

CARNIVORA. An order of **mammals** made up largely of flesh-eating species, mostly predacious in habits, although some are omnivorous and some eat carrion They have four or five toes on each foot, armed with claws, the canine teeth are prominent, and the premolar and molar teeth are formed for cutting Common examples of the several families into which the order is divided are the **bears**, the **wolves**, the **raccoons**, the **weasels**, **minks**, and **skunks**, and the **cats** (A W L)

CARNOT CYCLE. An ideal cycle of four reversible changes in the physical condition of a substance, useful in thermodynamic theory Starting with specified values of the variable temperature, specific volume, and pressure, the substance undergoes in succession (1) an isothermal (constant temperature) expansion, (2) an adiabatic expansion (See **Adiabatic Processes**), and (3) an isothermal compression to such a point that (4) a further adiabatic compression will return the substance to



Carnot cycle on v p diagram ab and cd, isothermals, bc and da, adiabatics, which for some theoretical purposes, are produced to infinity.

its original condition These changes are represented on the volume-pressure diagram respectively by *ab*, *bc*, *cd*, and *da* in the accompanying figure Or the cycle may be reversed *a d c b a*

In the former (clockwise) case, heat is taken in from a hot source and an equivalent amount of work is done by the hot substance during the high-temperature expansion *ab*, and additional work is done at the expense of the thermal energy of the substance during the further expansion *bc* Then a less amount of work is done on the cooled substance, and a less amount of heat discharged to the cool surroundings, during the low-temperature compression *cd*, and finally, by the further application of work during the compression *da*, the substance is raised to its original high temperature The net result of all this is that a quantity of heat has been taken from a hot source and a portion of it imparted to something colder (a "sink"), while the balance is transformed into mechanical work represented by the area *a b c d* If the cycle takes place in the counter-clockwise direction, heat is transferred from the colder to the warmer surroundings at the expense of the net amount of energy which must be supplied during the process (also represented by area *a b c d*) The operation of the cycle thus illustrates the second law of **thermodynamics** (L D W)

CARNOTITE The mineral carnotite is a **vanadate** of **potassium** and **uranium** with small amounts of **radium** Its formula may be written $K_2O\ 2UO_3\ V_2O_5\ 2H_2O$ The amount of water, however, seems to be variable It occurs usually as a lemon yellow earthy powder disseminated through **sandstones**, rarely as **orthorhombic** scales It was mined in Colorado and Utah as a source of radium Other localities are in Arizona, Pennsylvania, and the Belgian Congo (E S C S)

CAROTIN. Pigments in plants.

CARP Pisces, Teleostei Large **fishes** belonging to the same family as the minnows, dace, and chubs The common carp is an introduced species, indigenous to eastern Asia but now thoroughly at home in the rivers and lakes of North America and Europe It is coarse and bony but it is widely used as food The **goldfish** or golden carp is a related species native to China and Japan Many strange varieties have been developed in captivity and the species is thriving in some lakes and streams in the eastern United States. Several other species of carp occur in Europe and Asia. (A W L)

CARP SUCKER. Pisces, Teleostei *Carpiodes* Fishes (**Pisces**) of several species related to the buffalo and suckers They are found in streams and lakes of the United States and Mexico Most species are known by this name but one member of the genus is called the **quillback** (A W L)

CARPAL BONES. The small bones of the wrist in man and the similar group in the forelegs of animals. (A W L)

CARPEL. Flower.

CARPENTER-BEE. Insecta, Hymenoptera A **bee** which excavates its nest in wood The small carpenter-bee, *Ceratina dupla*, of North America merely digs out the pith or soft wood of a plant, such as sumac, while the large carpenter-bees, *Xylocopa*, of which there are several species, bore into solid wood, even attacking unpainted wood in construction The larger bees are not unlike **bumblebees** in appearance (A W L)

CARPENTER MOTH. Insecta, Lepidoptera **Moths** whose larvae bore in the trunks of trees, entering the solid wood A few species, including the locust borer, are of large size, and because of their narrow wings and long bodies may be mistaken for sphinx moths These insects make up the small family Cossidae (A W L)

CARPINCHO. Capybara.

CARPOPODITE. The third segment from the tip of the **crustacean** appendage (A W L)

CARRIER A person who carries the specific organisms of any disease, and who can, though showing no signs of the disease himself, distribute this disease through contact with others (R S M)

CARRIER CURRENT. The multiplex system of electrical communication allows the maximum use of a telegraph or telephone company's investment in an electrical circuit, for it is by systems using the carrier current that a single set of line wires may be used to transmit several messages simultaneously The means by which this is accomplished involves the use of carrier currents of different frequencies, a separate **frequency** for each message The carrier current is modulated at the sending end in accordance with the voice or code signals to be transmitted To be successful, the carrier current frequencies must exceed that of the signal which is being transmitted The modulated carrier current is separated from the others at the receiving end and by an electric wave filter The carrier current is then demodulated, and the signal components so obtained are transmitted to the receiver (F T M)

CARRION BEETLE. Insecta, Coleoptera Moderate to large **beetles** which are found about decaying flesh and to some extent about other decaying matter Applied to members of the family Silphidae, although many other beetles breed in decaying matter and are found in it, both as adults and as **larvae** (A W L)

CARRION BIRD. Aves, Falconiformes The English equivalent of the Dutch name **aasvogel**, applied to some of the larger South African **vultures** (A W L)

CARROT FAMILY. Umbelliferae The plants of this family, mostly found in the north temperate zone, are nearly all annual or biennial herbs, with a few trees or shrubs They are characterized by having stems hollow except at the nodes, alternate leaves which are either pinnately or ternately compound, and large numbers of small flowers produced in simple or compound **umbels**

The distinctive umbel is an inflorescence in which the pedicels of the individual flowers arise from a very short axis and are of nearly equal length, producing a flat-topped or rounded cluster

The single **flowers** are small and regular, the **calyx** being either absent or adnate to the **ovary**, and five-toothed, the **corolla** composed of five separate **petals**, the stamens five and the single pistil with inferior ovary, with two one-seeded **carpels** The flowers are insect-pollinated. The fruit is a form known as a schizocarp, a dry fruit having two carpels which separate at maturity into two mericarps, each of which usually has five longitudinal ridges Between the ridges are found longitudinal oil canals containing the volatile oils which give the odors characteristic of many members of this family

Many members of this family are important food plants to man and domestic animals Among these are plants grown for their roots, the carrot, *Daucus carota*, and parsnip, *Pastinaca sativa*, both natives of Europe, also **celery**, *Apium graveolens*, grown for its leaf stalks, and parsley, *Apium petroselinum*, grown for the much dissected leaves which are used as a garnish and for flavoring A large number of plants in this family are frequently cultivated, especially in Europe, for flavorings and medicinal use, though possibly their therapeutic value is rather overrated Among these are **anise** (*Pimpinella anisum*), caraway (*Carum carvi*), coriander (*Coriandrum sativum*), fennel (*Foeniculum officinale*), and dill (*Peucedanum graveolens*) Many of these are also used in flavoring confections *Ferula assafetida* produces a drug, **asafoetida**

In contrast to these, which are useful to man, are many members of the family which contain violent poisons *Conium maculatum*, the Poison Hemlock, is reputed to have been the source of the poison which Socrates drank *Cicuta maculata* and related species are sometimes eaten by livestock with fatal results (R M W)

CARTESIAN COORDINATES Cartesian coordinates of a point are either its **rectangular coordinates** or its **oblique coordinates** They are called Cartesian after the French mathematician and philosopher Descartes, who first introduced the idea of **coordinates** as a basis for the analytic study of geometry (L L S)

CARTESIAN OVAL. This curve is defined as the *locus* of a point P that moves so that its distances from the origin $O(o)o$ and the point $A(a,o)$, in **rectangular coordinates**, satisfy the relation $AP = \pm b\ OP \pm c$, where b and c are given positive constants (L L S)

CARTHAMUS TINCTORIUS. Safflower Compositae This plant, a native of the East Indies, is now widely cultivated in tropical Asia and Egypt, and to a limited extent in southern Europe It is a low annual plant with yellowish-red flowers which have tubular corollas

Of commercial importance are the flowers, which are washed in water to remove the yellow pigment present, dried, and ground to a powder This powder is mixed with starch and talc to make rouge (R M W)

CARTILAGE. 1 The internal structure of the ligament which connects the valves of the shell in some of the **bivalve** mollusks 2 A supporting tissue associated with the skeleton of **vertebrates**

Cartilage, like the other connective and supporting tissues, contains a relatively large amount of intercellular substance in which the cells are scattered This substance is a complex mixture of organic materials, bluish in color and translucent It contains organic fibrils and around the cavities in which the cartilage cells lie it differs chemically as shown by its reaction to stains The cells are rounded and may lie singly or in groups in the capsules.

Three kinds of cartilage are recognized· hyaline, elastic, and fibrocartilage. The first contains few fibrils. It is flexible, slightly elastic, and provides a support of moderate rigidity. It covers the ends of bones in movable joints as the articular cartilages, forms the rings of the trachea, and occurs in other parts of the body where such qualities are required Elastic cartilage is similar to hyaline but has many elastic fibers in the intercellular matrix It occurs in the pinna of the ear, where its qualities provide support and elasticity, the latter very necessary in a delicately formed projecting structure of this kind which might otherwise be easily broken Fibrocartilage contains many inelastic white fibers which give it extreme toughness It is associated with some joints and forms the intervertebral disks of the backbone These disks provide very firm connections between the separate vertebrae and at the same time cushion the series

The term cartilage is also applied to separate skeletal units formed of this material Each cartilage is surrounded by a tough connective tissue sheath called the perichondrium

Cartilage is a primitive skeletal material of the vertebrates It precedes bone in embryonic development and persists in the adult skeleton in the sharks and related fishes It is not transformed into bone but is replaced by bone in the formation of some of the parts of the skeleton (A W L)

CARYOPSES. Fruits.

CASCARA SAGRADA. The bark of *Rhamnus Purchiana*, a shrub growing in western North America It is a **drug** used as a laxative and cathartic (R S M)

CASE HARDENING. When a low carbon **steel** is used for a purpose where a hardened surface would be desirable, as in gear teeth, cams, or armor plate, the character of the surface may be altered to form a case which is very hard The combination of this hard surface with a soft and ductile core is often more desirable in machine parts than a completely hard piece The hard-surfaced case is obtained by adding **carbon** to the steel, a process which is commonly carried out by keeping the iron at a sufficiently high temperature in contact with suitable material containing carbon, whereby the iron readily absorbs some of the carbon The operation of case hardening, then, consists of carburizing the material by heating it in contact with a carburizing substance to around 1700° to 1800° F for several hours This prolonged heating at a high temperature develops a coarseness of grain in the core, and in order to refine the structure, the metal should be reheated slightly above the critical temperature of the core, and then quenched It should then be reheated to above the critical temperature of the case, and again quenched By means of this double heat treatment, there is produced a hardened case having fine structure, and a ductile core having a full measure of toughness (F T M)

CASEIN Casein is a protein present in milk that is used to make **plastics.** (See **Aminoacids, Polypeptides and Proteins**)

CASHEW. *Anacardium occidentale* The cashew nut is the fruit of a Brazilian tree of moderate size The kidney-shaped nut grows at the end of a curiously enlarged fleshy **peduncle** which is juicy and bright yellow or red This fleshy portion is much eaten in tropical America The nut itself contains a biting caustic oil which is driven off by roasting The single kernel of this fruit is the familiar cashew nut so widely known as a confection The oil is used to a limited extent, to protect book bindings and wood against the attack of **termites** (R M W)

CASING. The casing is that part of a machine which encloses or encases the working portions Not all machines are said to have a casing, the term is usually applied in instances where a nearly complete enclosure

is made, such, for example, as the fan casing and the turbine casing

The pipe which is used to line a well is called casing pipe, and is a prominent feature of oil and gas wells It is usually characterized by light weight, and joints with fine pitched threads In sinking a deep well the casing constituting the first section may be 6 inches in diameter When the 6-inch casing has been sunk as deep as practicable, the size will be stepped down to, say, 5 inches, which is lowered into the well inside the 6-inch casing Thus progressively the size of the casing is decreased as the well deepens (F T M)

CASINGHEAD GAS. A large amount of technically pure **gasoline** termed casinghead or "aviation gas" is now extracted by condensation from vapors present in certain **natural gases** as they flow from the well This product is also used to blend with gasoline which has been refined from **petroleum** (R M F)

CASSAVA. Spurge Family.

CASSEGRAINIAN. Telescope.

CASSIA. *Cinnamomum cassia* Lauraceae Cassia is one of the earliest used of all spices, and is mentioned in the Old Testament as a spice It is a bushy plant native to Cochin China, from which region it had spread in cultivation to much of southeastern Asia in early times Its presence in the island of Ceylon led the Portuguese to seize that island in 1636 That and other spices were the main cause of the bitter and bloody struggles among various European nations for possession of tropical Asian lands

In cultivation the much-branched plant is ready for harvest about six years after planting In harvesting, the bark on the young stems is split longitudinally and peeled back in cylinders about sixteen inches long The adherent **periderm** is planed off With continued drying the bark rolls up rather tightly and turns dark brown in color This is the product used mainly as a spice in pastry making Immature fruit may be dried and also used for spice

By distillation, oil of cassia, mainly cinnamic **aldehyde**, is obtained from the bark and leaves This oil is used mainly as a flavoring for candies Some of it is used in making scented soaps, and in medicines, where its principal value is in concealing unpleasant tastes (R M W)

CASSIOPEIA. (Map, page 306) This is one of the most widely known and striking **constellations** of the northern latitudes It is easily recognized by the five bright stars forming an irregular W, some observers seeing not only a W but also a chair Since this object is circumpolar (i e, remains above the **horizon** at all hours every night) for most northern countries, and is easily recognized, it is frequently used as a rough indicator of sidereal time The leading bright star of the W (the star Beta Cassiopeiae) lies almost in zero hours **right ascension** Hence a line drawn through **Polaris** and Beta Cassiopeiae must pass close to the vernal equinox The **hour angle** of this line must be equal to sidereal time Hence when Beta Cassiopeiae is on the meridian directly above the pole the sidereal time is zero, when on the meridian directly below the pole the sidereal time is twelve hours, etc

One of the brightest **novae** on record appeared in this constellation in 1572 and was observed and recorded by Tycho Brahe (W K G)

CASSIQUE. Aves, Passeriformes South American birds (**Aves**) of several species, related to the Old World starlings (A W L)

CASSITERITE—TIN STONE. The mineral cassiterite, chemically tin dioxide, SnO_2, is almost the sole ore of tin It is a noticeably heavy mineral crystallizing in the **tetragonal** system, as low pyramids, prisms, often very slender, and as twinned forms It is a brittle mineral, hardness, 6 0–7 0, specific gravity, 6 8–7 1, luster, adamantine, color, generally brown to black, but may be red, gray to white, or yellow, streak whitish, grayish, or brownish, may be almost transparent to opaque A fibrous variety somewhat resembling wood is called wood tin Cassiterite occurs in widely scattered areas, but deposits of a size to be commercially important are few It is associated with **granites** and **rhyolites** and is believed to be, in part at least, the result of **pneumatolytic** action The weathering of the cassiterite bearing rocks often permits the distribution of it along stream beds where it is known as stream tin The Malay Peninsula deposits are stream tin Other productive regions are Australia, Africa, and South America In the United States cassiterite has been mined in the Black Hills of South Dakota and elsewhere but the deposits are not of great consequence The tin veins, now about exhausted, in Cornwall, England, were known to the Phoenicians before the Roman invasions Saxony and Bohemia were formerly important producing regions also

The word cassiterite is of Greek origin (E S C S)

CASSOWARY. Aves, Casuariiformes *Casuarius* A large flightless bird (**Aves**) of Australia, New Guinea, and adjacent islands The several species are all forest birds, unlike the related **emus** The naked skin of the head and neck is brightly colored with blue, green and red, and the head is surmounted by a bony crest, in some species of large size The wings are rudimentary (A W L)

CAST IRON. Iron.

CAST STEEL. Steel.

CASTING Casting is the process of producing metal shapes by pouring molten metal into molds of the required form where it is allowed to solidify The metal part formed as a result of this operation is called a casting The art of casting is one of the oldest methods for making metal parts and is still extensively used in spite of more modern developments such as **forging.**

The production of a casting involves the use of a pattern, usually of wood or metal, which is similar in shape to the desired finished piece and slightly larger in all dimensions to allow for shrinkage of the metal upon solidification. The pattern is bedded down in a special damp sand by an operation called molding When the pattern is removed it leaves an impression of the shape of the desired casting This impression is completely surrounded by sand and provided with openings called gates through which the molten metal enters After pouring and cooling the mold is broken open and the casting removed All adhering sand particles together with any extraneous projections such as those left by the gate system are removed after which the casting is machined to the required finish (C W C)

CASTOR. Castor (α **Geminorum**) is the fainter star of the twins Since these two stars are always considered together in the ancient literatures, the history and astrological significance will be found discussed under **Pollux,** the brighter of the two

Astronomically, Castor is a very remarkable star It was discovered in 1719 to be a visual **binary,** with the **magnitudes** of the components 2 8 and 2 0 The separation is about 6″ and the star is certainly a true binary, but the period has not yet been accurately determined The period is probably of the order of magnitude of 350 years Each of the two components of the binary system is also a **spectroscopic binary** so Castor is a quadruple system Castor has a faint companion separated from it by about 72″ but having the same **parallax** and **proper motion** This companion is also a spectroscopic binary with a period of slightly less than one day (W K G)

CASTOR-OIL. *Ricinus communis.* Euphorbiaceae Castor oil is obtained from a short-lived perennial tree which occurs wild in tropical Africa and perhaps in India Cultivation of the tree is widespread not only in the tropics but also in temperate regions, where it is often grown as an ornamental plant In the tropics it becomes a tree thirty-six feet tall, with large coarse leaves often of reddish color, and green flowers The seeds, borne three in each of the smooth or prickly capsules, have a hard mottled shell These seeds are ejected violently from the mature fruit

The principal use of the plant is for the oil which is contained in the seeds This oil is pressed out without heating the seeds It is used as a lubricant for airplane and marine engines, either in the pure state or mixed with mineral oils Much castor oil is used in preparing various dyes used in coloring textiles Certain soaps, also, are prepared from castor oil Not a little has been used as a lubricant for the human system where, however, its action has proved mildly irritating The seeds contain a violent poison which must be removed before the oil can be used medicinally India produces most of the castor bean crop of today (R M W)

CASUARIIFORMES An order of flightless birds (**Aves**) containing the **emus** and **cassowaries** of Australia and New Guinea (A W L)

CAT Mammalia, Carnivora Although commonly used in the unqualified form only to designate the domestic cat, *Felis domestica*, this term properly indicates any member of the large family Felidae, which includes the **lion, the tiger, leopards, lynxes,** and many species of smaller size

Among the distinctive characters of the family are the simple dentition and the sharp, curved, retractible claws In most species the claws can be withdrawn completely into sheaths

The larger cats of the Old World include the lion, tiger, leopards, and the moderately large serval, jungle-cat, and **caracal,** all African and Indian species In North America the only large form is the **puma** or mountain lion, also known as the panther, painter, catamount, and cougar, which is represented by four species ranging from Florida to the west and northward in the Rocky Mountains and in the coastal area South America has the **ocelot** or tiger cat, the **jaguar,** and the **jaguarondi** cat or eyra, all of which enter Texas by way of Mexico The lynxes include a European species and in North America the **wildcat** or bobcat, the Canadian lynx, and a few less familiar species (A W L)

CATABOLISM **Metabolism.**

CATACLASTIC As proposed by Teall in 1887 this term has the same meaning as **crush breccias** This term is also applied to the deformation and granulation of minerals such as may take place during dynamic **metamorphism.** (R M F)

CATACLYSM. Before the doctrine of uniformitarianism (the uniformity of all geologic processes throughout all time) had been promulgated by Sir Charles Lyell, it was believed that mountains, mountain ranges, deep valleys and rugged highlands or other features of the earth's surface had been produced by great and sudden convulsions called cataclysms The word cataclysm is derived from the Greek words denoting downward and to wash away, i e, floods, the implication being that great floods or violent earthquakes had been instrumental in producing the relief features of the surface of the globe, now known to be the result of the slow but ever-continuous action of the processes of weathering and **erosion.** (E S C S)

CATALEPSY. A nervous seizure, marked by absence of voluntary motion and of sensibility The trance lasts from a few minutes to several days During the attack, the body is cold and pale, and the pulse and breathing are slow It commonly occurs in **melancholia** and **dementia.** (R S M)

CATALYSER. **Catalysis.**

CATALYSIS. This is a phenomenon observed in chemical reactions whereby the reaction between two or more substances is influenced by the presence of a third substance (the catalyst) which remains unchanged in the process For instance **hydrogen** and **oxygen** gas do not react with each other appreciably at room temperature The introduction of **platinum** powder produces an instantaneous union of these gases to give water The platinum is chemically unchanged in this process and if proper precautions are taken can convert an infinite amount of hydrogen and oxygen into water This is an example of positive catalysis There are cases known of negative catalysis in which the rate of a reaction is repressed by the presence of a foreign body An example is the inhibition of the **hydrogen peroxide** decomposition by traces of **acetanelid** In the case of gaseous reactions in the presence of solid catalysts, the reaction takes place on the surface of the solid and the adsorption of the gaseous reactants and products plays an important role It has been found that certain substances (called promoters) having themselves but little catalytic ability, when added to a catalyst enhance the latter's catalytic ability An example is the use of **alumina** to promote the catalytic ability of **iron** for the reaction of **hydrogen** and **nitrogen** to form **ammonia.** Since the catalytic reactions take place on the surface of the catalyst the latter must be prepared in as highly subdivided a state as possible This is accomplished by using the catalyst in a colloidal state or dispersing it on inert carriers Charcoal, alumina, silica gel, kieselguhr, etc, are common catalytic carriers Many catalysts lose their catalytic activity completely when exposed to the action of minute amounts of certain substances called poisons Thus arsenic compounds poison platinum catalysts The following are a few of the more important catalytic reactions

1 **Hydrogen** and **oxygen** react to form water in the presence of **platinum** and other finely divided metals
2 Hydrogen and **nitrogen** react to form **ammonia** in the presence of iron, and alumina (promoter)
3 **Sulfur dioxide** and oxygen react to form **sulfur trioxide** in the presence of platinum or of **vanadium** oxide
4 **Carbon** monoxide and hydrogen react to form **methane** in the presence of nickel
5 Carbon monoxide and hydrogen react to form **methanol** in the presence of **zinc** and **chromium** oxides
6 **Carbon** monoxide and hydrogen react to form a synthetic gasoline in the presence of **nickel** and **thoria**
7 Liquid fats and hydrogen react to form solid fats in the presence of nickel
8 Coal and hydrogen react to form **petroleum** (Bergius Process), in the presence of various catalysts
9 Carbon monoxide and oxygen react to form carbon dioxide in the presence of copper and manganese oxides

See also **Chemical Changes** and **Hydrogenation.** (R K S)

CATALYST. **Catalysis.**

CATAMOUNT Mammalia, Carnivora The **puma** or mountain lion Sometimes applied to the **wildcat.** (A W L)

CATARACT. Any opacity that develops in the crystalline lens of the **eye** or the capsule of the lens

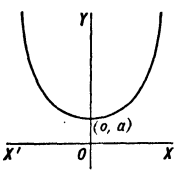
Cataracts may be primary or secondary to another condition They also may be partial or complete, stationary or progressive, hard or soft They may be due

to a number of causes. The most common predisposing cause is age, hence a senile cataract is frequently seen. Other causes, either direct or predisposing, are **heredity**, faulty intra-uterine development, general diseases (especially **diabetes**), injury, and various diseases of the eye.

Treatment of cataract, uncomplicated by other eye disorders, is very successful. Useful and even perfect vision follows in the great majority of cases. The usual treatment is surgical removal of the lens when vision is impaired. After removal of cataract, the patient must wear strong convex glasses to compensate for loss of the lens of the eye. (R.S.M.)

CATARRH. An inflammation, usually chronic, of any mucous membrane. The term generally applies to the mouth, throat, or nose. (R.S.M.)

CATAWBERITE. The term applied by Lieber to a **metamorphic** rock chiefly composed of **magnetite** and **talc.** (R.M.F.)



Catenary

CATBIRD. Aves, Passeriformes. 1. A common North American bird, *Damatella carolinensis*, related to the mockingbird and the thrashers. Although quietly colored in slate gray it is a welcome resident because of its fine singing. 2. An Australian **bower-bird.** (A.W.L.)

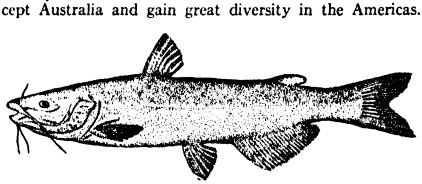
CATENARY. The catenary is the **locus of the equation.**

$$y = \frac{a}{2}(e^{x/a} + e^{-x/a}) = a \cosh \frac{x}{a}.$$

It is the shape of the curve assumed by a uniform, heavy flexible cord freely suspended from its extremities. (L.L.S.)

CATERPILLAR. The **larval** form of the **butterflies** and **moths.**

CATFISH. Pisces, Teleostei. Fishes (**Pisces**) of many species without scales, although the skin has bony plates in some species. Barbels occur on the head. They are represented in the fresh waters of all continents except Australia and gain great diversity in the Americas.


Catfish.

The catfishes are important food fishes in some parts of the world. In North America the channel cats are especially desirable. They reach large size in some of the larger rivers and lakes.

Some of the species included in the group whose names do not indicate the association are the **bullheads,** horned pout, goujon or **mud cat,** mad toms, and the wels of Europe. (A.W.L.)

CATGUT. Sheep's intestine which has been treated, made **aseptic,** and prepared into strands of various strengths for used in surgery as an absorbable **suture** or **ligature** material. Chromic catgut is treated with **chromium** trioxide and takes a longer time to be absorbed by the body than plain untreated catgut. (R.S.M.)

CATHODE. The cathode is that electrode in an **electrolytic cell** or a gaseous discharge **vacuum tube** which has the lower electric potential. (R.K.S.)

CATHODE RAYS. An emission from the cathode in a **vacuum tube,** which becomes more conspicuous as the tube is cleared of gas molecules with diminishing pressure. At pressures of 0.01 millimeter of mercury or lower, the rays leave the cathode normally to its surface and move in straight lines across the tube, as shown by the early experiments with the **Crookes tube.** By using a concave cathode, they may be brought to a focus, and any obstacle placed at the focus becomes intensely hot. For some time doubt existed as to the nature of these rays, but Sir J. J. Thomson finally proved that they are negatively electrified particles with a **charge-mass ratio** of about 1.7×10^8 coulombs per gram; and that they move with speeds varying with the voltage but commonly of the order of one-third the speed of light. We now know that they are **electrons,** released from the metal of the cathode and driven away by its negative voltage.

Lenard (1898) showed that cathode rays will penetrate through thin aluminum or gold leaf and can thus be allowed to pass outside the tube. Electrons so escaping are called Lenard rays. Recent technique due to Coolidge and others has produced Lenard rays of such high speed as to be comparable to the **beta rays** from radium. (L.D.W.)

CATIONS. Cations are positively charged **atoms** or **radicals.** (R.K.S.)

CATKIN. **Ament.**

CATLINITE. A red, siliceous **clay** occurring in Minnesota. (R.M.F.)

CATNIP. **Mint Family.**

CAT'S-EYE. This name is applied to varieties of several mineral species that enclose fine fibers or cellular structures in parallel arrangement, causing, particularly when cut and polished *en cabochon*, a band of reflected light to play on the surface of it. Because of fancied resemblance to the eyes of cats, such stones are called cat's-eyes, and the effect is referred to as chatoyancy. The stone is said to be chatoyant. True cat's-eye is a variety of **chrysoberyl,** but **tourmaline** and **quartz** are also found which show this same effect. Ordinary quartz cat's-eyes are a pale yellowish or greenish, but a beautiful golden yellow sort is known from South Africa called tiger's-eye which probably represents a replacement of **crocidolite** by quartz. (E.S.C.S.)

CAT-TAILS. *Typha. latifolia* and related species. Typhaceae. These are well-known plants growing in marshy places and along the margins of ponds and slow-flowing streams. Usually they form extensive stands, crowding out nearly all other plants. The cat-tail plant has a thick horizontal **rhizome** which grows along the surface of the ground or just beneath it, generally in several inches of water. From this rhizome the long linear leaves grow in erect bunches. These leaves have widely overlapping bases and are from three to six feet long. The flower stem rises stiffly erect in the center of the bunch of leaves and is from three to eight feet tall. Near its tip the cat-tail bears a dense cylindrical spike of flowers which are unisexual. The **pistillate** flowers are found below the **staminate** flowers. Each staminate flower consists of from two to five or more stamens surrounded by a number of hairs. Soon after the pollen grains are shed the staminate flowers drop off, leaving the naked tip of the stem projecting above the pistillate spike. Each pistillate flower consists of a single pistil surrounded by a group of long hairs. Cat-tails are entirely wind-pollinated. After pollination the **ovaries** develop to one-seeded **achenes** surrounded by the fine hairs. These fruits form the familiar black or dark-brown cat-tail of late summer and fall. The seeds are blown about by the wind, the long hairs greatly aiding in distribution.

The dried leaves of cat-tails were formerly used in making the seats of rush-bottomed chairs. The hair-covered seeds have been used to a slight extent for stuffing for pillows and small things. The entire fruiting stem is often used as an ornament. (R.M.W.)

CATTLE. Mammalia, Artiodactyla. Broadly applied to all bovine animals, including oxen, buffalos, sheep, goats and others but more commonly restricted to the **buffalos, oxen,** and related species and especially to the domesticated races. (A.W.L.)

CAUCHY-RIEMANN DIFFERENTIAL EQUATIONS. *Analytic Functions of a Complex Variable.*

CAUCHY'S THEOREM ON ANALYTIC FUNCTIONS. If $f(z)$ is an **analytic function of a complex variable** z which has no singularities within or on a given closed curve C, then $\int_C f(z)dz = 0$, where the integral is extended over the entire contour C. (L.L.S.)

CAUDAL FILAMENT. A median jointed appendage resembling an antenna and sensory in function, found in some of the primitive **insects.** (A.W.L.)

CAUDATA. Urodela.

CAULDRON-SUBSIDENCE. A term proposed by E. B. Bailey and other Scottish geologists for the sinking of the portion of the roof or cover of a deep-seated **igneous intrusion,** aided by circumferential **faults.** (R.M.F.)

CAULIFLOWER. Brassica.

CAUSTIC. Term applied to bases or alkalis. Caustic potash, **potassium** hydroxide; caustic soda, **sodium** hydroxide; caustic lime, **calcium** oxide; lunar caustic, **silver** nitrate. (R.K.S.)

CAUSTICS. Spherical Aberration.

CAVE. A cave is a natural opening in the earth's surface, and from time immemorial caves have attracted much attention because of the inherent mystery suggested by them or from the fact that they have been used as the refuge of robbers, as depositories for their plunder, and as the first habitations of primitive man. Caves are chiefly developed in **limestone** regions where because of the easy solubility of **calcium** carbonate the ground water succeeds in dissolving and carrying away large quantities of this otherwise physically resistant rock. The water enters through the joint cracks or bedding planes, passing downward by gravity until it becomes saturated with calcium carbonate or reaches the ground water level where more or less complete saturation exists. With the continued solution of the limestone, large channels and even great underground chambers are formed. The steady removal of the limestone in solution thus tends to weaken the whole formation with the result that the roofs of underground channels or chambers frequently collapse, forming depressions varying in size from a few feet in depth and of small area to those of many acres and a hundred or more feet in depth. Such fallen-in areas are called sink holes or simply sinks. If they contain water they are then referred to as sink hole lakes. Sometimes after the continued collapse of the roofs of caverns a small portion will remain thus forming a natural bridge, the classical example of which is the Natural Bridge, Virginia.

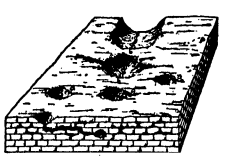


Diagram illustrating the origin of caves (in black), sink holes (a), and natural bridges (b) in limestone. (After H. F. Cleland.)

Wherever limestones occur, if there is a sufficient supply of ground water, underground drainage will develop.

Among the more famous caverns of the United States are the Luray and Shenandoah Caverns in Virginia, Mammoth Cave, Kentucky and Carlsbad Caverns in New Mexico.

Certain parts of Florida abound in sink holes and sink hole lakes. An important feature in caverns is the so-called rock icicles or stalactites and their associated stalagmites. (E.S.C.S.)

CAVE-CRICKET. Camel cricket.

CAVENDISH EXPERIMENT. *Gravitation Constant.*

CAVIARE, CAVIAR. The roe of **sturgeons,** preserved in brine and used especially as an hors d'oeuvre. (A.W.L.)

CAVITATION. It is possible to operate the blades of a water screw propeller or a hydraulic turbine at a condition such that cavities are formed in the wake or about the blade, resulting in vibrations, loss of efficiency, or corrosion of the blades. The chief cause of trouble with **hydraulic turbine** runners is corrosion and attendant pitting of the blades or buckets. This occurs chiefly in regions of high vacuum, as, for instance, near the **draft tube,** and is probable due to the liberation of oxygen from the water at low vapor pressure. The use of too high **specific speed** for the head available is thought to aggravate this trouble.

When the engines or turbines of a ship drive the propeller blade through the water at excessive speeds the blade may move through the water faster than the water can close in around it. The cavities that are thus formed cause a great loss of propulsive efficiency, and should be avoided. To avoid cavitation the blades of a marine propeller are made short and wide. (F.T.M.)

CAVY. Mammalia, Rodentia. Stoutly built **rodents** with short legs and a small or rudimentary tail, represented by the common **Guinea-pig.** Among the other species are the **capybara,** largest of the rodents and aquatic in habits, although most of the species are small and terrestrial. All are native to South America. They constitute the family Caviidae. (A.W.L.)

CAYMAN. Caiman.

CECOSTOMY. An artificial opening made through the abdominal wall into the **cecum.** This is done temporarily or permanently to provide an artificial **anus** when the large intestine is obstructed or is the site of certain chronic diseases such as **colitis.** It is also a frequent operation when **cancer** is present in the large intestine, as a preliminary stage before removal of the cancerous growth. (R.S.M.)

CECUM, CAECUM. A sac-like, blind, pouch of the large intestine, situated below the level of the junction of the small intestine into the side of the large intestine. At the lower portion of the cecum, but variable in position, is the **appendix.** (R.S.M.)

CEDAR. Under this name many trees, of several genera, are included. All are characterized by having in the woody tissue an aromatic **volatile oil** which persists for a long time after the tree is cut down and dried. The wood of many cedars is very resistant to rotting, therefore cedar was a favored material for rail fences. The oil present in the wood is repulsive to insects. Among the many cedar trees are *Thuia plicata,* the Western Red Cedar, much used for shingles; *Juniperus virginiana,* Eastern Red Cedar, an important wood used in the making of cedar chests and also lead pencils; *Cedrela odorata,* Spanish Cedar, a tree related to the true **Mahogany** tree, and used in the manufacture of furniture and for cabinet work, also for cigar boxes. In

these and in its other uses, Spanish Cedar is frequently cut into thin sheets and applied as a veneer over cheaper woods Cedar of Lebanon, *Libocedrus Leboni*, and White Cedar, *Chamaecyparis occidentalis*, are frequently planted for ornamental purposes, wherever they are hardy. (R M W)

CEILING. The term ceiling is used to designate vertical operating limits of an **airplane.** An airplane flies by virtue of expenditure of a certain amount of horsepower by an engine When the horsepower thus available from the engine exceeds that required to overcome the air resistance due to motion of the plane, the excess may be employed by the pilot for increasing the velocity or for climbing at constant velocity However, as the altitude is increased the performance of the internal combustion engine is affected by the rarefied air, with the result that the horsepower available from the engine will have diminished until it is just sufficient to maintain horizontal flight This altitude is the absolute ceiling of the plane, above which it is not possible to climb Since theoretically it takes a plane an infinite time to reach absolute ceiling, the service ceiling is a more practical measure of performance This is the altitude at which the rate of climb has diminished to 100 feet per minute

From a meteorological standpoint, ceiling is the maximum altitude at which existing meteorological conditions allow visibility of the ground sufficient for practical piloting operations (F T M)

CELERY. *Apium graveolens* Umbelliferae A biennial plant growing wild in the marshes of western Europe The wild plant has a rank taste and strong characteristic odor cultivation has largely resulted in the elimination of these objectionable features, and has produced a very much enlarged leaf-stalk extensively used as a salad plant In another form, celeriac, the root stock and stem are much enlarged (R M W)

CELESTIAL MECHANICS The term celestial mechanics is applied to that field of astronomical study and research which deals with the motions of two or more bodies in space under the influence of their mutual gravitational attractions The fundamental elements of the field are found in the **Newtonian** law of universal gravitation, the laws of motion, and the **Keplerian** laws of planetary motion In the classical theory we find space of three dimensions treated, with time considered as an independent variable Within recent years some slight modifications of the classical theory, particularly when the time interval is very long or velocities and accelerations are very high, have become necessary on account of the **Theory of Relativity.** Under the general heading of celestial mechanics we find such problems discussed as the development of the various methods for **orbit** computation, methods for computing **perturbations,** and solutions of the **problem of three bodies.** (W K G)

CELESTIAL SPHERE The concept of a sphere on which all of the so-called "fixed stars" are projected persisted in all descriptions of the structure of the universe from the earliest historical records down through the 17th century Even in modern times such a concept is very convenient for discussing the common motions of the stars, and the individual motions of the different members of the solar system

This celestial sphere may be defined as a sphere of infinite radius with the center located within the solar system. The reference frames for all systems of astronomical **spherical coordinates** are established on the celestial sphere

When projecting the different members of the solar system onto the celestial sphere it becomes necessary to restrict the location of the center to some particular point within the solar system If the center of the celestial sphere is considered as a point on the surface of the earth we have systems of **apparent coordinates;** with the center at the center of the earth we have **geocentric coordinates;** at the center of the sun, **heliocentric coordinates,** at the center of **Jupiter,** Jovicentric coordinates, etc

Due to the fact that the earth is actually rotating about an axis, the celestial sphere is apparently rotating, as seen from the earth, about an axis parallel to the axis of the earth and with the same angular velocity as the earth, but, of course, in the opposite direction For purposes of convenience it is customary to refer to this apparent rotation simply as the rotation of the celestial sphere All systems of spherical coordinates which are established on the sphere, such as the **equatorial, galactic, ecliptic,** etc, rotate with the sphere, while the **horizontal** system apparently remains fixed in space (W K G)

CELESTITE or CELESTINE. The mineral celestite is composed of **strontium** sulfate, $SrSO_4$, occasionally with **calcium** and **barium.** It crystallizes in the **orthorhombic** system in tabular or prismatic crystals More rarely it may be pyramidal or simply fibrous or granular Two essentially perfect cleavages may be observed, one parallel to the base, the other parallel to the prism Its fracture is uneven, hardness, 3–3 5, specific gravity, 3 95–3 97, luster, vitreous, color, white, but may be slightly reddish or bluish, transparent to translucent Celestite may occur with **gypsum** and salt associated with beds of limestone, or by itself in large commercially important veins It sometimes occurs with sulphur in volcanic localities and is often a gangue mineral in veins of **galena, sphalerite** and similar metallic minerals In Europe there are many localities for fine crystals, especially in England In the United States celestite is found in New York, Pennsylvania, West Virginia, Tennessee, Kansas, Colorado, and California The first celestite described was the delicate blue material from Blair County, Pennsylvania Its "celestial" tints suggested the name Celestite resembles barite very strongly (E S C S)

CELIOTOMY. The opening of the abdominal cavity by a surgical incision (R S M)

CELL. For the cell as a source of electricity, see **Electrical Cell** In biology a cell is (1) Essentially a small chamber, and so applied in the designation of cells in honey-comb, the water cells in the stomach of the camel, and other structures (2) Also the unit of living matter Early observation of cells were based on plant **tissue** in which the cell walls were the most prominent structure, hence the units were regarded as small compartments Even after the discovery that these units are small masses of living substance and that the enclosing wall is merely one component which is not always present, the name cell was retained with the new meaning The first sound expression of the cell theory is credited to Schleiden and Schwann, in 1838 and 1839

Cells are divided into two principal parts, a nucleus which is usually central or nearly so and an enveloping cytosome, more often known by the name of the material composing it, cytoplasm Together the nucleus and cytosome make up a living unit which has been named the protoplast or energid, it is enveloped by various membranes which complete the cell In some cells the nuclear constituents are more numerous, including several separate parts which may be similar and may differ visibly, as in the micronuclei and macronuclei of certain single-celled animals All of these major parts of the cell are themselves complex

The cytosome is the part of the cell in which are differentiated the structures by which its special functions are carried out, hence cells are much more varied in cytoplasmic structure and in general form than in their nuclei Cells often show a clear peripheral zone of

cytoplasm called the ectoplasm and an inner mass containing various formed constituents and called endoplasm The more common of the formed constituents are mentioned in the following paragraphs

The nucleus differs greatly in form Although most often spheroidal to slightly elongate it is sometimes of complex shape It is invested by a delicate nuclear membrane and contains a ground substance called the karyolymph or enchylema in which are two formed components, the linin or supporting network and the chromatin In the resting cell chromatin is usually dispersed in granules or in a reticular form It is named for its strong affinity for stains, usually for the basic dyes, which leads it to color readily in preparation for microscopic observation Since it sometimes takes acid stains the tendency to distinguish the chromatin according to its staining reaction led to the terms oxychromatin and basichromatin, and these led in turn to the suggestion of another collective term, karyotin

The nucleus also contains knots of chromatin known as karyosomes and other chemically different bodies called nucleoli or plasmosomes In some cells the two are closely united to form amphinucleoli

All evidence points to the chromatin as an essential substance which controls the differentiation and constructive action of the cell and as the bearer of hereditary characteristics The chief evidence of these functions is found in **cell division** and **heredity**, although the removal of nuclei from living cells by microdissection has disclosed the importance of this body in metabolism Enucleate one-celled animals continue their activities as long as they have the energy but are unable to assimilate more energy-bearing materials

The cytoplasm contains an important body known as the central body or centrosome which is active during cell division and is often self-perpetuating In some cases a structure of similar functions lies within the nucleus The centrosome contains a central granule or minute rod, sometimes paired, which is called the centriole This structure is the most common constituent, it is always present, whether or not the surrounding structures appear, and is the active part during cell division When the investing portion of the centrosome is large it has been called attraction sphere, centrosphere, periplast, and idiosome in various cases but the term centrosome is commonly adopted The centriole may also be associated with motile appendages of the cell, forming the basal body from which the central filament of a flagellum or cilum arises, it is then called a blepharoplast

The cytosome of many cells contains differentiated fibrils which are very fine thread-like structures of various functions Good examples are the myofibrils of muscle cells and the neurofibrils of nerve cells, the former are contractile and the latter may be conductors

Plastids are relatively large self-perpetuating bodies which are frequent in plant cells but rare in those of animals The chloroplasts found in the green parts of plants are the most abundant example

Chondriosomes are specialized bodies of various forms, varying from granular mitochondria to rod-like chondrioconts Mitochondria sometimes associate in linear groups called chondriomites or in rounded chondriospheres The functions of all such bodies are uncertain According to one view they have the power to act upon special chemical constituents of the cytoplasm

Vacuoles are globular cavities filled with liquid In the one-celled animals they contain food and water during digestion, and in the case of the contractile vacuoles the waste products in solution

The Golgi apparatus is one of the most baffling of all cell structures Since it is revealed by definite methods of preparation it seems to have definite chemical properties, yet it is extremely diverse and is of uncertain function It has also been named Golgi bodies, trophospongium, internal reticular apparatus, dictyosomes, and canalicular system

The Golgi apparatus is either a somewhat reticular structure, usually near the central body and nucleus, or a scattered lot of reticular or granular parts The separate bodies of which it is composed are of many shapes and have been designated as batonettes, among other terms

Many cells contain cytoplasmic granules of various kinds whose functions are well understood They include pigment granules, granules of material for storage, secretory granules which are transformed into the special secretion of the cell during periods of activity, and other special forms

The membranes surrounding the cytosome in animal cells are thin They include a delicate plasma-membrane which is regarded as a peripheral layer of the cytoplasm itself, in addition to which there may be an outer cell wall The latter is secreted by the cell but is not a part of the living cytosome, it is formed of cellulose in many plant cells and in animal cells is represented most strikingly by such highly developed structures as cuticular layers

Other facts concerning cells are discussed under **tissues, cell division, gamete,** and **gametogenesis** (A W L)

CELL DIVISION. The subdivision of cells is a fundamental expression of the power of reproduction inherent in all living matter All living cells are capable of dividing to form others or are the products of such division

Cell division is of two kinds, amitosis and mitosis The former is an apparently simple elongation, constriction and division of the cell, including its nucleus, and is of relatively rare occurrence It takes place chiefly in cells of temporary value, as in certain accessory reproductive structures

Mitosis is a much more complex process of cell division which prevails in the organic world and by its orderly sequence of stages indicates the precise maintenance of essential constituents of the cell It is conveniently divided into four stages, the prophase, metaphase, anaphase, and telophase

During the prophase the centrioles separate, or if only one is present it divides and the two halves separate, and a series of radiating lines, the astral fibers, forms about each As these two asters continue to draw apart similar fibers appear between them in the form of a spindle The whole structure constitutes the achromatic or mitotic figure

At the same time the chromatin within the nucleus collects into a more compact filament called the spireme, the nuclear membrane breaks down, and all of the nucleus but the chromatin disappears in the cytoplasm The spireme breaks up into a number of parts characteristic of the species These bodies, called chromosomes, migrate into the equator of the spindle to form an equatorial plate, and the prophase is completed

The metaphase is characterized by the longitudinal splitting of each chromosome, or by a similar paired condition resulting from a previous change, perhaps a splitting in the spireme stage The exact details of this process are not known and it is entirely possible that it varies in different species

During the anaphase one half of each chromosome moves toward the nearest aster

In the telophase this migration is completed, the cytoplasm constricts and divides, or is separated by the formation of a partition between the two groups of chromosomes, and the two daughter cells undergo a return to the resting form

Since the differentiation exhibited by many chromosomes is longitudinal, this process of cell division apparently results in the formation of daughter chromosomes exactly equivalent to those of the parent cell, and guarantees to each daughter nucleus a similar assortment of these bodies With the exception of the centriole the cytoplasmic constituents appear not to be evenly divided

Gametogenesis is a special type of cell division (A W L)

CELLULITIS. Inflammation of the cellular tissues, marked by swelling, redness, heat and tenderness During this stage of inflammation, **pus** is absent, although an abscess is usually surrounded by an area of cellulitis (R S M)

CELLULOID. Plastics.

CELLULOSE This is a polysaccharide having the formula $(C_6H_{10}O_5)_n$ (See **Carbohydrate**) It is the substance which composes the greater part of the **cell** walls of plants **Cotton** fibers are over 90% pure cellulose Cellulose is insoluble in water, but when dry it soaks up water readily until it is saturated Water passes readily through the cellulose walls of plant cells In many cells the cellulose wall is strengthened by the addition of lignin, forming lignocellulose Being insoluble in water and not affected by digestive juices, cellulose is not digestible and so is not a food stuff for most animals

In many cells, especially in those of seeds and in fungi, the walls are formed of hemicellulose, a substance resembling cellulose in many of its properties, but more soluble Hemicelluloses, of which there are many kinds, are apparently a food reserve of the plant and may be used when need arises (For further details on cellulose and its chemistry, see **Carbohydrates**) (R M W)

CELSIUS SCALE. Temperature Scales.

CEMENT. Cement is a finely powdered substance which possesses strong adhesive powers, when combined with water Gypsum plaster (See **Calcium**), common lime, hydraulic limes, Puzzolan, natural and Portland cements are a few of the materials which are used for cementing purposes

Portland cement, which is the most important of these materials since it is a basic ingredient of concrete, was first manufactured in England in the early part of the nineteenth century It derived its name from the fact that this newly discovered cement resembled a building stone that was quarried near Portland, England

There are three fundamental stages in the process of manufacture of Portland cement, namely, (1) preparation of the raw mixture, (2) production of the clinker, (3) preparation of the cement Whether the process used is wet or dry, the raw materials are selected, analyzed, and mixed so that, after treatment, the product, or clinker, has a desired, narrowly specified composition A factory analysis of slurry, where the wet process is in use, is as follows **calcium** oxide 44%, **aluminum** oxide 3 5%, **silicon** oxide 14 5%, **ferric** oxide 3%, **magnesium** oxide 1 6%, loss on ignition about 33% (largely carbon dioxide), showing that the composition of the resulting burned clinker is essentially a calcium aluminosilicate. The system calcium oxide-aluminum oxide-silicon oxide has been determined by Rankin and co-workers In some places the composition of the rock is practically of the desired composition, and in other places clay and limestone are mixed in the desired proportions

The raw mixture is heated in a continuously operated, long, almost horizontal, slowly rotated furnace or kiln at a high temperature The temperature is regulated so that the product consists of sintered but not fused lumps This is clinker Too low a temperature causes insufficient sintering, and too high a temeprature results in a molten mass or glass, the product in either of these cases being valueless for cement purposes Clinker is unaffected by water, and may be stored indefinitely without detriment In 1824, Joseph Aspin, an English bricklayer, took out a patent for the manufacture of an improved cement, which he called Portland cement because, after hardening, it looked like Portland stone, a famous English building stone The cement thus produced was not what is known as Portland cement as the temperature of burning was not sufficiently high The value of burning at a temperature sufficiently high to cause incipient fusion was soon afterwards discovered

In order to obtain the desired setting qualities in the finished cement, there is added to the clinker about 2% of gypsum (calcium sulfate, $CaSO_4 \cdot 2H_2O$), and the mixture is pulverized very finely For every ton of Portland cement shipped, over two and one-half tons of raw materials *and* cement clinker must be ground to the fineness of flour, and in addition one-half ton of coal or equivalent fuel is burned Since most of the coal so used is powdered, the total weight of materials to be ground per ton of cement is about three tons Furthermore, some six million firebricks are used annually in the United States for relining cement kilns

When Portland cement is mixed with water the product sets in a few hours and hardens over a period of weeks The initial setting is caused by the interaction of water and tricalcium aluminate ($3CaO \cdot Al_2O_3$), present in the cement, accompanied by the separation of gelatinous hydrated product The later hardening and the development of cohesive strength are due to the interaction of water and tricalcium silicate ($3CaO \cdot SiO_2$), also present in the cement, accompanied by the separation of gelatinous hydrated product In each case the gelatinous material surrounds and cements together the individual grains The hydration of dicalcium silicate ($2CaO \cdot SiO_2$), also present in the cement, proceeds still more slowly than of the above compounds The ultimate cementing agent is probably gelatinous silica (SiO_2), and it is thought by some that the value of the aluminate lies in its action as a flux in the burning of the clinker

The analysis of the finished cement made from the above noted slurry is as follows calcium oxide 64%, aluminum oxide 5 5%, silicon oxide 21%, ferric oxide 4 5%, magnesium oxide, 2 4%, sulfate 1 6%, loss of ignition about 1% (largely water)

ANALYSIS OF MATERIALS USED FOR MANUFACTURE OF LIME AND CEMENT

Material	From	SiO_2	Fe_2O_3 Al_2O_3	CaO	MgO	CO_2	SO_3	Used for
Limestone	Annville, Pa	0 36	0 45	54 45	0 54	43 24		Portland cement
Limestone	Glens Falls, N. Y	3 30	1 30	52 15	1 58	40 98		" "
Limestone	Mitchell, Ind	0 74	0 13	52 94	1 87	43 68		" "
Marl .	Bronson, Mich	1 78	1 21	49 55	1 30	40 35		" "
Cement rock	Nazareth, Pa	13 44	6 60	41 84	1 94	32 94		" "
Cement rock	Martin's Creek, Pa	11 11	6 31	42 51	2 89	36 57		
Clay .	Alpena, Mich ..	61 09	26 97	2 51	0 65	.	1 42	" "
Clay .	Suisun, Cal ..	58 44	26 50	1 70	1 88			" "
Cement rock	Rondout, N Y	15 37	11 38	25 50	12 35	34 20		Natural cement
Limestone	Union Bridge, Md	0 89	0 47	54 68	0 32	43 44		Lime
Limestone	Woodville, Ohio	0 78	0 48	31 15	20 78	45 76		"
Oyster shells . .	Long Island Sound	3 30	0 25	52 14	0 25	41 61		"

Deductions regarding the mechanism of setting and hardening, and the identity of the substances concerned are the results of extensive studies, involving the use of the microscope in the examination of thin sections, on the individual compounds, the clinker, and the resulting concrete Elaborate researches have also been conducted to determine the best way of incorporating the ingredients of concrete, the nature of the aggregate (sand, gravel, crushed rock) to be used, and the proportions of cement, water, and aggregate, in order that the resulting concrete, really an artificial rock, shall possess the greatest possible strength

ANALYSIS OF PORTLAND CEMENTS *

Where Made	Made from	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Loss
New Jersey	Cement rock and limestone	21 82	2 51	8 03	62 19	2 71	1 02	1 05
Pennsylvania		21 94	2 37	6 87	60 25	2 78	1 38	3 55
Michigan	Marl and clay	22 71	3 54	6 71	62 18	1 12	1 21	1 58
Ohio		21 86	2 45	5 91	63 09	1 16	1 59	2 98
Virginia		21 31	2 81	6 54	63 01	2 71	1 42	2 01
Missouri	Limestone and clay	23 12	2 49	6 18	63 47	0 88	1 34	1 81
Pennsylvania †		23 56	0 30	5 68	64 12	1 54	1 50	2 92
Illinois		22 41	2 51	8 12	62 01	1 68	1 40	1 02
Germany	Blast furnace slag limestone	20 48	3 88	7 28	64 03	1 76	2 46	
Belgium		23 87	2 27	6 91	64 49	1 04	0 88	
France		22 30	3 50	8 50	62 80	0 45	0 70	
England		19 75	5 01	7 48	61 39	1 28	0 96	
Germany ‡	Iron ore and limestone	20 5	11 0	1 5	63 5	1 5	1 0	

* From Meade's "Portland Cement" † White Portland cement ‡ Sea water cement

AVERAGE CHARACTERISTIC TESTS OF CEMENT IN THE UNITED STATES *

Class	Materials Used in Making Cement	Specific Gravity	Per Cent Passing Through Sieve		Time of Setting		Tensile Strength in Pounds per Square Inch								
							Neat					1 to 3			
			No 100	No 200	Initial Min	Hard Min	1 Day	7 Days	28 Days	6 Months	12 Months	7 Days	28 Days	6 Months	12 Months
Portland cement	Limestone and cement rock	3 14	93 7	75 2	155	392	371	675	750	789	945	239	315	366	442
	Limestone and clay or shale	3 13	95 0	76 2	172	341	341	696	825	916	919	252	353	401	403
	Limestone and granulated basic blast furnace slag	3 10	98 5		260	500	358	636	790	888	916	226	298	382	396
	Marl and clay or shale	3 11	94 0	79 2	151	357	328	670	772	780	790	269	352	385	395
	Average	3 12	95 3	76 9	185	398	350	669	784	843	893	247	330	384	409
Natural-rock cement	Argillaceous limestone	2 87	92 6	79 9	34	144	129	197	289	404	501	143	226	295	368

* From Meade's "Portland Cement" (R,K S)

CEMENTATION. In geology, cementation is the process of deposition from solution of mineral matter in the interstices of rocks, and is an important factor in the **consolidation** of coarse-grained **clastic** rocks such as **sandstones** and **conglomerates** or **breccias** This action is continually going on in the ground water zone, so much so that the term zone of cementation has come into common use

Cementation may occur in fissures or other openings of the rocks and in time all such spaces will be closed to further deposition or entrance of ground water In metallurgy, cementation is the process by which one substance is caused to penetrate and change the character of another, by the action of heat, at temperatures below the melting points (E S C S, R K S)

CENOGENESIS. The development during **evolution** of **adaptations** which persist only during early stages in the life of the individual, giving way finally to the more primitive adult characters Thus among the insects the **beetle, fly,** or **butterfly** appears to be the original form of the species and the **larva** is a special adaptation which enables the individual to meet special conditions during its growth without giving up the advantages of its adult form (A W L)

CENOZOIC. The latest major subdivision of the geologic time-scale The Era of "recent" life, or age of mammals and modern flora Subdivided, from the base, up into the following Periods **Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, Recent** The term Tertiary is applied to the first five periods The Quaternary begins with the Pleistocene The Era was characterized by vanishing of **Archaic Mammals** (Eocene), rise of higher mammals (Oligocene); culmination of mammals (Miocene), transformation of the ape-like ancestor into man (Pliocene), periodic glaciation and rise of man (Pleistocene) The Cenozoic Era began 60–70 million years ago. (R M F)

CENTAURUS. (The centaur) (Map, page 306) This is a large and brilliant **constellation** of the southern sky, being invisible to observers in North America or Europe Centaurus has two bright stars which are frequently spoken of as the "southern pointers" since the line through them passes through the southern cross (the constellation Crux) The brighter one of these two (Alpha Centauri) is not only the third brightest star in the entire sky, but is also the nearest bright star The distance of this star is 4 3 **light years**, the only star closer than this to the earth being also in the constellation of Centaurus, a faint star known as Proxima Centauri Alpha Centauri is a **double star** and its brighter component is interesting in that it is almost a duplicate of our **sun** in size, temperature, and other physical characteristics (W K G)

CENTER OF CURVATURE OF A CURVE. Curvature of a Plane Curve

CENTER OF GRAVITY. Center of Mass.

CENTER OF MASS. This is a more accurate term for what is commonly referred to as the center of gravity If we imagine a body divided into infinitesimal particles or elements of **mass**, and if each of these elements is acted upon in the same direction, chosen at random, by a force proportional to its mass, it is easily shown that, whatever the direction of this set of parallel forces, their resultant always passes through a certain point, which is the center of mass of the body Since the weights of the particles of a small body constitute approximately such a system of forces, it has become customary to call this point the center of gravity, though it is in general not strictly correct to do so

If the body is given a linear acceleration in any direction without rotation, since the **inertia** of each particle is proportional to its mass and acts in direct opposition to the acceleration, the resultant inertia of the whole body acts in a line through the center of mass, which is therefore properly called also the center of inertia

If any plane is passed through the center of mass of a body, it divides the body into two parts which have the property that their mass moments with respect to the plane are equal but of opposite sign This means that if the mass of each particle is multiplied by its distance from the plane, and the products added, the sum is numerically the same for both parts of the body This principle may be put into mathematical form and the position of the center of mass calculated therefrom It may be shown, for example, that the center of mass of a homogeneous right circular cone is on its axis at a distance from the apex equal to two-thirds of the altitude (I D W)

CENTER OF PRESSURE The point of application of the resultant of all the pressure forces acting upon an exposed area is called the center of pressure Water and air create pressures which are of importance in phases of engineering The center of pressure on a horizontal plane immersed in water to a depth h is the center of the area, that is, the point corresponding to the center of mass of a flat, uniform plate coinciding with the area

More generally, if a plane surface is completely immersed in a liquid at an angle θ with the horizontal, the center of pressure upon that surface lies at a depth below the top of the liquid, given by the equation $d = \sin\theta\ I/M$, in which I is the areal **moment of inertia** of the plane figure with respect to the line of intersection of its plane with the plane of the top of the liquid, and M is the areal **moment** of the figure with respect to the same intersection For a vertical surface ($\theta = 90°$), $d = I/M$ Thus, in the case of a vertical rectangle whose upper and lower edges are horizontal and at depths h_1 and h_2, and whose width is b, we have $I = b/3(h_2^3 - h_1^3)$, while $M = b/2(h_2^2 - h_1^2)$; hence the depth of the center of pressure is

$$d = \frac{2}{3}\frac{h_1^2 + h_1h_2 + h_2^2}{h_1 + h_2}.$$

In particular, if the upper edge is at the top of the liquid, and if the altitude of the rectangle is a, so that $h_1 = 0$ and $h_2 = a$, $d = \frac{2}{3}a$ A rectangular dam 12 feet high, and completely filled with water, would thus have a center of pressure at a depth of 8 feet

Water which is assumed by engineers to weigh 62 5 pounds per cubic foot exerts a horizontal pressure varying uniformly from zero at the water surface to 62 5 h at a depth h The total horizontal water pressure acting on the vertical rectangle mentioned above at two-thirds a below the water surface is 31 25 h^2b pounds in which b is the other principal dimension of the vertical width of the rectangle

The point of application of the resultant air pressure upon an airplane wing is the center of pressure Usually this is taken as the intersection of the pressure line with the basic chord of the wind The center of pressure of the conventional airplane wing varies with the **angle of attack** It is relatively far back towards the trailing edge at the low angles of attack corresponding to high speeds, but moves forward to approximately 28% or 30% of the chord as the angle of attack is increased This movement of the center of pressure is of great importance in any study of aircraft stability That wing which has the least travel of center of pressure is best from the standpoint of stability of the airplane which it supports (F T M, L D W)

CENTIGRADE SCALE Temperature Scales.

CENTIMETER CGS System; Electric and Magnetic Units.

CENTIPEDE Arthropoda, Chilopoda Worm-like animals with segmented bodies, a distinct head, and a pair of jointed legs on most segments of the body They have a pair of **antennae** and the first pair of legs are modified as poison claws for the capture of prey

Centipede.

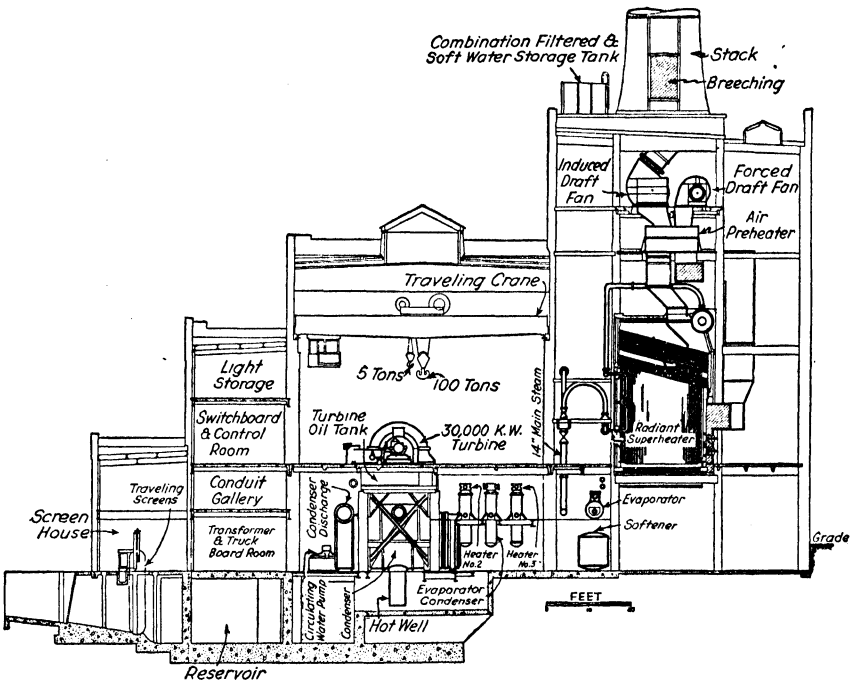
The centipedes differ from the nearly related millipedes (**Diplopoda**) in the presence of poison claws, in having only one pair of legs to a segment, and in the more flattened body Each segment has a dorsal and a ventral plate connected by softer tissue and has the legs joined to the sides of the body (A W L)

CENTRAL CONICS. Conic Sections.

CENTRAL STATION A central station is a place where electrical energy is produced from an original source such as **fuel** or water power, and from which the energy is sent out over a network of transmission lines radiating from the station to the load served The central station is illustrative of the fact that large scale production is the most economical way of providing electrical energy to the individual consumer, for energy thus produced may usually be sold to the individual for less than he could generate it himself, in spite of the fact that there will be transmission losses on the line between the central station and the customer

A typical steam central station will consist primarily of a **boiler, turbine,** and **condenser,** the boiler to produce steam, the turbine to utilize the steam for the production of mechanical power, and the condenser to receive the exhaust steam and reduce it to liquid for returning to the boiler, and at the same time provide a vacuum for the more economical operation of the turbine **A generator** directly connected to the turbine effects conversion of mechanical into electrical energy with a minimum of loss The boiler-turbine-condenser

group must be serviced by auxiliary equipment which might, for clarification, be grouped under two heads,—that auxiliary equipment which might be said to be connected with the flow of air or flue gas in the combustion portion of the plant, and that having to do with the proper conditioning of the condensate produced by the condenser, so that it possesses the requisite heat, pressure, and purity for boiler feed. Included in the first of these groups will be such equipment as **draft fans, stokers, air preheaters,** etc., while in the second group there would be found **feedwater heaters** and **pumps,** feedwater treatment, etc. Between the generator or generators and the outgoing transmission lines, there is contained in the central station no inconsiderable amount of electrical equipment needed for the control and electrical protection of the generators, the supply of auxiliary power, and switching equipment. The accompanying figure is typical of the type of station just described. It shows a boiler room containing the fan and combustion equipment as well as the boiler, a turbine room, which contains little other than the turbines with their generators, but below which will be a basement well filled with condenser and feedwater auxiliaries. Electrical galleries and control rooms on the opposite side of the turbine room from the boiler complete the picture as far as the central station itself is concerned. However, the switching and control as done in the plant, is frequently the remote control of high voltage switching equipment which is located in an outdoor type **substation** usually placed adjacent to the plant. (F.T.M.)



Central station.

CENTRECHINOIDEA. Echinodermata, Echinoidea. An order of sea urchins with a central mouth about which are gills. The commoner sea urchins of North America belong in this order. (A.W.L.)

CENTRIFUGAL FORCE. A manifestation of the **inertia** of a body moving in a curved path, the effect being that of a force directed radially toward the convex side of the curve. The stresses developed in a rotating rigid body which may cause it to fly asunder, the sensations experienced upon rounding a corner in an automobile, and the action of cream separators, centrifuges, and centrifugal driers, are well known examples.

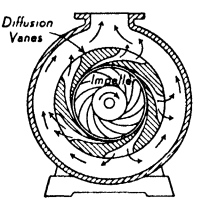
When a particle moves in a circle of radius r with uniform speed V, it is subject to an **acceleration** toward the center equal to V^2/r. This can be produced only by the application of a force in that direction, whose value in absolute units is mV^2/r, m being the mass of the particle. The particle may therefore be regarded as pulling or pushing outward against its constraint with a force of this magnitude. In the case of a rigid body of finite size, it may be shown that the centrifugal force is the same as if the body were concentrated at its **center of mass.**

The centrifugal force involved in the motion of a vehicle around a curve makes desirable the "superelevation" or "banking" of the roadway at an angle dependent upon the curvature and the speed, in order that the wheels of the vehicle may push perpendicularly against the pavement or track. If the speed is V and the radius of the curve is r, then the roadbed should be inclined at an angle s given by the formula: $\tan s = V^2/gr$, where g is the acceleration of gravity. For example, if $V = 40$ feet per second and $r = 1000$ ft., the value of g being 32.15 feet per second per second, the formula gives $s = 2^\circ\ 51'$; which on a standard-

gauge railroad track would require the outer rail to be 2 8 inches above the inner (L D W)

CENTRIFUGAL PUMP. Although this type of pump is now widely used, it is a comparatively new development The centrifugal pump operates at higher speeds than were easily obtainable before the day of the steam turbine or the electric motor, but with the advent of these high speed devices, high efficiencies were made possible in the centrifugal pump field, and its advantages, insofar as size, simplicity, and quietness of operation are concerned, have emphasized the possibilities of this type of pump The figure shows that the essential parts of a centrifugal pump are a rotating member called the impeller, and the stationary case surrounding it The pump action is derived from the conversion of velocity head into pressure head, following the well-known Torricelli formula $V = \sqrt{2gh}$ The liquid to be pumped is let into the pump at the center of the impeller where it is caught in the rotating vanes and caused to take up the angular rotation This rotation produces a centrifugal force outwardly directed, and since the liquid, say water, is free to move outward between the vanes of the propeller, it does so, and is thrown from the periphery with considerable velocity If this velocity were converted to pressure in a haphazard fashion accompanied by eddies, whirlpools, etc, a large portion of the velocity head would be lost in heating effect, and the pressure delivered by the pump would be much less than that which may be achieved through proper control of the water leaving the impeller

Generally speaking, centrifugal pumps are either of the turbine or the volute type The illustration pictures a turbine type pump, in that the case is circular and conversion of the velocity to pressure head is accomplished by stationary diffusing guide vanes in the expanding passages of which the water loses its velocity and builds up a pressure The turbine pump is the more efficient, especially on high heads, but is the more costly Usually the function of the diffusion vanes is more economically obtained by the use of volute-type casing of proper design Since the head produced by a centrifugal pump is a function of the square of the water velocity at the periphery of the impeller, it follows that the pressure achieved by a pump is proportional to the square of the speed of rotation and to the square of the impeller diameter This fact places a practical limitation on the head that can be developed by a single impeller, and pumps for heads higher than practical in a single-stage design are built with several impellers in series, that is, although the impellers are mounted on the same shaft, water passes from the first into the second, etc, each impeller producing an additional increment of pressure Extremely high heads are possible in multi-stage centrifugal pumps With few exceptions, all single stage pumps are the volute type, but builders of high pressure pumps frequently employ diffusers or guide vanes



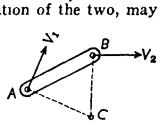
Centrifugal pump

Standard lines of pumps are constructed with impellers of different diameters, and a standard casing Different capacities are obtained either by changing the impeller diameter, or the speed of rotation At constant speed the head is proportional to the square of the impeller diameter, the capacity is proportional to the impeller diameter, and the power required is proportional to the cube of the impeller diameter A pump using a given impeller, but having speed variable, will show that the head is proportional to the square of the speed, that the capacity is proportional to the speed, and that the power is proportional to the cube of the speed The efficiencies of centrifugal pumps vary with the size of the pump Smaller sizes have efficiencies as low as 25%, but 70% to 80% is not uncommon for a large well-designed pump. A workable theory has been derived for the centrifugal pump, but in its simple form it is incomplete, due to certain indeterminate flow conditions in the propeller For example, we find that there are friction and eddying of water in the impeller, and shock loss where the water leaves the impeller and enters the case There is leakage through clearance spaces, and there is disk and bearing friction (F T M)

CENTRIFUGE. A centrifuge is any machine used to separate liquids from solids which might normally be held by them in suspension, or a liquid of one density from that of another The operation of the centrifuge is based upon the setting up of **centrifugal force** by high rotative speed, and thus intensifying otherwise minute differences in the weights of two substances Primarily, a centrifuge consists of a vessel containing the liquid to be centrifuged and the means for whirling that vessel at a high rate of rotation A simple type of centrifuge is frequently seen in medical offices In it the container or containers are simply test tubes which are mounted so as to be balanced and revolved in a horizontal plane by means of a geared handwheel The ordinary cream separator is a centrifuge of a type in which the flow is continuous The centrifugal force throws the heavier milk into a different container than the lighter cream This same principle may be used to dry wet or damp textiles, and has a number of other industrial uses (See **Filtration**) (F T M)

CENTRIOLE. The small body in the centrosome of a cell, important in **cell division.** (A W L)

CENTRODE The path of the instantaneous center of a plane figure having plane motion, that is, motion resulting when all points in the figure move in parallel fixed planes, is called the centrode Any plane body having plane motion which is neither entirely rectilinear nor entirely rotative, but a combination of the two, may be considered at any instant as having rotary motion about a moving point called the instantaneous center of rotation As shown in the illustration the plane body AB has a motion such that the velocity of A is V_1 while the velocity of B is V_2 At the instant corresponding to the position shown for AB the body must be rotating about a point C, which is located at the intersection of the perpendiculars to V_1 and V_2 dropped from A and B respectively C is the instantaneous center of rotation of AB and the centrode is the path traced by the point C while AB is in motion (C W C)



CENTRODORSAL. The central or basal plate (ossicle) of a free-swimming **crinoid.** (A W L)

CENTROID. The centroid of a given geometrical figure (curve arc, portion of a plane or curved surface, or solid) is the point whose **coordinates** are the **mean values** of the coordinates of the points of the given figure, it is independent of the choice of axes The centroid of geometrical figure corresponds to the center of gravity (or center of mass) of a material body of similar form

For a plane curve arc, the centroid is given by formulas

$$\bar{x} = \frac{\int_a^b x ds}{L}, \qquad \bar{y} = \frac{\int_a^b y ds}{L},$$

$$ds = \sqrt{1 + \left(\frac{dy}{dx}\right)^2} \cdot dx = \sqrt{1 + \left(\frac{dx}{dy}\right)^2} \cdot dy,$$

where L is the length of the arc

For a plane area, the centroid is given by:

$$\bar{x} = \frac{\iint_A x\,dS}{A}, \qquad \bar{y} = \frac{\iint_A y\,dS}{A},$$

where A is the area of the given region.

For a solid, the centroid is given by:

$$\bar{x} = \frac{\iiint_V x\,dV}{V}, \quad \bar{y} = \frac{\iiint_V y\,dV}{V}, \quad \bar{z} = \frac{\iiint_V x\,dV}{V},$$

where V is the volume of the given region. (L.L.S.)

CENTROSOME. A small body in the **cell.** (A.W.L.)

CENTROSPHERE. A specialized structure in the **cell.** (A.W.L.)

CENTRUM. Earthquakes.

CENTURY PLANTS. Agave americana, the Maguey or American aloe, is often called the century plant. It has a very short thick stem which bears a rosette of thick fleshy leaves, in which are stored food reserves. Each year the plant adds three or four leaves to the rosette. After a period varying from five to many years (perhaps a century) vegetative growth ceases and flowering occurs. A gigantic terminal flower bud is formed and grows rapidly. It bears many flowers. After the fruit has formed the whole plant dies. It is this habit of bearing flowers only after a prolonged period of vegetative growth that has given this plant the common name, century plant. It is widely grown in cultivation, and seldom flowers under such conditions. The plant propagates vegetatively by means of suckers which grow out from the base of the stem. (R.M.W.)

CEPHALASPIS. Fossil Fishes.

CEPHALIC GLAND. A structure lying in the anterior end of nemertine worms. (A.W.L.)

CEPHALOCHORDATA. Chordata. A subphylum containing a number of species of small marine animals called lancelets. From one of the included genera the name Amphioxus has become common in laboratories, to designate any lancelet, although the animals so designated more commonly belong to the genus *Branchiostoma.*

The lancelets differ from the other groups of lower **chordates** in their fish-like form. They are small, usually from an inch and one-half to rather more than two inches long, and taper toward both ends; the body is laterally compressed. Like other members of the phylum they have a dorsal nerve cord, below it a stiffening longitudinal rod, the **notochord,** and a **pharynx** perforated by many slits. A depression called the vestibule leads to the mouth. It is surrounded by a circlet of slender **cirri. Cilia** about the mouth carry food particles into the alimentary tract where they are caught by the mucus in a ventral groove, the endostyle, carried forward, upward, and then back to the intestine, all by ciliary action.

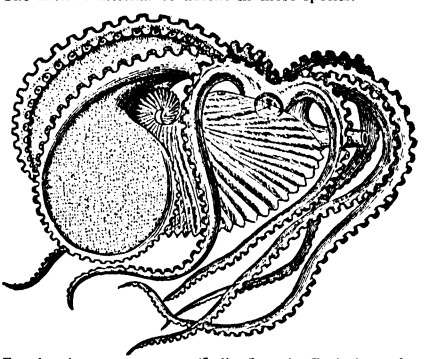
The lancelets are important to the evolutionist in several ways. Since they swim actively in the tides and bury themselves in the sand at other times, taking their food like sessile animals, they illustrate possible ancestral conditions for the tunicates on the one hand and the fishes on the other. The peculiar food-concentrating mechanism described above is also important; it occurs in larval lampreys and provides one of the few well-marked evidences of relationship between the vertebrates and lower chordates.

Although of great scientific interest the lancelets have been of little economic importance. They are caught in large numbers for food by the Chinese. (A.W.L.)

CEPHALONT. An attached form of certain parasitic one-celled animals (**Protozoa, Sporozoa**). (A.W.L.)

CEPHALOPODA. A class of the phylum **Mollusca** containing the **squids, cuttlefish, octopus** or devilfish, and **nautilus.** The class is relatively small but it includes the most highly developed of unsegmented invertebrates and is of some economic importance. All of the species are marine.

These mollusks are distinguished by the following characteristics: 1. The head bears a pair of large eyes which are of the camera type like those of man although they differ fundamentally in structure. 2. The mouth is surrounded by a group of tentacles provided with many cup-like suckers and sometimes with hooks. 3. The **mantle** cavity opens to the exterior by a broad entrance and by a slender tube, the funnel or siphon; by forcing jets of water from the cavity through the siphon the animal propels itself through the water in the opposite direction. 4. The foot is modified to form the siphon and possibly the tentacles. 5. The mouth is provided with a sharp beak superficially like that of a bird of prey. 6. Some species have an ink-sac from which a dark fluid is discharged for concealment. 7. The shell is internal or absent in most species.



Female *Argonauta argo.* (Lull, *Organic Evolution,* after Claus-Sedgwick. Courtesy of Macmillan and Co., Ltd.)

Squids and cuttlefish are eaten by some peoples. The latter species furnishes the cuttlebone so familiar in bird cages and the true sepia pigment. Squids are of importance in North America chiefly as bait in the fisheries of the Atlantic Coast. The octopus has been credited with amazing feats of destruction at sea which are probably entirely imaginary. Giant squids are known to occur, with a total length of fifty feet, which are more likely subjects of these tales, but there is no satisfactory evidence that even these creatures are greatly to be feared by man.

The class is divided into two orders. The first was abundant in the past but is now almost extinct.

Order Tetrabranchiata. Shell external, spiral, and divided into a series of chambers of increasing size, in the last of which the animal lives. Once abundant, now limited to four known species in the genus *Nautilus.*

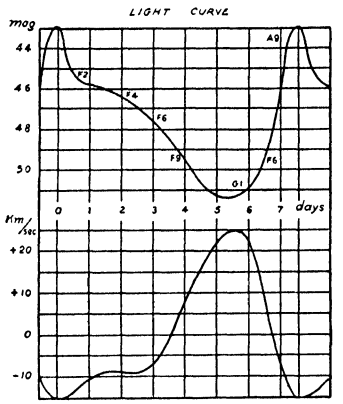
Order Dibranchiata. Shell internal or lacking and usually straight. The **squids** and **cuttlefishes** have ten tentacles, the **octopus** or devilfish and the **argonaut** or paper nautilus only eight. (See also **Invertebrate Paleontology.**) (A.W.L.)

CEPHALOTHORAX. The anterior body region of **spiders, crustaceans** and some other **arthropods,** consisting of the compactly associated head and thorax. (A.W.L.)

CEPHEID. Examination of the curve in the article on **variable stars,** showing the number of variable stars of

different periods, indicates that there are two groups of periodic variables with periods less than fifty days. The term Cepheid, derived from the typical short period variable δ **Cephei**, is applied to all variables with periods under fifty days The group with periods less than one day are frequently referred to as cluster type variables, because of the fact that they are most numerous in globular star **Clusters**, while for purposes of differentiation Cepheids with periods greater than five days are referred to as "typical Cepheids"

The mean **light curve** of a typical Cepheid, together with the mean **velocity curve** plotted on the same time



Light and Velocity Curves of W Sagittarii (From a diagram by Curtiss in *Lick Observatory Bulletins*)

scale, is shown in the accompanying figure (Light and Velocity Curves of W Sagittarii) The general characteristics of the curve are typical for all Cepheids with the rapid rise to maximum followed by a more gradual decline to minimum The descending portion of the curve is characterized in typical Cepheids by certain irregularities

With the change in brightness of a Cepheid there is also a change in **spectral type**, the stars being somewhat bluer at maximum as shown by the letters along the light curve Also correlated with change in brightness of the typical Cepheid is a change in **radial velocity**, with the star approaching the observer at maximum and receding at minimum

The cause of the variability of the Cepheids has been a mystery ever since the study of this type of variables was begun For many years it was believed, because of the variations in radial velocity, that the objects were **spectroscopic binaries** Shapley, Eddington, and others have conclusively shown that this cannot be the true explanation, and have proposed an alternative hypothesis that the stars are pulsating On the basis of this theory the star when approaching its minimum is relatively cool and is contracting under the influence of gravitational attraction As the mass of gas contracts the increased pressure in the interior produces a rise of temperature and eventually outward pressure due to high temperature overbalances the gravitational force and the star suddenly expands The sudden expansion produces cooling until gravitation overbalances the outward force and contraction takes place again. Since at the time of expansion, the outer surface will be approaching the observer and also the temperature is higher than during the contracting stage, we find the correlations between brightness, spectral type, and radial velocity all accounted for on this theory Many details remain to be accounted for before we are entitled to say that the problem of Cepheid variation is completely solved, but the pulsation hypothesis certainly seems to be a step toward the final solution

In the course of the study of typical Cepheids in the Small Magellanic cloud, Miss Leavitt, of the Harvard College Observatory, found a direct correlation between the average **magnitude** of the Cepheids and the period of variation Since all variables in the cloud are at approximately the same distance from the earth, it appeared that the period of variation was directly correlated with intrinsic brightness or, in other words, with average **absolute magnitude**. Shapley, after an exhaustive study of numerous Cepheids with known distances and hence known average absolute magnitudes, was able to show that the correlation between period and luminosity was apparently characteristic of all Cepheids and, by plotting period against average absolute magnitude, obtained what is commonly known as the period-luminosity curve After this curve is established, it is possible to determine the absolute magnitude of any Cepheid, no matter how distant, by simply determining the period With the absolute magnitude and the apparent magnitude known, the calculation of the distance of the Cepheid is a relatively easy task The period-luminosity relationship has been extended to the cluster type Cepheids and, while there is still some question as to the "zero point" of the various curves, it has served a very valuable purpose in determining distances of globular clusters Cepheid variables are also found in distant extragalactic **nebulae** and hence they may be used to determine distances of objects outside of our own **galactic system.** For this reason the Cepheids have been referred to as "the measuring rods of the universe" The explanation of the period-luminosity relation has not yet been found, but it may very probably be connected with the **mass-luminosity** relationship found by Eddington and others for all stars (W K G)

CEPHEUS. (Map, page 306) This **constellation** is particularly interesting because it contains the remarkable **variable star** delta Cephei This star is the typical **Cepheid** variable, a class of stars which is most valuable in providing a measuring rod for probing the remote regions of space (W K G)

CERAMICS. The requisite raw material for making ceramic materials is clay Clay is essentially an **aluminosilicic** acid ($H_2Al_2Si_2O_8$), containing more or less foreign matter such as (1) **ferric** oxide (Fe_2O_3), which contributes the reddish color frequently associated with clay, (2) **silica** (SiO_2) as sand, (3) **calcium** carbonate ($CaCO_3$) as **limestone.** Since clay is formed by the decomposition of igneous rocks, followed by transportation of the fine particles by running water and later deposition of these particles by sedimentation when the flow of water diminishes in speed, the quality of clays shows a wide range When clay is wet it is plastic and can be shaped according to the desire and skill of the operator The shape is retained on drying, and subsequent heating produces a coherent, hard mass, which suffers in the process more or less shrinkage and deformation depending upon the composition of the raw materials, and the method and temperature of treatment Common bricks are made of crude materials without careful regulation of the conditions of treatment

Bricks and plain clay products possess an earthy surface and fracture, are porous, and the strength depends upon the materials and treatment. Porcelain, on the other hand, possesses a glass-like or vitreous surface and fracture, and is not porous Porcelain is made by mixing with the clay some powdered feldspar mineral potassium aluminosilicate ($KAlSi_3O_8$ approximately) At the temperature of firing, feldspar undergoes a gradual change from the crystalline to the glassy state, the rate depending upon the time of heating and the temperature to which it is subjected The fusion point of **feldspar** is of the order of 1300° C, whereas that of **kaolin**

(pure clay) is of the order of 1700° C. Subjection of the porcelain raw material to the latter temperature would result in the formation of a glass. But when the temperature used is below the melting point of the clay portion and about the melting point of the feldspar, the latter produces a glass cement which binds together the particles of the former When ground **quartz** (SiO_2) is added to the original clay mixture the shrinkage of the material in the processes of drying and firing is reduced, the resistance to deformation during firing is increased, and the temperature coefficient of expansion of the product is affected

The range of clay, feldspar, and quartz, as to the ratios in the mixture and as to individual composition of each (See tables 1 and 2), as well as the available range of temperature of firing makes possible the production of products of a wide variety of physical structure There has been proposed an arbitrary line of demarcation, namely that the unglazed product, such as has been described, which absorbs not more than one per cent of its weight upon and after immersion in water, shall be termed porcelain, otherwise it shall be called earthenware Such a non-porous material as porcelain which includes chinaware is also distinctly translucent in thicknesses of a few millimeters, whilst earthenware is non-translucent and somewhat porous

Materials that are to be glazed are dipped in a slip (the mixture of raw materials and water), dried, and refired The glaze mixture is made up so that its fusion temperature is lower than that of the body of the ware, and the firing temperature is such that a surface of glass is formed over the body of the ware

Designs and colors may be placed, as is commonly done, on the glaze and refired, or, as less commonly and more recently with fine effect, directly on the body under the glaze, in which case the glaze when produced covers and protects both the body of the ware and the decoration

The range of ceramic products is great, as is illustrated by the following materials, namely, common bricks, hollow bricks, pipes, tiles, terra cotta, fire bricks resistant to high temperatures, stoneware, crockery, earthenware, porcelain, chinaware Fire bricks are indispensable in high temperature industries that use electric furnaces, blast furnaces, reverberatory furnaces, converters, that produce ceramics, Portland cement, glass, and in the high temperature furnaces for producing steam and for subjecting coal to destructive distillation (R K S)

TABLE 1

Raw Materials	Chinaware	Earthenware
Total clay, usually blended	46 5%	50 5%
Feldspar	15	13 5
Quartz	36	36
Dolomite	2 5	
Porosity average	0 5	8

TABLE 2

TABLE SHOWING ANALYSES OF CERTAIN CERAMIC RAW MATERIALS

	Silica	Alumina	Lime	Magnesia	Iron Oxides	Soda	Potash
	%	%	%	%	%	%	%
Kaolin	58	29	0 2	0 3	1	1	1
Fire clay	61	26	0 3	0 4	1	1	1
Common brick clay	58	14	7	1 5	4	3	3
Feldspar	71	16	0 3	0 0	0 5	4	7
Quartz.	100						

CERARGYRITE (Horn Silver). The mineral cerargyrite, **silver** chloride, AgCl, crystallizes in the **isometric** system but is usually massive appearing like wax or horn, hence the name horn silver It has no cleavage, is highly sectile yielding bright surfaces, hardness, 1–1 5, specific gravity, 5 55, luster, resinous to adamantine, color, gray, white to colorless, may be blue, violet brown after exposure to light, transparent to translucent Cerargyrite is largely a secondary mineral, usually associated with other silver minerals as well as with compounds of **lead**, **zinc**, and **copper** Saxony and the Harz Mountains are European localities The Broken Hill district of New South Wales is a well known occurrence, but probably the most important deposits are found in Atacama, Chile It is found also in Bolivia and Mexico In the United States cerargyrite comes from Colorado, Idaho, Utah, Nevada, Arizona and New Mexico The name cerargyrite is derived from the Greek meaning horn and silver. (E S C S)

CERATA Projecting respiratory organs found on the upper surface of the body in some of the marine **snails** (A W L)

CERATITE. Invertebrate paleontology.

CERCARIA. A larval form of the **flukes** (parasitic flatworms) with a compact body and slender tail (A W L)

CERCOPOD. Slender projections at the posterior end of the body in certain crustaceans (Phyllopoda) (A W L)

CERCUS, CERCI ANALES. Paired jointed appendages at the posterior end of the body in some **insects.** (A W L)

CEREALS Grass Family.

CEREBELLUM. A division of the vertebrate **brain.** (A W L)

CEREBRAL GANGLION. 1 The simple brain of many invertebrates 2 Either member of the anterior pair of **ganglia** in the molluscan nervous system 3 The upper posterior component of the brain of **cephalopod mollusks** (A W L)

CEREBRAL TUBE. A ciliated tube associated with the brain in certain marine worms (Sipunculids) (A W L)

CEREBROSPINAL FEVER (SPOTTED FEVER, EPIDEMIC CEREBROSPINAL MENINGITIS, MENINGOCOCCUS MENINGITIS). An infection caused by the meningococcus, characterized by primary local involvement of the nose and throat, secondary invasion of the blood stream and inflammation of the brain and spinal cord and their covering membranes The disease is almost solely conveyed by droplet infection from mouth or nose of the **carrier.**

The disease may occur in sporadic or epidemic form It was first described in 1805 as a clinical entity Serum therapy was first established by Jackman in Germany and by Flexner in the United States

The disease varies in severity but is, at best, accompanied by considerable mortality Complications are common, the heart, lungs, eyes, sinuses, abdomen, etc, becoming the seat of active invasion by the organism

The chief form of treatment is the immediate administration of antimeningococcus serum when there is the slightest suspicion of the disease. The serum is in-

jected into the spinal canal, into the blood stream, or wherever the active infection exists (R S M)

CEREBRUM. A region of the vertebrate **brain.** (A W L)

CERES. Asteroid.

CERIUM. Symbol Ce Atomic number 58 Atomic weight 140 13 Density 6 8 Melting point 640° C Types of compounds Ce_2O_3, white cerous oxide, CeO_2, pale yellow ceric oxide Color of salts cerous, colorless, ceric, yellow Discovered by Berzelius and Hisinger in 1803 (Isotopes page 238)

Cerium occurs in **monazite** sand, a cerium phosphate (50%–75% ceria), **cerite,** a basic silicate of **calcium** and **iron** (50%–70%), and **allanite,** a hydrated silicate (up to 50%)

The cerium sub-group of the rare earth metals (See **Yttrium**) consists of the elements scandium, lanthanum, cerium, praseodymium, neodymium, illinium, camarium, europium, and gadolinium, all of whose potassium sulfate compounds are relatively insoluble in water Cerium is the most abundant of the rare earth metals, and each member of the cerium sub-group, except camarium, is said to be more abundant than yttrium Cerium metal is prepared by electrolysis of the fused chloride, and is used as a pyrophoric alloy (70% Ce with iron) in gas and tobacco lighters

Nitrates Cerous nitrate ($Ce(NO_3)_3 \cdot 6H_2O$), pink to colorless crystals, soluble, ceric nitrate ($Ce(No_3)_4$), reddish-yellow crystals, soluble

Oxide cerous oxide (Ce_2O_3), grayish-green powder, ceric oxide (CeO_2), pale yellow powder, soluble in sulfuric acid, used in gas mantles (1% CeO_2 with thorium oxide), and in coloring glass and ceramic ware

Sulfates Cerous sulfate ($Ce_2(SO_4)_3$), green to pink, depending upon the amount of water of crystallization, ceric sulfate ($Ce(SO_4)_2$), yellow to orange-red solid, soluble, used in **sulfuric acid** solution as a strong oxidizing agent (R K S)

CERUMEN The waxy secretion that collects in the external **ear.** (R S M)

CERUSSITE The mineral cerussite, **lead** carbonate, $PbCO_3$, is **orthorhombic** with tabular, prismatic and pyramidal crystals, with twinned forms very common If not in crystal aggregates it may occur in granular or compact masses Cerussite is very brittle with a conchoidal fracture, hardness, 3–3 5, specific gravity, 6 46–6 57 (a heavy mineral), luster, adamantine but may be vitreous to resinous, pearly or even submetallic Its color is variable, white to gray, grayish black or blue or green, transparent to translucent

Cerussite is of secondary origin being found associated with other lead minerals, and is widely distributed There are many European and American localities Fine crystals have been obtained from Phoenixville, Pennsylvania, Joplin, Missouri, Leadville, Colorado, Pima County, Arizona, and Dona Ana County, New Mexico It is an ore of lead, and frequently carries values of **silver** Derived from the Latin *cerussa,* white lead (F S C S)

CERVALCES. Pleistocene.

CERVICAL GROOVE. A groove marking the boundary between head and thorax in the **crustaceans.** (A W L)

CERVIX Any narrow or neck-like portion of an organ Usually used in reference to the narrow end of the **uterus** that projects and hangs downward into the **vagina.** (R S M)

CESAREAN SECTION, OPERATION. Removal of the child from the **uterus** by means of an incision through the abdominal and uterine walls

It is generally thought that Julius Caesar was born in this way and that he obtained his name from the manner of his delivery (a *caeso matris utero*) However, this could hardly be correct since his mother lived for many years after his birth and also Julius was not the first to have the name Caesar The correct derivation of the name for the operation comes from the Roman law by which it was required that such an operation be performed upon women who died just before the termination of pregnancy At first this law was known as the *lex regia* but under the emperors its name was changed to the *lex caesarea* and the operation henceforth was known as the cesarean operation

As to when the first cesarean operation was done on a living woman there is no definite information although certain passages in the Talmud may indicate that it was done

The first record of an authentic cesarean operation on a living woman was in 1610 by Trautmann, of Wittenberg There were probably other operations done before this but we have no record of them Up to 1882 no sutures were used in the incision in the pregnant uterus and most of the women perished from hemorrhage Even after sutures were used the mortality was so great from **peritonitis,** shock, and hemorrhage, that in 1887 out of 11 operations performed in New York City only one mother survived

However, since then with improvements in the whole field of surgery, the operation became relatively safe. The mortality at present in the hands of capable surgeons is very low

It has been held by many writers that "once a cesarean, always a cesarean" This is not always the case, however

The operation is done when (1) there is any bony deformity or narrowing of the bony pelvis that does not permit delivery through the vaginal route (2) Tumors which block the birth canal in the pelvis (3) Certain cases with heart disease that could not stand the strain of labor (4) Other conditions which may make normal labor dangerous (R S M)

CESIUM Symbol Cs Atomic number 55 Atomic weight 132 91 Density 1 87 Melting point 28 5° C Boiling point 670° C

Cesium is a silver-white, very soft metal, possibly the softest of all the metals, tarnishes instantly on exposure to air, soon igniting spontaneously with flame to form oxide, preserved under kerosene, reacts vigorously with water forming cesium hydroxide solution and hydrogen gas Discovered by Bunsen and Kirchoff in 1860 by means of the spectroscope

Cesium occurs in **pollucite** (cesium aluminosilicate, 35% Cs_2O), **lepidolite** (lithium aluminosilicate), and traces in certain mineral waters The localities having the highest known concentrations of cesium are in Maine, Black Hills, South Dakota, and the island of Elba Cesium salts may be recovered from the mother liquor upon crystallization of lithium salts, but are separable from rubidium salts with great difficulty Cesium metal is obtained (1) by **electrolysis** of fused cesium **barium** cyanide mixture out of contact with air, (2) by distillation of cesium chloride with **calcium** metal

Chloride Cesium chloride (CsCl), white deliquescent solid, melting point 646° C, soluble

Hydroxide Cesium hydroxide (CsOH), white, deliquescent solid, melting point 272° C, soluble

Oxide Cesium oxide (Cs_2O), red solid, by heating cesium metal in oxygen or dry air, reactive with water to form soluble cesium hydroxide, several higher and lower oxides have been reported

Other soluble salts Cesium sulfate (Cs_2SO_4); cesium nitrate ($CsNO_3$), cesium carbonate (Cs_2CO_3), cesium fluosilicate (Cs_2SiF_6)

Slightly soluble salts Cesium perchlorate ($CsClO_4$), insoluble in alcohol, cesium chloroplatinate (Cs_2PtCl_6), cesium permanganate ($CsMnO_4$)

Volatile cesium salts, such as the chloride, color the bunsen flame violet (R K S)

CESTIDA. An order of ctenophores (**Ctenophora**) (A W L)

CESTODA, CESTOIDEA. The tapeworms A class of the phylum **Platyhelminthes.** The tapeworms, like other members of the phylum, are flat-bodied The body consists of two regions, a head or scolex usually bearing hooks, suckers, or both, and a strobila which, in all but the simplest species, is formed of a series of segments called proglottids Tapeworms are parasitic in vertebrates

In addition to the characters mentioned, tapeworms are distinguished by a complex life cycle The adults live in the intestine of the host, absorbing food through the wall of the body since they have no alimentary tract, and produce a long succession of **proglottids** which break off as they mature and pass out with the faeces of the host, break off and remain in the intestine, or mature while still attached to the worm They are reproductive bodies containing the organs of both sexes, rarely those of only one The fertilized egg becomes a simple **embryo** with six hooks called the onchosphere In this stage it is taken into the alimentary tract of a new host, migrates into the blood vessels, and after drifting along the blood stream lodges in some part of the body and develops into another form, usually vesicular, called the bladder worm In this stage it remains inactive unless the tissue containing it is eaten by another animal, in which case it attaches itself to the intestinal wall of the new host and develops into an adult tapeworm

Tapeworms are among the important parasites of man Some of these species live in hogs and cattle and become established in man as the result of eating imperfectly cooked meat and one of the most dangerous species is found in the dog during its adult stage and in domestic animals and man in the bladder worm stage The elimination of tapeworms from the human body requires the careful attention of a physician

The tapeworms are classified as follows

Subclass Cestodaria Parasitic in fishes as adults and in **annelid** worms and **mollusks** in the early stages No distinct **scolex** and no segments
- Order Amphilinidea Species of leaf-like form
- Order Gyrocotylidea Leaf-like, with a projecting organ of attachment at the posterior end

Subclass Cestodes Usually segmented Proglottids with organs of both sexes
- Order Tetraphyllidea Scolex without retractile projections (proboscides), with four suckers or bothria Parasitic in cold-blooded vertebrates
- Order Tetrarhynchidea Scolex with proboscides Parasitic in fishes
- Order Pseudophyllidea No proboscides, only two suckers or bothria In vertebrates of all classes
- Order Cyclophyllidea Four suckers and usually hooks Body elongate, with distinct segments, often numerous Principally in warm-blooded vertebrates (A W L)

CETACEA. The whales, dolphins, porpoises and related mammals An order, now replaced by two, **Odontoceti** and **Mystacoceti**, for the toothed whales and whalebone whales, respectively (A W L)

CHABAZITE. The mineral chabazite is a member of that group of hydrous **silicates**, the **zeolites**, and corresponds to the formula $CaAl_2Si_4O_{12}$ $8H_2O$ with sodium sometimes replacing a part of the **calcium** **Potassium**, **barium** and **strontium** may be present in very small amounts Chabazite is **hexagonal**, usually in rhombohedrons that tend to resemble cubes It has a rhombohedral cleavage, is brittle, hardness 4–5, specific **gravity** 2 08–2 16, luster vitreous, color white to flesh red, streak white, translucent to transparent Chabazite is found in the amygdaloidal cavities of **basalts** often associated with other zeolites It is occasionally found in such crystalline rocks as **syenites**, **gneisses** and **schists** Chabazite is a rather common zeolite, being found in many localities in Europe In the United States it occurs in the Triassic traps of New Jersey and Maryland The **Triassic** lavas of Nova Scotia have yielded fine specimens The name chabazite is derived from the Greek word meaning a precious stone (E S C S)

CHACHALACA. Guan. (A W L)

CHACMA Mammalia, Primates The largest of the baboons, *Papio porcarius*, resident in the extreme southern part of Africa Also called the pig-tailed baboon (A W I)

CHAETA. A slender pointed structure secreted by cells of the **integument** in many invertebrates, such as the **annelids** A **seta** (A W I)

CHAETOGNATHA The arrow-worms, a group of small marine animals sometimes included in the phylum Annelida but now more often regarded as a separate phylum

Arrow-worms are usually elongate transparent animals They have two or three pairs of horizontal fins, one forming a caudal fin at the end of the body The head bears a pair of eyes and a group of spine-like jaws which give the name to the phylum The alimentary tract runs through the body as a straight tube to an anus near the caudal end The body cavity is divided into three chambers by two transverse septa Although the phylum includes only about thirty species arrow-worms are found from the surface to great depths and in all of the oceans (A W L)

CHAETONOTOIDEA An order of **rotifers** (A W L)

CHAETOPODA A division of the **annelid** worms including the forms which have setae set in pockets in the integument The **coelom** is well developed and is at least partially divided into **metameric** chambers, and the external segmentation of the body is also metameric Most of the marine annelids such as the lobworm and **clam worm** and the **earthworms** and freshwater annelids are included here The **leeches** and a few more primitive worms make up the rest of the phylum

By some authorities this division is called a class and is divided into two orders
- Order **Polychaeta** Free-swimming and sedentary worms, mostly marine, with lobed appendages (**parapodia**) and many **setae**, Usually a head with sensory organs This group is sometimes regarded as a class and is then divided into two orders, the Errantia with similar body segments, most species free-swimming or burrowing, and the Sedentaria with specialized body regions, living in tubes in the bottom of the ocean, or between the tides
- Order **Oligochaeta** Fresh-water and terrestrial worms with few setae and with neither parapodia nor sensory appendages The earthworms are common examples Sometimes ranked as a class (A W L)

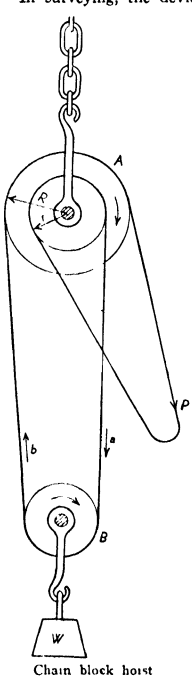
CHAFER Insecta, Coleoptera A name applied to certain plant-eating **beetles**, including the rose chafer of the United States The adults of this species are sometimes a troublesome pest on small fruits, especially grapes They damage the fruit itself Spraying with **lead** arsenate is recommended for their control (A W L)

CHAFFINCH. Aves, Passeriformes Birds (**Aves**) of several species found in Europe and western Asia The brambling is a member of the same genus, *Fringilla* (A W L)

CHAIN. In mechanical terminology, a chain is a flexible connector consisting of links of metal joined together A fundamental classification of chains is based on use, i e , chains used for holding or lifting weights, called coil chains, and chains used to transmit power The chains in the first classification are usually made of wrought iron or steel links which are left open until the adjacent link is in place and are then welded closed Some chains are cast, but this is a very tedious process, and is seldom used, since they must be cast link by link Chain links having a stud or bridge across the center of the link are superior to plain links from the standpoint of freedom from kinking

Power transmission chains are advantageous when a positive drive between short center shafts is wanted, and when the shafts are too far apart for use of gears Due to their low cost, **belts** are frequently preferred to chains, where applicable, but in many cases chains must be used A power transmission chain must be used with a sprocket, which is a toothed wheel so constructed that the teeth engage the openings in the links of the chain Simple chains, such as the block chain or square-link chain, while low in first cost, are relatively inefficient Roller chains, or other improved types, are generally preferred for the transmission of power The simpler types of chains have very definite limitations on speeds at which they may be operated, whereas the best forms of patented "silent" chains may be operated at speeds approaching 2000 feet per minute with good results These improved chains are based on various improvements such as case-hardened rollers, sprocket-gripping links, rocker-type joints, etc

In surveying, the device formerly used by surveyors for the direct measurement of distance is called the chain The surveyor's or Gunter's chain, which has a length of 66 feet, is made of 100 links, each 7 92 inches long It was particularly advantageous to use this chain in area measurements since an acre is equal to ten square Gunter chains The engineer's chain consists of 100 links, each 12 inches in length These chains have been almost wholly superseded by the steel tape, which is a thin ribbon of steel The steel tape most commonly used has a length of 100 feet This hundred foot length is divided into one hundred parts each 1 foot long, with the first and last foot subdivided into tenths These graduations are generally inscribed on a small spot of soft metal such as Babbitt which is brazed onto the tape The process of measuring with a chain or tape is frequently referred to as chaining (F T M)



Chain block hoist

CHAIN BLOCK. Chains and sheaves may be employed in combination to produce an unusually powerful lifting mechanism The best of these is the differential chain block, the action of which is explained in connection with the accompanying diagram. The mechanism consists of two sheaves, A and B, A being double sheave having diameters R and r It will be shown that the multiplying power of this mechanism depends upon the ratio of these diameters If they are equal, the pull P will not move the weight, and the efficiency of the mechanism will be zero percent, but the theoretical mechanical advantage is infinity A slight difference in radii will produce a very large lifting effort, although the efficiency may still be very low The sheaves are made with link pockets so that the chain fits nicely into the circumference, and is restrained from slipping. Furthermore, the chain is endless, and the mechanism is self-locking by virtue of the friction intentionally allowed on the journals

In explanation of the chain block, if the pull P revolves sheave A one revolution, the vertical chain at a is lowered through a distance to $2\pi r$, while the side b is raised the distance $2\pi R$ The net vertical displacement of the sheave B is $\pi(R-r)$ upward With no friction considered, the work of lifting W through this distance must be equal to the work done by the pull P moving through $2\pi R$ Solving this equation for advantage $\frac{W}{P}$,

$$\frac{W}{P} = \frac{2R}{R-r}$$

Applying the mechanical efficiency e to this equation, the actual mechanical advantage is

$$\frac{W}{P} = \frac{2Re}{R-r}.$$

These chain blocks are built in different sizes for hoisting loads from one-quarter ton to three or four tons, by hand On account of the self-locking feature depending on friction, the average mechanical efficiency of this device is only about 30% (F T M)

CHALCEDONY. Chalcedony is one of the cryptocrystalline varieties of the mineral **quartz,** having a waxy luster It may be semi-transparent or translucent and is usually white to gray or grayish blue or some shade of brown, sometimes nearly black Other shades have been given different names. A clear red chalcedony is known as **carnelian** or **sard**, a green variety colored by nickel oxide is called **chrysoprase. Prase** is a dull green **Plasma** is a bright to emerald green chalcedony which sometimes is found with small spots of **jasper** resembling blood drops, it is then referred to as **blood stone** or **heliotrope** The term chalcedony is derived from the Greek word meaning Chalkedon, a town in Asia Minor (E S C S)

CHALCID FLY. Insecta, Hymenoptera Minute **insects** of many species, usually shining or metallic and with very simple wings showing a single vein A few feed on plants and the fig insects, *Blastophaga psenes*, are essential for the fertilization of Smyrna figs, but most species are parasitic on other insects during their larval life The host species are attacked by these parasites in all stages of metamorphosis, including the egg

A few species are important pests in wheat but the chief economic importance of the group lies in the destruction of other pests by the parasitic species It is difficult to estimate the importance of such natural checks (A W L)

CHALCOCITE (COPPER GLANCE). The mineral chalcocite is **cuprous sulfide,** Cu_2S, crystallizing in the **orthorhombic** system, often in pseudo-**hexagonal** forms Above a temperature of 91° C chalcocite changes into an **isometric** form It has conchoidal fracture, hardness 2 5–3, specific gravity, 5 5–5 8, metallic luster, color dark gray to blackish gray, frequently with bluish green tarnish Chalcocite is of widespread occurrence and a valuable copper ore It seems in some cases to be definitely secondary in origin, in other cases primary. It may have been formed from bornite by the action of alkaline solutions It sometimes carries valuable amounts of silver

Among the many European localities might be mentioned Cornwall, England, the Ural Mountains, and Rumania It occurs also in the French Congo, South West Africa, Peru, Mexico, and Alaska In the United States it is found at Bristol, Connecticut, in fine crystals, Montana, Tennessee, Arizona, Nevada, and California

The word chalcocite is derived from the Greek word meaning copper (E S C S)

CHALCOPYRITE (COPPER PYRITES). The mineral chalcopyrite is a **sulfide** of **copper** and **iron** corresponding to the formula $CuFeS_2$ Its **tetragonal** crystals are often complex with repeated twinning, massive chalcopyrite is common It has an uneven fracture, is brittle, hardness, 3 5–4, specific gravity, 4 1–4 3, luster, metallic, color, brass-yellow, may be iridescent from tarnish, streak, greenish black, opaque Chalcopyrite is the most common copper-bearing mineral known and it is the most important ore of copper It is a primary mineral in many igneous rocks and from it a host of secondary copper minerals have been derived Among the many localities where fine specimens of this mineral have been obtained might be mentioned Freiberg, Saxony, Alsace, Rio Tinto, Spain, Cornwall, England, Australia, Chile, Peru, and Bolivia, South America, and in the United States, Ellenville, New York, Chester County, Pennsylvania, Joplin, Missouri, Gilpin County, Colorado, Arizona, Montana, Utah, Nevada, California, New Mexico, and Tennessee In Canada there are notable deposits of chalcopyrite in the Provinces of British Columbia, Ontario, and Quebec The name chalcopyrite is derived from the Greek word meaning copper, and the word pyrites (E S C S)

CHALK. Chalk is a soft, porous **limestone** of white, grayish white or buff color made up of the minute shells of **foraminifera** and fragments of **cocospheres.** It occurs extensively in England and France and less so in the United States (E S C S)

CHALYBITE. Siderite.

CHAMELEON. Reptilia, Sauria Any member of several genera of lizard-like **reptiles** of very peculiar form, occurring in Africa, the Oriental region, and about the Mediterranean They are arboreal species with grasping feet, a crested head, and a long extensile tongue with a clubbed sticky tip which is used to catch insects They are able to change color readily The most common genus is *Chamaeleon*

The little lizard commonly sold at street fairs in the United States is not a true chameleon but is more closely related to the iguanas (A W L)

CHAMOIS Mammalia, Artiodactyla A goat-like European **antelope,** *Rupicapra tragus,* found in the forests of mountainous regions and to a limited extent under alpine conditions Noted for its agility (A W L)

CHANCRE. The first manifestation of **syphilis** It is a hard, elevated sore which gives forth a thin secretion containing the spirochete (See **Bacteria**), and which on contact with mucous membrane of another individual will produce syphilis

The usual sites of a chancre are, the penis, vagina or external genitalia, the breast and lips It usually appears three weeks after exposure to syphilis (R S M)

CHANCROID. A venereal sore, non-syphilitic in origin, that appears on the **genital** organs The secretion of the sore is contagious (R S M)

CHARACTERISTIC EQUATIONS. A class of equations connecting those variables, such as temperature, pressure, and volume, which define the physical condition of a given substance.

The **ideal gas law** and the **Boyle-Charles** law represent approximately the behavior of all gases, but if one wishes to be accurate, some modification of these must be sought which will take account of the differences between individual gases The best known characteristic equation for gases is that of van der Waals Using the same notation as for the ideal gas law, this may be written

$$\left(p + \frac{a}{v^2}\right)(v - b) = RT.$$

(Here, however, the volume is not in liters but is in terms of the volume of the same body of gas at normal temperature and pressure, and the pressure is in atmospheres) a and b are constants characteristic of the gas in question They are very small, if they were zero we should have the ideal gas law Following are their values for certain gases

Gas	a	b
Air	0 00257	0 00156
Helium	0 00005	0 00070
Hydrogen	0 00042	0 00088
Nitrogen	0 00259	0 00165
Oxygen	0 00273	0 00142

Clausius modified van der Waals' equation as follows.

$$\left(p + \frac{a}{T(v + c)^2}\right)(v - b) = RT,$$

employing three empirical constants a, b, c, while the equation of Dieterici has an exponential factor

$$p \cdot e^{\frac{a}{RTv}} \cdot (v - b) = RT.$$

None of these equations represents the behavior of all gases equally well

Beattie and Bridgman have recently proposed a characteristic equation for fluids in general, as follows

$$pv^2 = RT\left(1 - \frac{c}{vT^3}\right)\left[v + B\left(1 - \frac{b}{v}\right)\right] - A\left(1 - \frac{a}{v}\right),$$

in which a, b, c, R, A, and B are empirical constants to be determined for each fluid (L D W)

CHARACTERISTIC OF A COMMON LOGARITHM Logarithms.

CHARACTERISTIC SPEED. Specific Speed.

CHARACTERISTIC TEMPERATURE. Dulong and Petit's Law of Specific Heats.

CHARADRIIFORMES A large order of shore and wading birds (**Aves**) including the **gulls, terns, auks, puffins, plovers, sandpipers, snipes,** and many others (A W L)

CHARGE-MASS RATIO This term refers to the relationship between the electric charge of a particle and its mass, so important in the physics of **electrons, ions,** and other electrified bodies of molecular order

The earliest information on the subject followed from the researches of Faraday on electrochemical equivalents From his results it appears that in the electrolysis of chlorine, for example, one **coulomb** of negative electricity is carried by 0 00037 gram of this element, and hence that the carriers or ions have a charge-mass ratio of about 2700 coulombs or $8\ 1 \times 10^{12}$ electrostatic units of electricity to the gram Similarly, one coulomb of positive electricity is carried by 0 0000104 gram of hydrogen, which gives about 95,700 coulombs or $2\ 87 \times 10^{14}$ e s u to the gram for hydrogen ions This is 35 times the ratio for chlorine ions But the atomic masses of hydrogen and chlorine are in the ratio 1 35, which means that if the carriers are atoms, the charge per carrier is the same for both elements Bivalent elements, on the other hand, carry twice this charge per ion

When J J Thomson applied a magnetic field to a stream of hydrogen **canal rays,** and then neutralized the resulting deflection by means of an electric field, he was able to calculate the charge-mass ratio of these particles

from the curvature of the magnetically deflected stream and the values of the two field intensities This he found to be either 95,700 coulombs per gram as in the electrolysis of hydrogen, or one-half that value, which indicated that some of the ions were atoms and some were molecules carrying the same charge as the atoms But when a similar test was applied to the **cathode rays** in a **Crookes tube**, the ratio was found to be about $5\ 303 \times 10^{17}$ e s u per gram, or 1850 times that for hydrogen atoms, whatever the nature of the cathode We know now that this enormous difference is one of mass, not of charge, and that these experiments were the first direct revelation of the identity of the **electron**, which has a mass only 1/1850 of that of the hydrogen atom (L D W)

CHARLES' LAW Although the coefficients of expansion of different solids or of different liquids are notably different, the coefficients of expansion of all gases are nearly the same, namely, about 1/273 of the volume at 0° C per centigrade degree The law, stated by Charles in 1787 and independently by Gay-Lussac in 1802 (hence sometimes called Gay-Lussac's law) is not strictly true Regnault obtained the following values of the volume coefficient for various gases

Air	0 00367o6
Hydrogen	0 00366l3
Carbon dioxide	0 0037099
Sulphur dioxide	0 0039028
Carbon monoxide	0 0036688
Nitrous oxide	0 0037195
Cyanogen	0 0038767

None of these is far from 1/273 = 0 003663, which is therefore commonly taken as the expansion coefficient for gases, especially as the value for hydrogen, commonly used in the standard gas thermometer, is very near it If the pressure as well as the volume is allowed to vary, the behavior of the ideal gas must be expressed by the **Boyle-Charles law** or the **ideal gas law** (I D W)

CHARNOCKITE Charnockite is a granular variety of **hypersthene granite** which was first described from the gravestone of Job Charnock, who founded the city of Calcutta, India, whence the derivation of the name charnockite (I S C S)

CHARR Pisces, Teleostei *Salvelinus* A lake fish (**Pisces**) of the British Isles, related to the trout (A W I)

CHART A chart, or map, is a representation of a portion of the surface of the earth on a plane surface There are certain properties that it would be desirable to have present in any chart that is constructed and various forms of projections have been devised by cartographers in the attempt to realize these ideals (1) The chart should represent features of the surface of the earth in their true form (conformal projection), (2) The features represented should have the proper relative sizes all over the chart (equal area projection), (3) Geodesic lines on the earth, which are the shortest distances between two points, should appear as straight lines on the chart (**great circle** or **gnomonic projection**), (4) The geographic latitudes and longitudes of places should be easily found from their positions on the chart and, conversely it should be easily possible to plot positions on the chart from the given latitudes and longitudes, (5) The directions of every other point on the map from any one point should be the same as the apparent directions on the surface of the earth (azimuthal projection) If the earth was a plane or a solid whose surface could be readily developed on a plane, such as a cylinder, then the above properties could be realized easily Since the earth is an oblate spheroid it is not possible to completely realize more than two of the above properties except at the expense of the other For navigational purposes three compromise types of projection are in common use the **mercator projection**, the **great circle or gnomonic projection**, and the **polyconic projection**

Charts for navigational purposes contain many details of value to the navigator other than the mere outline of the coast Upon charts are found such material as prominent landmarks to be observed when approaching the land from seaward, lighthouses, lightships, coast-guard stations, beacons, buoys, etc Such information as depth of water and character of the bottom, deviation of the **compass** from true north, prevailing currents in the water, prevailing winds, etc, are also often found on charts

Charts are divided into three main classifications general, sheet, and harbor charts, the elaborateness of detail depending on the scale used and the purposes for which the particular chart is designed General charts usually compromise an entire ocean with comparatively little detail being given relative to the coast line In addition to the general information listed above, the principal sailing routes over the charted ocean are usually given Sheet charts are sections of general charts, giving coastal information in far greater detail than found on the general charts themselves Harbor charts give very detailed information regarding the buoyage, depth of water, etc, of the various channels within a harbor The scale on which harbor charts is constructed permits the chart to be constructed with practically no distortion

General charts are plotted either on the Great Circle or Mercator projection, depending upon the purpose for which the chart is to be used Sheet charts are plotted on the Mercator projection or the polyconic if the scale is not too large Harbor charts are usually plotted on the azimuthal form of projection by selecting a carefully measured base line and running azimuth lines to important landmarks either with a **theodolite** or a **sextant**, filling in detail, and running lines of soundings (W R G)

CHAT Aves, Passeriformes Birds (**Aves**) of several species, usually designated by a compounded word, as the stonechat and whinchat of Europe, the yellow-breasted chat of North America (*Icteria virens*), and several North African species The European wheatear and hedge warbler are also chats (A W L)

CHATOYANCY Cat's-eye.

CHATTERER. Aves, Passeriformes South and Central American birds (**Aves**) making up the family Cotingidae They are quite varied, some with strangely formed plumage and some beautifully colored The family includes the umbrella bird, **bell-birds**, **cotingas**, manakins, and **cocks-of-the-rock** A single species, the xantus becard, *Platypsaris aglaiae*, enters the United States near the Mexican border

These birds are near the flycatchers (A W L)

CHATTER MARKS. Moon-shaped scratches or gouges on the bed rock which are supposed to be caused by the "chattering" action of angular boulders which are carried in the bottom of a glacier (R M F)

CHAULMOOGRA OIL *Teraktagenos* (*Hydnocarpus*) *kurzii* Flacourtiaceae Chaulmoogra oil is expressed from the seeds of a tall tree native to the jungles of northern Burma The tree has a smooth light-brown bark, large leathery evergreen leaves and inconspicuous flowers The fruits have a soft hairy surface and contain several large seeds

The plant has long been known and used in Burma and other Malasian countries in the treatment of various skin afflictions and **leprosy**, often with very favorable results Modern science has advanced this problem by expressing the oil and purifying it, so that the painful effects associated with the use of the crude oil have

been eliminated. Thus, ethyl esters of the fatty acids in the oil are prepared This product is given by intramuscular injection into the buttocks Treatment is continued over long periods of time—three to five years or more, with intervening periods of rest without treatment. (R M W, R S M)

CHEEK The lateral wall of the oral cavity (A W I)

CHEETAH, CHETAH, CHITA. Mammalia, Carnivora A large **cat** found in Africa and India It is marked by its slender build and is tawny with black spots, thus somewhat resembling the leopards The species is known as the hunting leopard and has been tamed for use in the chase (A W L)

CHELA. A form of grasping appendage found in **lobsters, crabs,** and other **arthropods** The large pincers of these species are the most familiar examples

All chelate appendages have the next to the last segment prolonged into a process against which the terminal segment works to form a forceps-like organ (A W L)

CHELICERAE. The first pair of appendages in **spiders** and related animals They are associated with the mouth and are formed for chewing and in some cases for grasping, as in the **scorpions** (A W I)

CHELIPED. An appendage of the **thorax** formed for grasping, in the **crustaceans** The chela or pincher of the lobster and crayfish (A W L)

CHELLEAN **Paleontology of man.**

CHELONIA **Testudinata**, and also **Fossil Reptiles**

CHEMICAL CHANGES The chemical composition of a substance is subject to various changes under various conditions, depending upon (1) the nature of the individual substance, (2) the nature of other substances present, and (3) the conditions The vast majority of reactions take place between two substances—occasionally one substance only, and sometimes three or more different substances There are many cases where simple contact of the substances is sufficient to bring about the chemical change, e g, the rust of iron in oxygen In many other cases, the change is not spontaneous, but must be induced, frequently by raising the temperature, as in the burning of fuels The conditions that are considered important and fundamental are (1) temperature, (2) pressure, (3) medium, if any, (4) catalyzer, if any, (5) electric direct current, (6) light In a given reaction, the change in composition of the substance or substances involved is inherently connected with a change in energy Thermal, electrical or light energy of a certain potential or intensity and in definite amounts, is requisite to initiate and carry on the reaction, and thermal, electrical or light energy of definite amount is liberated or consumed in the reaction Every reaction, properly speaking, has both a matter and an energy aspect While the energy aspect is frequently neglected directly, the conditions must always be in accord with the energy demand, even if apparently not considered See **Thermochemistry; Electrochemistry; Photochemistry.** Chemical changes require consideration of three topics, namely, I Natural rate of chemical reactions, II Acceleration of the natural rate in the presence of a catalyzer, and III The end-point of chemical reactions

I *Natural Rate of Chemical Reactions* Various factors operate to affect the rate of chemical reactions By natural rate is understood the rate of a reaction in the absence of a **catalyzer** Excluding electrochemical and photochemical reactions, and giving attention to thermochemical reactions only, there are four factors or conditions to be considered, namely, (1) concentration of constituents, (2) temperature, and (3) pressure—important where a gas is involved, (4) nature of the medium, if any

(1) Relation between concentration of reactants and rate of reaction The rate of a given reaction, at constant temperature and pressure under stated conditions of concentration of the reacting substances, is quantitatively expressible by a velocity constant, which is the fraction of the substances transformed in a unit of time Many reactions occur instantaneously—true for most reactions in solution in inorganic chemistry—and many others are complicated by subsidiary reactions, so that the velocity constant is measurable in comparatively few cases The principle, however, holds as stated, whether or not the desired value can be ascertained experimentally

A simple reaction that was studied by Wilhelmy (1850), and since then by various investigators, is the transformation (hydrolysis) of **sucrose** ($C_{12}H_{22}O_{11}$) in water solution into **glucose** ($C_6H_{12}O_6$, a polyhydroxy aldehyde) plus **fructose** ($C_6H_{12}O_6$, a polyhydroxy ketone), which proceeds at a measurable, steady rate in the presence of acid (**hydrogen ion**) The rate of reaction at any instant is found to be proportional to the amount of sucrose present at that instant

When a dilute water solution of an **ester**, such as methyl acetate, is similarly hydrolyzed in the presence of hydrogen ion, the reaction is of the same type And this statement also applies to the decay of **radioactive** elements One of the important radioactive constants is the period, that, is, the time required for the decay of one-half of the element present at a given instant

The preceding cases are instances of monomolecular reactions—in the case of sucrose and of methyl acetate the concentration of water, when it is in large excess, remains constant throughout the reaction Only in monomolecular reactions is the velocity constant independent of the initial concentration

The rate of bimolecular and higher types of reactions depends upon the concentration of each reactant, and is specific in each case

When a reaction involves two different phases, that is, when the system is not homogeneous but heterogeneous, as in reactions between a solid phase, such as **zinc** or **calcium** carbonate, and a liquid phase, such as **hydrochloric acid** solution, the rate of reaction involves consideration of (1) the area of the surface of contact of the solid with the solution, and (2) the rate of diffusion from the surface of the solid, as well as (3) the concentration of hydrogen ion of the acid solution

When the rate of a chemical process is dependent upon (1) two or more *consecutive* reactions, the observed rate is limited by the rate of the slowest reaction in the series, (2) two or more *concurrent* reactions, the products are in the same ratio at any instant only when the reactions themselves are of the same rate

(2) Relation between temperature of reactants and rate of reaction The rate of chemical reaction is increased two or three times for a rise in temperature of 10° C The rate of decay of radioactive elements has been found to be unaffected by temperatures from the lowest to the highest attainable

(3) Relation between pressure of reactants, if gaseous, and rate of reaction Since pressure changes amount to concentration changes in such systems, the behavior is as described above under concentration

(4) Relation between nature of the medium and rate of reaction Very slight changes in the nature of the medium greatly affect the rate of a chemical reaction, but attempts to relate any physical property of a solvent with the effect observed on the rate of a given reaction appear to have proved unsuccessful

Summarizing, the rates of chemical reactions are subject to highly specific influences in each case, as has been abundantly demonstrated by experimental investigations, and recognized in numerous legal battles in chemical patent suits

II *Acceleration of the Natural Rate of Chemical Reactions* in the presence of a positive or negative catalyzer When, in the presence of a given substance, the natural rate of a chemical reaction is changed, either increased

or decreased, the given substance is called a **catalyzer** Examples are numerous (1) When a gas-lighter of the type known as **platinum** black, the active part of which consists of very finely divided platinum, is held in a stream of **hydrogen** or city gas, the gas is ignited in air Platinum is a catalyzer for this reaction, and causes ignition to take place at a temperature much lower than by subjecting to fire (2) The changing of **sulfur dioxide** into **sulfur trioxide** is accomplished by passing a mixture of sulfur dioxide and air (one-fifth oxygen) over asbestos coated with finely divided platinum The temperature required is much lower by the use of platinum catalyzer than without its use (3) Solutions of sulfites are subject to oxidation to sulfites by oxygen upon allowing to stand in air The addition of sugar or glycerol retards the speed of this reaction These substances act in this case as negative catalyzers (4) The combination of **nitrogen** and **hydrogen** gases under high pressure to form **ammonia** gas is accomplished at a lower temperature in the presence of a catalyzer than in its absence, thus increasing the yield of ammonia (See **Equilibrium**) One of the catalyzers is composed of **iron**, intimately mixed with 1% **aluminum** oxide and 1% **potassium** oxide Iron is a catalyzer for this reaction, but is more active as such in the presence of aluminum oxide and potassium oxide, which are spoken of as promoters, a sort of catalyzer of a catalyzer (5) The hydrogenation of liquid fatty oils and of oleic acid is conducted in the presence of finely divided nickel as a catalyzer (6) **Enzymes** are very specific catalyzers, "the most selective and delicate of all known catalysts (Hilditch)," at ordinary temperatures, say 25° to 30° C Dextro-glucose is converted into ethyl **alcohol** in the presence of the enzyme (zymase) of yeast, and ethyl alcohol into **acetic acid** (vinegar) in the presence of the enzyme of *Mycoderma aceti* (7) **Nitric acid** reacts slowly with copper metal, but the rate of reaction is accelerated more and more as nitrogen tetroxide (catalyzer) is formed in the solution This is an example of autocatalysis, wherein the reaction brings about the formation of its own catalyzer (8) **Arsenic** containing substances are extreme negative catalyzers, called inhibitors or poisons, of platinum catalyzer

When the catalyzer is a solid substance, the greatest difficulty in use is to maintain a clean surface The presence of a positive catalyzer enables a reaction to proceed more rapidly at a lower temperature than corresponds to the natural rate of the reaction This increases the amount of substances converted in a given time, decreases the demands as to temperature resistance of materials of construction of the apparatus, and frequently makes possible a state of equilibrium (below) more favorable to the yield of desired material

III *The End-point of Chemical Reactions* If a chemically reactive system is isolated from the rest of the universe at a constant temperature and pressure, a definite end-point is often attained short of the complete transmutation of reactants into resultants In order to be certain that this end-point (short of complete transmutation) is what is known as the **equilibrium** point, the equilibrium must be approached from both directions, e g, $A + B \rightarrow C + D$ and $C + D \rightarrow A + B$ If the value of the equilibrium constant (below) is the same when approached from both directions, then the reaction is one of true chemical equilibrium Such equilibrium reactions are also referred to as balanced or reversible reactions In such reactions the extent of the chemical change is proportional to the concentrations of all the reactants—reactants and resultants being interchangeable, depending upon the direction of the reaction (Generalization of Guldberg and Waage, 1864, called Law of Mass Action, or more correctly Law of Concentration Effect Reaction studied by Guldberg and Waage (1867) **Barium sulfate plus potassium carbonate plus barium carbonate plus potassium sulfate**)

A classical case, frequently cited, is that investigated by Berthelot in 1863. When 1 mol (60 grams) of acetic acid (CH_3COOH) and 1 mol (46 grams) of ethyl alcohol, both of which substances are soluble in water, are mixed, a reaction takes place which results in the formation of water and ethyl acetate ester, which is likewise in water in the ratio of 1 mol (18 grams) of water, and 1 mol (88 grams) of ethyl acetate On the other hand, when 1 mol of water and 1 mol of ethyl acetate ester are mixed, a reaction takes place which results in the formation of acetic acid and ethyl alcohol in the ratio of 1 mol of acetic acid and 1 mol of ethyl alcohol Three important observations have resulted from the detailed study of this reaction, namely, (1) the reaction between acetic acid and ethyl alcohol as reactants proceeds at such a rate that the fraction 0 00575 of the amount present at any instant reacts, at 6° to 9° C, in 1 day to form equivalent amounts of water and ethyl acetate ester, (2) the reaction between water and ethyl acetate ester as reactants proceeds at such a rate that the fraction 0 00144 of the amount present at any instant reacts, at 6° to 9° C, in 1 day to form equivalent amounts of acetic acid and ethyl alcohol, and (3) the end-point of each reaction is the same, that is, the reaction is one of true chemical equilibrium, and the resulting equilibrium mixture contains, in each case, 0 33 mol acetic acid plus 0 33 mol ethyl alcohol plus 0 67 mol water plus 0 67 mol ethyl acetate ester This system attains practical equilibrium, at 6° to 9° C in about 1 year, at 100° C in about 8 days, and at 200° C in about 24 hours

The equilibrium constant is calculated numerically as follows.

Equation	$CH_3COOH + C_2H_6OH$	$\rightleftarrows$	$HOH +$	$CH_3COOC_2H_5$
Reaction Weights	60		16	88
Molar ratio at equilibrium	0 33		0 67	0 67
Weights at equilibrium	0 33×60		0 67×16	0 67×88

$$\text{Equilibrium constant at } 9^\circ \text{ C} = \frac{\text{conc HOH} \times \text{conc } CH_3COOC_2H_5}{\text{conc } CH_3COOH \times \text{conc } C_2H_5OH} = \frac{0\ 67 \times 0\ 67}{0\ 33 \times 0\ 33} = 4$$

Knowing the equilibrium constant at any stated temperature enables one to calculate the equilibrium end-point at that temperature for any ratio of reactants Thus, when 1 mol (60) grams of acetic acid and 10 mols (460) grams of ethyl alcohol at 9° C are taken

$$\text{Equilibrium constant at } 9^\circ \text{ C} = 4 = \frac{X \times X}{(1 - X) \times (10 - X)}$$

where X is the number of mols of water and also the number of mols of ethyl acetate ester formed (1 mol of each is formed by reaction of 1 mol acetic acid plus 1 mol ethyl alcohol) Solution of this equation shows $X = 0\ 97$ Therefore, by taking the above ratio of acetic acid (1 mol) to ethyl alcohol (10 mols) 0 97 (or 97%) of the acetic acid, the excess reactant being ethyl alcohol (9 mols), is converted at equilibrium into water plus ethyl acetate ester In practice, the reaction is conducted by the use of a catalyzer, e g, sulfuric acid concentrated, zinc chloride

In cases where one of two resultants can be separated from the reactants and the other resultant, by precipitation as a solid, by condensation as a liquid, or by volatilization as a gas or vapor, the yield of the desired substance from a given amount of reactants can sometimes be materially increased In the case of heterogeneous systems (those that are not homogeneous) whenever a solid participant is present, the *concentration* of said solid is considered constant The precipitation and solution of solids are in this category, as well as the reactions between a gas and a solid, e g, the system ferroferric oxide plus hydrogen gas plus iron plus water vapor.

The effect of change of temperature on a system in chemical equilibrium is that the equilibrium point is shifted (1) towards the side *away* from that which

evolves heat when the temperature is *raised*, and (2) towards the side which evolves heat when the temperature is lowered It is *as if* the amount of heat were a *material* reactant and its concentration (temperature or intensity of heat) increased, in respect to the *direction* of the shift of the equilibrium point The amount of the shift at constant pressure can be calculated in cases where one possesses the proper data See Thermochemistry

The effect of change of pressure on a system in chemical equilibrium is that the equilibrium point is shifted (1) towards the side possessing the smaller aggregate volume when the pressure is increased, and (2) towards the side possessing the larger aggregate volume when the pressure is decreased The amount of the shift at constant temperature can be calculated by means of the equilibrium constant (above) recalling that increase of pressure is equivalent to increase of concentration of gases (temperature constant) When the volume of resultants equals the volume of reactants, no effect is produced on the equilibrium point by change of pressure See **Equilibrium**

Chemical Equations In calculating the equilibrium constant (above) the equation of the reaction was presented and the reaction weights inserted Every chemical reaction between pure substances (individual chemicals) with the formation of pure substances is capable of being represented in the form of a chemical equation, wherein the formula of each pure substance has the significance stated in chemical composition, section II, Compounds and related topics The only difficulty which should present itself to the uninitiated is that of always recalling that the formula of each chemical substance stands for a definite chemical unit weight (or volume, if a gas) In the vast majority of reactions encountered in practice the writing of the chemical equation of a reaction is comparatively simple when one knows (1) what substances are reactants, (2) what substances are resultants, (3) the formula of each The sum of the weights (masses) of reactants equals the sum of the weights (masses) of the resultants Without this information, equations cannot be written

Grand Groups of Chemical Reactions Certain grand groups of reactions are recognized The classification may be carried further with extensive additions as desired

1 **Reactions involving recombination of ions**
2 **Reactions involving water**
  (a) Consumption of water
  (b) Production of water
  (c) Water as catalyzer
3 **Reactions involving oxidation—reduction**
  (a) In solutions of electrolytes
  (b) Not in solutions of electrolytes (R K S)

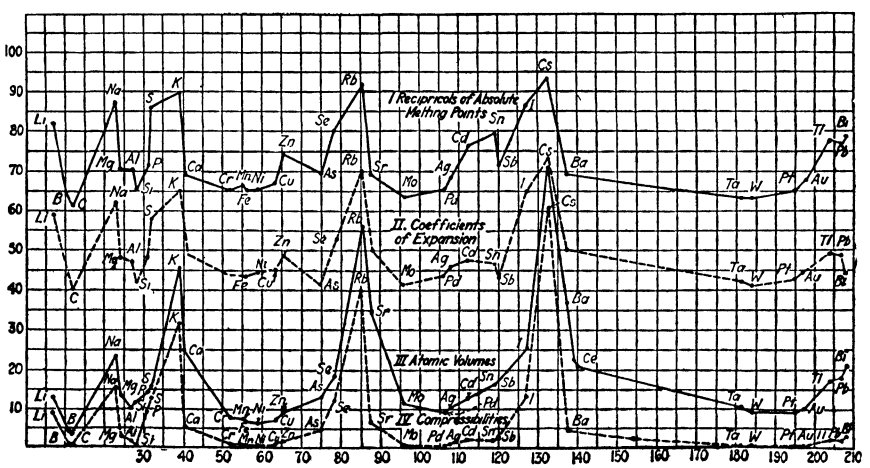
CHEMICAL COMPOSITION. The following outline will make clear the subjects discussed under chemical composition of substances. For the chemical changes undergone by such substances see **Chemical Changes**

I Elements, symbols, atoms, allotropes (allotropy), isotopes (isotopy), isobares, atomic constants
II Compounds, formulas, molecules, allotropes (allotropy), molecular constants, isomers (isomerism, stereoisomerism)
III Radicals
IV Equivalents, valency, graphical formulas

I. Elements and Related Topics.

At the present time there are recognized by the Committee on Atomic Weights of the International Union of Chemistry 86 chemical elements For list see **Chemistry** The most recent additions to the list are **hafnium** in 1927, **rhenium** in 1929, and **protoactinium** in 1937 Some elements have been known since prehistoric times, e g , the common metals, some have been proved to be elements that were previously considered not elements, e g , **chlorine** (Davy, 1810), some have been discovered by new methods of investigation, e g , by the spectroscope (Bunsen and Kirchhoff), **cesium** (1860), **rubidium** (1861), **helium** in the spectrum of the sun by Janssen and Lockyer in 1868 and in certain minerals of the earth by Ramsay and by Cleve independently in 1895, by the **X-ray** spectra (Moseley, 1914), e g , hafnium by Coster and Hevesy in 1923, and rhenium by Walter Noddack and Ida Tacke in 1925

The introduction of a systematic relationship among the chemical elements is due to Mendeléeff in 1869 His pronouncement was that the properties of elements, as well as the forms and properties of their compounds, are in periodic dependence on the atomic weight of the elements A full account is given in the Faraday Lecture of the Chemical Society (London) on "The Periodic Law of the Chemical Elements" delivered by Men-



Graph showing periodicity of the physical properties of the elements.

deléeff on June 4, 1889 This periodic arrangement is the one in common use at the present time Extension and experimental verification of the periodic arrangement is due to the work on X-ray spectra of the chemical elements by Moseley in 1914, who was able to assign a serial number, called the atomic number, to each of the elements from hydrogen 1 to uranium 92 As was stated above, the identity of 86 of these has been officially recognized, and some of the remaining are known to exist in the radioactive series of elements, namely, uranium X 2 of atomic number 91, mesothorium 2 of atomic number 89, and several of atomic numbers 81, 82, 83, 84, 86, 88, 90, 92 See **Radioactive Changes**

The following arrangement, using the accepted symbols (see Atomic Weights, page 235), summarizes the above

PERIODIC CLASSIFICATION OF THE CHEMICAL ELEMENTS
ACCORDING TO MENDELÉEFF AND MOSELEY

Number	Group O	Group I	Group II	Group III	Sub-Group IV	Sub-Group V	Sub-Group VI	Sub-Group VII	Sub-Group VIII			Sub-Group I	Sub-Group II	Sub-Group III	Group IV	Group V	Group VI	Group VII
1		H																
2–9	He	Li	Be	B											C	N	O	F
10–17	Ne	Na	Mg	Al											Si	P	S	Cl
18–35	A	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br
36–53	Kr	Rb	Sr	Y	Zr	Cb	Mo	(43)	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
54–85	Xe	Cs	Ba	La–Lu 57–71 (Below)	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	(84)	(85)
86–92	Rn	(87)	Ra	(89)	Th	Pa	U											
57–71 of Group III					La	Ce	Pr	Nd	(61)	Sa	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu

NOTES Element 43, masurium, announced by Walter Noddack and Ida Tacke 1925
Element 61, illinium, announced by Harris, Yntema and Hopkins, 1926
Element 84, radioactive element known
Element 85, alabamine, announced by Allison and Murphy, 1929
Element 87, virginium, announced by Allison and Murphy, 1929, and by Papish and Wainer, 1931
Element 89, radioactive element, mesothorium 2

Groups by name
Group O, rare or noble gases
Group I, Li–Cs, alkali metals
Group II, alkaline earth metals
Group III, Sc–Lu, rare earth metals
Group VIII, Ru, Rh, Pd, Os, Ir, Pt, rare or noble metals
Group VII, halogens

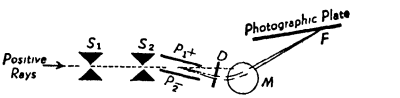
It is not attempted here to define a chemical element in a simple manner, as could have been done some years ago with some confidence The Moseley atomic number is probably the best peg on which to hang the concept of atom as used practically This constant, along with the Mendeléeff placement of the elements, makes it clear that the elements form a system Other data confirm this Symbol weights—commonly known as atomic weights—of the elements are relative numbers for the mass of each element based on the standard of reference, oxygen equal to 16 0000 The alphabetical table of elements on page 235 gives the name, symbol, atomic number and atomic weight

Other constants of certain atoms are given (pp 236, ff) namely, atomic volume, atomic heat, atomic radius, atomic compressibility Constants in frequent use are hardness, crystal form, melting point, boiling point, vapor pressure, also important, spectrum, both visible and x-ray

Atomic volume is the volume in milliliters occupied by 1 atomic weight in grams of the solid element, therefore, atomic weight (grams) divided by density (specific gravity) of the solid element equals atomic volume (milliliters)

Atomic heat is the amount of heat required to raise the temperature 1° C of 1 **atomic weight** in grams of the solid element at a given temperature, therefore, atomic weight (grams) multiplied by specific heat of the solid element equals atomic heat (calories) The atomic heat values given are not exactly comparable—the temperature is as stated in each case. Omitting **beryllium, boron, carbon, sodium, silicon, potassium, titanium,** the remaining 23 elements show a value within 1% of 6 1 (Dulong and Petit's generalization of constancy of atomic heat (1819)) (For Molecular heat, see following section II, Compounds and related topics) Atomic radius as determined by Goldschmidt (1926) using x-ray studies Atomic compressibility is the fractional change in volume of the solid element corresponding to a given change in pressure at a constant temperature

Due to the investigations initiated by J J Thomson (1913) using **neon** gas in a low vacuum discharge tube and examining the effects of **anode** rays, the discovery was made that neon consists of two (later three) masses of atoms about 90% of the 20 and about 10% of the



Aston's mass spectrograph

22 mass (later, 20 (90%), 21 (0 27%), 22 (9 73%)) The work in this field has progressed since 1919 in the hands of Aston and co-workers to such a degree of accuracy that the atomic weight of **hydrogen** by this method of the mass-spectograph is, since 1929, the accepted value Substances which are recognized from their Mendeléeff-Moseley properties as chemical elements and which are *not* made up of atoms which are all of the same weight, as neon above, are said to consist of isotopes Isotopes of a given element possess the same chemical properties but different masses That is, neon 20, 21, 22 are chemically indistinguishable isotopes Physical confirmation of the existence of isotopes has been obtained by separation of neon into two fractions of different densities by effusion (Aston, 1920), (Hertz, 1932) The partial separation of isotopes of a given element has been successfully accomplished also in the case of **mercury** by Bronsted and Hevesy (1920) using **fractional distillation**, of **chlorine** by Bronsted and Hevesy (1920) and by Harkins and Hayes (1921) by

INTERNATIONAL ATOMIC WEIGHTS

1938

PUBLISHED BY THE JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

	Symbol	Atomic Number	Atomic Weight		Symbol	Atomic Number	Atomic Weight
Aluminum.....	Al	13	26 97	Molybdenum..	Mo	42	95 5
Antimony.....	Sb	51	121 76	Neodymium.	Nd	60	144 27
Argon	A	18	39 944	Neon....	Ne	10	20 183
Arsenic .	As	33	74.91	Nickel.... .	Ni	28	58 69
Barium .	Ba	56	137 36	Nitrogen..	N	7	14 008
Beryllium.	Be	4	9 02	Osmium	Os	76	190 2
Bismuth . .	Bi	83	209 00	Oxygen	O	8	16.0000
Boron . .	B	5	10 82	Palladium.	Pd	46	106.7
Bromine	Br	35	79 916	Phosphorus	P	15	31.02
Cadmium	Cd	48	112 41	Platinum . .	Pt	78	195 23
Calcium	Ca	20	40 08	Potassium.	K	19	39 096
Carbon	C	6	12 010	Praseodymium	Pr	59	140.92
Cerium	Ce	58	140 13	Protactinium.	Pa	91	231
Cesium	Cs	55	132 91	Radium ..	Ra	88	226.05
Chlorine	Cl	17	35 457	Radon..	Rn	86	222
Chromium	Cr	24	52 01	Rhenium.	Re	75	186 31
Cobalt .	Co	27	58 94	Rhodium .	Rh	45	102.91
Columbium	Cb	41	92 91	Rubidium	Rb	37	85.44
Copper . .	Cu	29	63 57	Ruthenium	Ru	44	101.7
Dysprosium	Dy	66	162 46	Samarium.	Sm	62	150 43
Erbium	Er	68	167 2	Scandium	Sc	21	45 10
Europium .	Eu	63	152 0	Selenium.	Se	34	78 96
Fluorine	F	9	19 00	Silicon.. .	Si	14	28.06
Gadolinium	Gd	64	157 3	Silver	Ag	47	107.880
Gallium	Ga	31	69 72	Sodium	Na	11	22.997
Germanium	Ge	32	72 60	Strontium.	Sr	38	87.63
Gold	Au	79	197 2	Sulfur	S	16	32.06
Hafnium .	Hf	72	178 6	Tantalum .	Ta	73	180 88
Helium	He	2	4 003	Tellurium .	Te	52	127.61
Holmium .	Ho	67	163 5	Terbium	Tb	65	159.2
Hydrogen ..	H	1	1 0081	Thallium	Tl	81	204 39
Indium ..	In	49	114 76	Thorium....	Th	90	232 12
Iodine . .	I	53	126 92	Thulium	Tm	69	169 4
Iridium....	Ir	77	193.1	Tin . .	Sn	50	118.70
Iron.....	Fe	26	55 84	Titanium	Ti	22	47.90
Krypton	Kr	36	83.7	Tungsten .	W	74	183 92
Lanthanum	La	57	138 92	Uranium.....	U	92	238.14
Lead	Pb	82	207.22	Vanadium .	V	23	50 95
Lithium ...	Li	3	6 940	Xenon	Xe	54	131.3
Lutecium .	Lu	71	175 0	Ytterbium ..	Yb	70	173 04
Magnesium.	Mg	12	24 32	Yttrium	Y	39	88 92
Manganese...	Mn	25	54 93	Zinc... ..	Zn	30	65 38
Mercury.....	Hg	80	200.61	Zirconium...	Zr	40	91 22

fractional diffusion through pipeclay, and of **hydrogen** by Urey (1932) Washburn and Urey (1932) found that the residual water of electrolytic cells, which had been operated for years without drawing off the caustic solution, contained a marked increase in abundance of mass 2 hydrogen relative to mass 1 (See **Water**)

Isotopes of radioactive elements are discussed under **Radioactive Changes**

A table of isotopes of the elements, arranged in two columns, the one containing the odd-numbered, the other the even-numbered elements, is presented (Page 237) Odd-numbered elements have at the most two isotopes (Aston) Of 38 odd-numbered elements, 19 are single; of 41 even-numbered elements, 4 only are single Isobares are elements of the same mass but different chemical properties, e g, titanium 50 and chromium 50

ATOMIC CONSTANTS OF ELEMENTS

		Atomic Volume of Solid	Atomic Heat of Solid at °C	Atomic Radius of Solid Goldschmidt 10^{-8} cm	Atomic Compressibility at 20° C × 10^{7}
1	Hydrogen	13 21			
2	Helium				
3	Lithium	11 8	6 6 (50°)	1 56	9 0
4	Beryllium	5 3	4 5 (0–300°)	1 05	
5	Boron	4 5	5 5 (900°)		0 3
6	Carbon	5 6 (graphite)	5 5 (900°) (graphite)	9 77 (diamond)	3 0 (graphite)
7	Nitrogen	13 6		0 71	
8	Oxygen	11 2		0 60	
9	Fluorine				
10	Neon				
11	Sodium	22 9	6 8 (20°)	1 86	15 6
12	Magnesium	14 0	6 0 (20°)	1 62	2 9
13	Aluminium	10 2	5 8 (20°)	1 43	1 47
14	Silicon	11 4	4 7 (14°)	1 18	0 32
15	Phosphorus	16 9 (yellow)	5 9 (90°) (yellow)		9 2 (yellow)
16	Sulfur	15 3 (rhombic)	5 7 (15–96°) (rhombic)	1 04	12 9 (rhombic)
17	Chlorine				
18	Argon				
19	Potassium	45 3	7 0 (14°)	2 23	31 7
20	Calcium	25 9	5 8 (0–20°)	2 21	5 7
21	Scandium			1 51	
22	Titanium	9 3	5 4 (0–100°)	1 49	
23	Vanadium	8 8		1 32	
24	Chromium	7 7	5 8 (18–100°)	1 25	0 9
25	Manganese	7 4	6 6 (20–100°)	1 36	0 84
26	Iron	7 1	6 0 (20°)	1 27	0 63
27	Cobalt	6 8	5 9 (20°)	1 26	
28	Nickel	6 6	6 2 (20°)	1 24	0 40
29	Copper	7 1	5 9 (15–100°)	1 28	0 75
30	Zinc	9 2	6 2 (0–100°)	1 37	1 7
31	Gallium	11 8		1 33	2 09
32	Germanium	13 6		1 39	
33	Arsenic	14 8	6 2 (0–100°)	0 16	4 5
34	Selenium	16 5		1 13	12 0
35	Bromine				
36	Krypton				
37	Rubidium	56 2		2 36	40 0
38	Strontium	34 5			
39	Yttrium	19 5			
40	Zirconium	14 0		1 62	
41	Columbium	12 7		1 43	
42	Molybdenum	10 7		1 36	0 46
43					
44	Ruthenium	8 3		1 32	
45	Rhodium	8 5		1 34	
46	Palladium	9 0		1 37	0 54
47	Silver	10 3	6 0 (20°)	1 44	1 01
48	Cadmium	13 0	6 2 (28°)	1 52	2 1
49	Indium	15 1		1 57	
50	Tin	16 3	6 4 (18°)	1 58	1 9
51	Antimony	18 2	6 1 (20–100°)	1 61	2 4
52	Tellurium	20 4		1 33	

ATOMIC CONSTANTS OF ELEMENTS—*Continued*

		Atomic Volume of Solid	Atomic Heat of Solid at °C	Atomic Radius of Solid Goldschmidt 10^{-8} cm	Atomic Compressibility at 20° C × 10^{7}
53	Iodine	25 9	6 6 (20°)	1 36	13 0
54	Xenon				
55	Cesium	70 4		2 55	61 0
56	Barium	39 0			
57-71					
72	Hafnium	13 4		1 59	
73	Tantalum	10 9		1 46	0 53
74	Tungsten	9 8		1 41	0 27
75	Rhenium	8 8		1 38	
76	Osmium	8 5		1 34	
77	Iridium	8 6		1 35	
78	Platinum	8 7	6 3 (20°)	1 38	0 38
79	Gold	10 2	6 2 (0–100°)	1 44	0 64
80	Mercury				
81	Thallium	17 2		1 71	2 3
82	Lead	18 2	6 3 (20°)	1 75	2 33
83	Bismuth	21 3	6 1 (20°)	1 82	3 0
84					
85					
86	Radon				
87					
88	Radium				
89					
90	Thorium	19 2	. .	1 82	
91	Protoactinium				
92	Uranium	12 8			

STABLE ISOTOPES OF THE ELEMENTS AND THEIR PERCENTAGE

At. No	Element	Mass Number of Isotope and Percentage: Odd No Elements	Even No Elements
1	Hydrogen	1 99 98 2 0 02 3 ?	
2	Helium		4 100
3	Lithium	6 7 9 7 92 1	
4	Beryllium		9 99 95
5	Boron	10 20 6 11 79 4	
6	Carbon		12 99 3 13 0 7
7	Nitrogen	14 99 62 15 0 38	
8	Oxygen		16 99 76 17 0 04 18 0 20
9	Fluorine	19 100	
10	Neon		20 90 0 21 0 27 22 9 73
11	Sodium	23 100	
12	Magnesium		24 77 4 25 11 5 26 11 1
13	Aluminum	27 100	
14	Silicon		28 89 6 29 6 2 30 4 2
15	Phosphorus	31 100	
16	Sulfur		32 97 0 33 0 8 34 2 2
17	Chlorine	35 76 37 24	
18	Argon		36 0 33 38 0 05 40 99 62
19	Potassium	39 93 4 40 0 01 41 6 6	
20	Calcium		40 96 76 42 0 77 43 0 17 44 2 30
21	Scandium	45 100	
22	Titanium		46 8 5 47 7 8 48 71 3 49 5 5 50 6 9
23	Vanadium	51 100	

(*Continued on next page*)

STABLE ISOTOPES OF THE ELEMENTS AND THEIR PERCENTAGE—*Continued*

At No	Element	Mass Number of Isotope and Percentage: Odd No Elements		Even No Elements	
24	Chromium			50	4 9
				52	81 6
				53	10 4
				54	3 1
25	Manganese	55	100		
26	Iron			54	6 5
				56	90 2
				57	2 8
				58	0 5
27	Cobalt	59	100		
28	Nickel			58	68 1
				60	27 2
				61	1 7
				62	3 8
				64	0 9
29	Copper	63	68		
		65	32		
30	Zinc			64	50 4
				66	27 2
				67	4 0
				68	17 8
				70	0 4
31	Gallium	69	61 5		
		71	38 5		
32	Germanium			70	21 2
				72	27 3
				73	7 9
				74	37 1
				76	6 5
33	Arsenic	75	100		
34	Selenium			74	0 9
				76	9 5
				77	8 3
				78	24 0
				80	48 0
				82	9 3
35	Bromine	79	50 6		
		81	49 4		
36	Krypton			78	0 42
				80	2 45
				82	11 79
				83	11 79
				84	56 85
				86	16 70
37	Rubidium	85	72 7		
		87	27 3		
38	Strontium			86	10
				87	6 6
				88	83 4
39	Yttrium	89	100		
40	Zirconium			90	48 0
				91	11 5
				92	22 0
				94	17 0
				96	1 5
41	Columbium	93	100		
42	Molybdenum			92	14 2
				94	10 0
				95	15 5
				96	17 8
				97	9 6
				98	23 0
43					

At No	Element	Mass Number of Isotope and Percentage: Odd No Elements		Even No Elements	
44	Ruthenium			96	5
				98	?
				99	12
				100	14
				101	22
				102	30
				104	17
45	Rhodium	103	100		
46	Palladium				
47	Silver	107	52 5		
		109	47 5		
48	Cadmium			106	1 5
				108	1 0
				110	15 6
				111	15 2
				112	22 0
				113	14 7
				114	24 0
				116	6 0
49	Indium	113	4 5		
		115	95 5		
50	Tin			112	1 1
				144	0 8
				115	0 4
				116	15 5
				117	9 1
				118	22 5
				119	9 8
				120	28 5
				122	5 5
				124	6 8
51	Antimony	121	56		
		123	44		
52	Tellurium			122	2 9
				123	1 6
				124	4 5
				125	6 0
				126	19 0
				127	?
				128	32 8
				130	33 1
53	Iodine	127	100		
54	Xenon			124	0 08
				126	0 08
				128	2 30
				129	27 13
				130	4 18
				131	20 67
				132	26 45
				134	10 31
				136	8 79
55	Cesium	133	100		
56	Barium			135	5 9
				136	8 9
				137	11 1
				138	74 2
57	Lanthanum	139	100		
58	Cerium			140	89
				142	11
59	Praseodymium	141	100		
60	Neodymium			142	36
				143	11
				144	30
				145	5
				146	18
61					

STABLE ISOTOPES OF THE ELEMENTS AND THEIR PERCENTAGE—*Continued.*

At No.	Element	Mass Number of Isotope and Percentage: Odd No. Elements		Even No. Elements	
62	Samarium			144	3
				147	17
				148	14
				149	15
				150	5
				152	26
				154	20
63	Europium	151	50 6		
		153	49 4		
64	Gadolinium			155	21
				156	23
				157	17
				158	23
				160	16
65	Terbium	159	100		
66	Drysprosium			161	22
				162	25
				163	25
				164	28.
67	Holmium	165	100		
68	Erbium			166	36
				167	24
				168	30
				170	10
69	Thulium	169	100		
70	Ytterbium			171	9
				172	24
				173	17.
				174	38
				176	12
71	Lutecium	175	100		
72	Hafnium			176	5
				177	19
				178	28
				179	18
				180	30
73	Tantalum	181	100		
74	Tungsten			182	22 6
				183	17 3
				184	30 2
				186	29 9
75	Rhenium	185	38 2		
		187	61 8		
76	Osmium			186	1 0
				187	0 6
				188	13 4
				189	17 4
				190	25 1
				192	42 5
77	Iridium	191	38 5		
		193	61 5		
78	Platinum			192	0 8
				194	30 2
				195	35 3
				196	26 6
				198	7 2
79	Gold	197	100.		
80	Mercury			196	0 10
				197	0 01
				198	9 89
				199	16 45
				200	23 77
				201	13 67
				202	29 27
				203	0 006
				204	6 85
81	Thallium	203	29 4		
		205	70 6		
82	Lead			203	?
				204	1 52
				205	?
				206	28 03
				207	20 40
				208	50 05
				210	?
83	Bismuth	209	100		
84					
85					
86	Radon				
87					
88	Radium				
89					
90	Thorium			232	100.
91	Protoactinium				
92	Uranium			238	99

The method of positive or anode-ray analysis by the mass-spectograph involves the use of a gaseous or volatilizable element or compound of the element. The blank spaces in the preceding table are accounted for by the fact that no satisfactory volatile compound has yet been found for the elements in question

Allotropic elements are those which present different physical forms of the same elementary chemical composition. The energy content and the volume of the different forms are not the same, and frequently a given temperature determines the transformation of one form to the other. In the case of **oxygen** and ozone the composition O_2 and O_3, respectively, makes it easy to understand the differences in behavior, but in other cases, different internal arrangements of the substances must be assumed.

SOME ALLOTROPIC ELEMENTS AND THEIR DISTINGUISHING PROPERTIES

Element	Crystal Form	Density	Melting Point	Transformation Temperature, °C	Heat of Combustion, Calorifs Per Gram
Carbon					
Diamond	Cubic	3 51 (20° C)			7870
Graphite, natural	Hexagonal	2 25 (20° C)		Stable form 400–800	7854
Amorphous (wood charcoal)					8080
Oxygen					
Oxygen	(Gas)	1 105 (air 1)	−218		Zero } Heat of
Ozone	(Gas)	1 658 (air 1)	−251		−720 } formation
Phosphorus					
Yellow (white)	Hexagonal	1 82 (20° C)	44		
Red	Cubic	2 20 (20° C)	590 (43 atm)		
Black	Rhombohedral	2 69			
Sulfur					
Rhombic	Rhombic	2 07	113	Stable below } 95 6	{ 2220
Monoclinic	Monoclinic	1 96	119	Stable above }	{ 2240
Iron					
Alpha-ferrite (magnetic)	Cubic, body centered			Stable below } 769	
Beta-ferrite	Cubic, body centered			Stable above }	
Beta-ferrite				Stable below } 906	
Gamma-ferrite	Cubic, face centered			Stable above }	
Gamma-ferrite				Stable below } 1404	
Delta-ferrite	Cubic, body centered		1535	Stable above }	
Cobalt				444	
(Magnetic below 1150° C)				1150	
Nickel					
(Magnetic below 350° C)				350	
Zinc					
Alpha				Stable below } 174	
Beta				Stable above }	
Beta				Stable below } 322	
Gamma				Stable above }	
Tin					
White, ordinary	Tetragonal	6 55		Stable above } 18–20	
Gray		5 80		Stable below }	
Rhombic, white	Rhombic	7 20		{ Stable above } 195	
				{ Ord stable below }	

II Compounds and Related Topics.

When two or more chemical elements are present in a substance possessing properties, e g , melting point, boiling point, density, percentage composition by elements, that are constant and individual for the substance, the given substance is regarded as a compound

Water and carbon dioxide are two of the most important substances of everyday life that are definite compounds See **Water**, and **Carbon, oxides**, for full description of these compounds, also **Hydrogen Peroxide** for another compound which contains the same elements, namely, hydrogen and oxygen, as water, and carbon, oxides, for other compounds which contain the same elements, namely, carbon and oxygen, as **carbon dioxide**—these are carbon monoxide and carbon **suboxide**

The formulas of gaseous compounds are obtained from a study of the composition by elements and the density, by a method introduced by the Italian chemist, Cannizzaro in 1858 Later, in 1872, in the course of his Faraday Lecture before the Chemical Society (London) on the subject "Some Points in the Teaching of Chemistry" Cannizzaro stated that "Symbols and formulas, in my opinion, constitute the introduction, preparation, and base of the study of the transformations of matter, which is the true object of our science" The simplest way to understand the method is to arrange in tabular form, (1) the individual gases, (2) the weight in grams of 1 liter (at 0° C , 760 millimeters of mercury pressure) of each gas, (3) the weight in grams of *each element* present in the above volume (1 standard liter) found by exact analysis (percentage composition by chemical elements using the methods of analytical chemistry), as on the following page

DISPLAY OF DATA TO ILLUSTRATE THE CANNIZZARO METHOD OF ARRIVING AT THE SYMBOL AND SYMBOL WEIGHT OF CHEMICAL ELEMENTS, AND THE FORMULA AND FORMULA WEIGHT OF CHEMICAL COMPOUNDS

	Gas	Grams per 1 Standard Liter	Percentage Composition by Chemical Elements	Grams per 1 Standard Liter by Chemical Elements					
				Hydrogen	Oxygen	Carbon	Nitrogen	Sulfur	Chlorine
1	Hydrogen chloride	1 639	Hydrogen 2 76% Chlorine 97 24	0 045					1 594
2	Ammonia	0 771	Hydrogen 17 75 Nitrogen 82 25	0 137			0 634		
3	Carbon dioxide	1 977	Oxygen 72 73 Carbon 27 27		1 438	0 539			
4	Carbon monoxide	1 250	Oxygen 57 14 Carbon 42 86		0 714	9 536			
5	Methane	0 717	Hydrogen 25 14 Carbon 74 86	0 180		0 537			
6	Ethylene	1 260	Hydrogen 14 38 Carbon 85 62	0 181		1 079			
7	Acetylene	1 173	Hydrogen 7 75 Carbon 92 25	0 091		1 082			
8	Oxygen	1 429	Oxygen 100 00		1 429				
9	Hydrogen	0 090	Hydrogen 100 00	0 090					
10	Nitrogen	1 251	Nitrogen 100 00				1 251		
11	Chlorine	3 214	Chlorine 100 00						3 214
12	Sulfur dioxide	2 927	Oxygen 49 95 Sulfur 50 05		1 462			1 465	
13	Hydrogen sulfide	1 539	Hydrogen 5 91 Sulfur 94 09	0 091				1 448	
14	Nitrous oxide	1 978	Oxygen 36 35 Nitrogen 63 65		0 719		1 259		
15	Nitric oxide	1 340	Oxygen 53 32 Nitrogen 46 68		0 715		0 625		
	Minimum weight (approximate)			0 045	0 715	0 538	0 626	1 45	1 60

Careful examination of the figures in the last six columns reveals the experimental fact that (1) in each separate vertical column the figures represent a minimum weight or a small multiple (approximately) of this weight, (2) the smallest of the six minimum weights is that for hydrogen, namely, 0 045 gram in 1 standard liter of hydrogen chloride gas

The next step involves changing 0 045 gram of hydrogen to exactly 1 000 gram and finding arithmetically the volume of hydrogen chloride containing this weight (1 000 gram hydrogen) The volume is found to be 22 2 standard liters

Therefore, 1 000 gram minimum weight of hydrogen is contained in 22 2 standard liters of hydrogen chloride

Using this standard volume of 22 2 liters, the next step is to ascertain the minimum weight of the other elements in this volume

Chemical Element	Hydrogen	Oxygen	Carbon	Nitrogen	Sulfur	Chlorine
Approximate minimum weight in grams of each of the six chemical elements in the standard volume, 22 2 liters	1 gram	16 grams	12 grams	14 grams	32 grams	35 5 grams

Then, the abbreviation is introduced of representing

Symbol Weights of Each Element by the Symbols

1 gram	of hydrogen	by the	symbol	H
16 grams	of oxygen	" "	"	O
12 grams	of carbon	" "	"	C
14 grams	of nitrogen	" "	"	N
32 grams	of sulfur	" "	"	S
35 5 grams	of chlorine	" "	"	Cl

By setting up again the second half of the table for the 15 gases, this time for 22 2 standard liters instead of 1 standard liter, the results obtained may be observed in the table on the following page

Thus, it is seen, the chemical formulas and formula weights (last column) of 15 gaseous chemical compounds have been arrived at, using the Cannizzaro method, by purely experimental and rational means, involving no theoretical considerations Extension of the method serves to ascertain the chemical formula of all gases and vaporizable substances For compounds which are neither gases nor vaporizable, other methods are available Of these the most used are those of Raoult depending upon the depression of the freezing point or the elevation of the boiling point of a compound dissolved in a given **solvent** See **Solutions**

It remains to be noted that, when there is no method available for ascertaining the formula weight of a compound, the *simplest* formula, based on chemical analysis and the use of symbol weights of the contained elements, is used, e g , ferric oxide, Fe_2O_3, ferroferric oxide, Fe_3O_4, ferrous oxide, FeO, cupric oxide (black copper oxide), CuO, cuprous oxide (red copper oxide), Cu_2O The customary formula of water is H_2O, which is correct at temperatures above 100° C —actually, liquid water is mainly dihydrol $(H_2O)_2$

It should be understood from the above discussion that a chemical formula is no chance throwing together of chemical symbols, but represents the results of careful analysis, and the scrutiny and deduction of the most skillful workers in the field On this score alone, chemical formulas demand the greatest respect in understanding and use

DERIVATION OF FORMULAS AND FORMULA WEIGHTS OF GASES, HAVING GIVEN THE PERCENTAGE COMPOSITION BY CHEMICAL ELEMENTS OF EACH GAS AND THE SYMBOLS AND SYMBOL WEIGHTS OF THE ELEMENTS CONTAINED

	Gas	In 22 2 Liters						Formula of Gas	Grams of Same in 22 2 Liters
	Symbol Weight / Symbol	1 g H	16 g O	12 g C	14 g N	32 g S	35 5 g Cl		
1	Hydrogen chloride	1					1	HCl	36 5
2	Ammonia	3			1			NH_3	17
3	Carbon dioxide		2	1				CO_2	44
4	Carbon monoxide		1	1				CO	28
5	Methane	4		1				CH_4	16
6	Ethylene	4		2				C_2H_4	28
7	Acetylene	2		2				C_2H_2	26
8	Oxygen		2					O_2	32
9	Hydrogen	2						H_2	2
10	Nitrogen				2			N_2	28
11	Chlorine						2	Cl_2	71
12	Sulfur dioxide		2			1		SO_2	64
13	Hydrogen sulfide	2				1		H_2S	34
14	Nitrous oxide		1		2			N_2O	44
15	Nitric oxide		1		1			NO	30

Symbol weights and atomic weights are used synonymously Formula weights and molecular weights are used synonymously Unless otherwise stated, symbol weights and formula weights are expressed in grams, and the numbers used are those taken from the accepted list of atomic weights See preceding section I, Elements and related topics

One formula volume of a gas is 22 2 liters It is necessary to state that actual gases under ordinary conditions show some variation from this value, so that for accurate work the records should be consulted in each case The volume, 22 4 liters (1% larger than used in the above deductions) is commonly used

Summarizing, the formula "HCl" states that "36 5 grams of hydrogen chloride gas occupies a standard volume of 22 2 liters and is composed of 1 gram of hydrogen element chemical united with 35 5 grams of chlorine element" The reason for the formulas of the simple gases, oxygen, O_2, hydrogen, H_2, nitrogen, N_2, chlorine, Cl_2, is apparent from the general method of deduction The formula O_2 represents 22 2 liters or 32 grams of oxygen *gas*, whereas O represents 16 grams of oxygen element in any substance

Other constants of **molecules** are similar in kind to those referred to under atoms (See preceding section I, Elements and related topics), namely, hardness, crystal form, melting point, boiling point, vapor pressure, molecular volume, molecular heat (see below), molecular dimensions of gases, allotropy and transformation temperatures Molecular properties of great significance in organic chemistry are those of **isomerism** and stereoisomerism, and molecular dissociation, and **association** A molecule of a chemical compound may be defined as the smallest unit which retains the characteristic properties of the compound

It has become customary in chemical literature to use the formula of a substance as an accepted abbreviation for the name of the substance, especially in cases of frequent repetition

The molecular heat of a solid compound is equal to the sum of the atomic heats (see preceding section I, Elements and related topics) of the elements of the compound This generalization is the result of investigations by Kopp (1864) Since several elements that are commonly found in solid compounds are not themselves solids or are not, at ordinary temperature, in agreement with the atomic heat constant 6 1, calculated values from experimental observations of the molecular heat of solid compounds have been assigned to them Nernst recommended that the following values be used

Oxygen	4 0	Phosphorus	5 4
Hydrogen	2 3	Sulfur	5 4
Carbon	1 8	Boron	3 7
Silicon	3 8	Fluorine	5 0

The term molar fraction is used to express the ratio of the number of gram mols of one compound present in a system to the total number of gram mols of all the compounds present in that system Thus, formaldehyde solution is approximately 40% formaldehyde (HCHO, formula weight 30) and 60% water (H_2O, formula weight 18)

$$\frac{\text{number of mols HCHO}}{\text{number of mols HCHO} + \text{number of mols } H_2O} = \frac{\frac{40}{30}}{\frac{40}{30} + \frac{60}{18}}$$

$$= \frac{1\ 33}{4\ 66} = 0\ 285, \quad \text{molar fraction of formaldehyde}$$

This value multiplied by 100 gives the molecular percentage, — 28 5 molecular per cent formaldehyde solution (40 weight per cent of formaldehyde solution For "volume per cent" see **Ethyl Alcohol**)

III Radicals.

In many chemical compounds there are groups of two or more elements that frequently have the properties of or enter into chemical reaction as a unit Of those which are of outstanding importance the following are cited

(1) **Ammonium** (NH_4—) behaves as a unit in ammonium compounds and in some of these compounds is very similar to **potassium** (K—) in potassium compounds Ammonium (NH_4—) is the only important metal-like radical cation in organic chemistry

(2) Hydroxyl (—OH) which behaves as a unit in bases (e g, **sodium** hydroxide, NaOH), **alcohols** (e g, methyl alcohol, CH_3OH), and **phenols** (e g, phenol, C_6H_5OH)

(3) Anion-groups of acids, their salts and their esters· **Sulfate** (>SO_4), **sulfite** (>SO_3), **nitrate** (—NO_3), **nitrite** (—NO_2), **phosphate** (>PO_4), **perchlorate** (—ClO_4), **chlorate** (—ClO_3), **chlorite** (—ClO_2), **hypochlorite** (—OCl), **carbonate** (>CO_3), **formate** (—CHO_2), **acetate** (—$C_2H_3O_2$), **palmitate** (—$C_{16}H_{31}O_2$), **stearate** (—$C_{18}H_{35}O_2$), **oleate** (—$C_{18}H_{33}O_2$), **oxalate** (>C_2O_4), lactate (—$C_3H_5O_3$), malate (>$C_4H_4O_5$), **tartrate** (>$C_4H_4O_6$), citrate (>$C_6H_5O_7$), ben-

zoate ($-C_7H_5O_2$), cinnamate ($-C_9H_7O_2$), phthalate ($>C_8H_4O_4$), salicylate ($-C_7H_5O_3$). See **Acids, Carboxylic**, for others

(4) Alkyl- and aryl-groups of alcohols, phenols, their esters and their alcoholates and phenolates (a) Alkyl (non-benzenoid)-methyl (CH_3-), ethyl (C_2H_5-), propyl (C_3H_7-), butyl (C_4H_9-) and similar radicals of alcohols (See **Alcohols** for others), (b) Aryl (benzenoid)-phenyl (C_6H_5-), tolyl (C_7H_7-), xylyl (C_8H_9-), naphthyl ($C_{10}H_7-$) and similar radicals of phenols (See **Phenols** for others)

(5) Acyl-groups of organic acids acetyl (CH_3CO-), benzoyl (C_6H_5CO-) (See **Acids, Carboxylic**, for others)

(6) Miscellaneous radicals, for example, cacodyl ($(CH_3)_2As-$), celebrated on account of the investigations by Bunsen (1838)

All of the above radicals are associated with a corresponding radical or element in a compound While a radical frequently and rather generally enters into chemical reaction as a unit, it is not implied that this is always so, the stability in each case is characteristic of each radical and each reaction in which it is involved Thus, **ammonium** hydroxide (NH_4OH) yields **ammonia** gas (NH_3) and water (H_2O) at room temperature, ammonium nitrate (NH_4NO_3) is decomposed, upon heating, with the accompanying disruption of both the ammonium and nitrate radicals to yield **nitrous oxide** (N_2O) gas and water (H_2O)

Radicals enter widely into reactions involving electrolytic dissociation of salts, acids, bases in water solution See **Reactions Involving Recombinations of Ions**

Except in rare cases, free radicals are not encountered Gomberg (1900), by treating triphenylmethyl chloride in an atmosphere of **carbon dioxide**, with zinc, silver, or mercury, obtained the free radical, triphenylmethyl On dissolving the colorless solid in organic solvents a yellow solution is obtained, and the reactivity (due to unsaturation) of the yellow solution is marked towards **oxygen**, dissolved **iodine**, **ether** Triphenylmethyl is present in solution in two forms, (1) monomolecular ($(C_6H_5)_3C$) yellow, in equilibrium with (2) dimolecular ($(C_6H_5)_3(C)_2$ colorless But tribiphenylmethyl ($(C_6H_5-C_6H_4)_3C$) occurs only in the monomolecular form, purple The action of alkali metals on **ketones** in some cases produces metallic ketyl (Schlenk, 1913) thus $\frac{R'}{R''}>C-ONa$, which is a free radical, or contains trivalent carbon as does monomolecular triphenylmethyl

IV. Equivalents, Valency, Graphical Formulas.

In the preceding section on radicals, each radical is written with one or more accompanying lines, characteristic for each, (a) on the right-hand side for ammonium, alkyl, aryl, acyl, and (b) on the left-hand side for hydroxyl, anion groups The metals in their salt compounds would be similarly written (a) on the right-hand side, thus, sodium ($Na-$), calcium ($Ca<$), aluminum ($Al<$), (also hydrogen ($H-$) of water, acids, etc), and the non-metals in their salt compounds would be similarly written (b) on the left-hand side, thus, chloride ($-Cl$), bromide ($-Br$), iodide ($-I$), sulfide ($>S$), nitride ($\rightarrow N$), (also oxygen ($>O$) of water, oxides, etc) Compounds that are known to consist of the union of these (a) and (b) radicals and elements are found to be united "bond for bond," thus water, (H_2O) (H—OH or H_2O), hydrochloric acid, (HCl) (H—Cl); sulfuric acid, (H_2SO_4) (H_2SO_4 or $(HO)_2SO_2$); nitric acid, HNO_3 (H—NO_3 or HO—N=O), phosphoric acid, H_3PO_4 (H_3PO_4 or $O=P(OH)_3$), acetic acid, $HC_2H_3O_2$ (H—$C_2H_3O_2$ or CH_3CO—OH or H—OOC CH_3 or $H_3C_2O_2$), oxalic acid, $H_2C_2O_4$ ($H_2C_2O_4$ or HOOC—COOH), acetyl chloride, (CH_3CO—Cl or H_3C_2OCl), silver chloride, Ag—Cl, cupric chloride, $CuCl_2$, green soluble solid ($CuCl_2$), cuprous chloride, CuCl, white insoluble solid, or Cu_2Cl_2 (vapor) (Cu—Cl or Cu—Cl), cupric oxide, CuO, black insoluble solid (Cu=O), cuprous oxide, Cu_2O, red insoluble solid (Cu_2O), magnesium oxide, MgO, white insoluble solid (Mg=O), magnesium nitride, Mg_3N_2, yellow solid yielding ammonia with water (Mg_3N_2), ammonium nitrate, NH_4NO_3 (NH_4—NO_3 or $H_4N_2O_3$), ethyl alcohol, C_2H_5OH (C_2H_5—OH or H_3C_2OH) Also, oxygen gas, O_2 (O=O), chlorine gas, Cl_2 (Cl—Cl), nitrogen gas, N_2 (N≡N), hydrogen gas, H_2 (H—H), cyanogen gas, $(CN)_2$ (NC—CN or N≡C—C≡N)

The last formula in each of the above examples is known as the graphical formula of the compound Graphical formulas are of great significance in the field of organic chemistry They are frequently partially abbreviated, thus, ethyl alcohol, above, is often written CH_3-CH_2OH

The number of lines shown accompanying each radical or element is a measure of its valency Univalent radicals are equivalent Higher valent radicals are equivalent "bond for bond" The univalent radicals, ammonium (NH_4-) and nitrate ($-NO_3$) are equivalent in *combining power* (ammonium nitrate NH_4NO_3) The divalent radical sulfate ($>SO_4$) and the univalent radical nitrate ($-NO_3$) are equivalent 1 to 2 in *replacing power* (copper sulfate $CuSO_4$, copper nitrate $Cu(NO_3)_2$) These values have been experimentally determined in each case, based on certain elementary assumptions, principally two, namely, (1) oxygen in most chemical compounds has a valency of minus two ($>O^{2-}$), (2) hydrogen in most chemical compounds has a valency of plus one ($H-^{1+}$) The cases where oxygen is zero ($-^{1+}O^{1-}-$) and hydrogen minus one ($-H^{-1}$) are rare (hydrogen peroxide ($H^{+1}-{}^{-1}O^{+1}$ $H^{+1}-{}^{-1}O^{-1}$) and calcium hydride ($Ca^{+2}(H^{-1})_2$) respectively)

Grand Groups of Chemical Substances—Elements and Compounds. Certain grand groups of substances are recognized The classification may be carried further with subdivisions extended as desired

1. Acids, bases, salts (See **Acids, Bases, Salts; Individual Acids; Acids, Carboxylic**)
2. Metals, non-metals, alloys (See *Individual* **elements. Alloys**).

VALENCY OF CERTAIN CHEMICAL ELEMENTS

Positive								Negative			
7	6	5	4	3	2	1	0	1	2	3	4
						H^{1+} In water, acids, methane			O^{2-} In water, oxides, bases, alcohols, aldehydes		
		N^{5+} In nitrogen pentoxide, nitrates, nitro-compounds		N^{3+} In nitrogen trioxide, nitrites, nitroso compounds	N^{2+} In nitric oxide					N^{3-} In ammonia, ammonium compounds ($N^{1+, 4-}$)	
		P^{5+} In phosphorus pentoxide, phosphates		P^{3+} In phosphorus trioxide, phosphites		P^{1+} In hypophosphites				P^{3-} In phosphine phosphonium compounds ($P^{1+, 4-}$)	
	S^{6+} In sulfur trioxide, sulfates		S^{4+} In sulfur dioxide, sulfites						S^{2-} In sulfides		
Cl^{7+} In perchlorates		Cl^{5+} In chlorates		Cl^{3+} In chlorites		Cl^{1+} In hypochlorites		Cl^{1-} In chlorides			
			C^{4+} In carbon dioxide, carbonates		$C^{2+,1-}$ In carbon monoxide, formic acid		$C^{2+, 2-}$ In formaldehyde		$C^{1+, 3-}$ In methyl alcohol		C^{4-} In methane
			Si^{4+} In silicates	Al^{3+} In aluminum compounds	Ca^{2+} In calcium compounds	Na^{1+} In sodium compounds	Free elements Na^0, Ca^0, Al^0 Si^0, Cu^0, Fe^0, Mn^0, Cr^0, C^0, S^0, P^0				
					Cu^{2+} In cupric compounds	Cu^{1+} In cuprous compounds					
				Fe^{3+} In ferric compounds	Fe^{2+} In ferrous compounds						
Mn^{7+} In permanganates	Mn^{6+} In manganates		Mn^{4+} In manganese dioxide	Mn^{3+} In manganic compounds	Mn^{2+} In manganous compounds						
	Cr^{6+} In chromates			Cr^{3+} In chromic compounds	Cr^{3+} In chromous compounds						

See **Reactions Involving Oxidation, Reduction** (B) (2) for more complete list

3 Oxides, chlorides, sulfides—most important grand group of 2-element compounds (See **Oxygen**, oxides, **Chlorine**, chlorides, **Sulfur**, sulfides, **Thermochemistry**)

4. Organic compounds (See **Chemistry**, 3 Organic Chemistry) (R K S)

CHEMICAL COORDINATION. The coordination of complex bodies by the reaction of various parts to substances whose occurrence within the body is conditioned by its own processes A simple example is the regulation of the rate of respiration by the concentration of **carbon dioxide** in the blood The more striking cases of chemical coordination concern special secretions produced by glands within the body and called **hormones** (A W L)

CHEMICAL FORMULAE. The formulae of chemistry constitute a short hand notation used to represent the composition by weight, the **molecular** properties, the characteristic chemical reactions or at times even the ordering of the **atoms** in space of the elements which go to make up the chemical compound Chemical formulae are classified into empirical, molecular, structural or configurational, the order given being that of increasing content of information The following steps indicate the type of chemical experiments necessary to establish the different kinds of formulae The first step

consists in the isolation of a pure chemical compound Chemical purification can be obtained by **crystallization, distillation, adsorption, sublimation,** etc. Some of the criteria of purity which a substance must satisfy are constancy and sharpness of melting point and boiling point on repeated purification As an example let us assume that we have succeeded in purifying a solid compound which we shall call **tartaric acid** and whose formula we wish to determine

The second step consists in a qualitative and quantitative analysis of the compound. In the case of tartaric acid qualitative analysis tells us that the compound contains carbon, oxygen and hydrogen, while quantitative analysis shows that the proportions are 48 parts by weight of carbon, 96 of oxygen, and 6 of hydrogen To obtain the empirical formula one divides each proportion by the atomic weight of the particular element, obtaining in this way a set of numbers which can be represented by a ratio of small integers The simplest ratio of integers is commonly used to indicate as subscripts on the right of the chemical symbol of the element to represent the empirical formula In the case of tartaric acid the atomic weights are 12 for **carbon,** 16 for **oxygen** and 1 for **hydrogen** Dividing the percentages as determined by analysis by the atomic weights we get

Carbon	48/12	= 4
Oxygen	96/16	= 6
Hydrogen	6/1	= 6

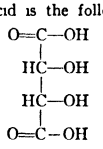
The set of numbers is 4,6,6 and can be represented in this case by the ratio of integers 2 3 3 The empirical formula is therefore $C_2O_3H_3$ Empirical formula is thus only a convenient method for representing the percentage composition by weight of the different elements in the compound The third step is the determination of the molecular weight of the compound in question This allows us to assign to the compound a molecular formula The molecular weight can be determined in a variety of methods such as by the determination of the weight of 22 4 liters of the vapor of the substance at 1 atmosphere pressure and 0° Centigrade, temperature Other methods are based on the lowering of the freezing point and the raising of the boiling point of solutions of known concentration Other methods are based on the differences in the boiling point or freezing point of solutions of known concentration and those of the pure solvent To determine the molecular formula from the knowledge of the empirical formula and the molecular weight the following procedure must be followed Multiply the atomic weight of each element by its subscript as indicated in the empirical formula and add the result On comparison of such a sum with the molecular weight it will be found that the molecular weight is equal to the sum times an integer To obtain the molecular formula multiply each subscript in the empirical formula by this integer and obtain a new set of subscripts We found the empirical formula of tartaric acid was $C_2O_3H_3$ The sum mentioned above is

$$12 \times 2 + 16 \times 3 + 1 \times 3 = 75$$

The molecular weight determined experimentally is 150 The integer multiple is 2 and the molecular formula becomes $C_4O_6H_6$

The molecular weight of the compound can be obtained from the molecular formula by summing the products obtained by multiplication of the atomic weights of the elements times their subscripts in the molecular formula The latter contains all the information that the empirical formula contains but in addition specifies the number of atoms in the molecule and also the molecular weight of the substance The chemical formulae met in practice are molecular formulae

Structural formulae have a twofold purpose they attempt to show which atom is attached to which in the molecule and also to summarize the more important chemical reactions of the molecules The cornerstone of the structural formula theory are the assumptions of definite valency for each element, the ability of certain atoms, especially carbon, to unite with each other to form chains and rings, and the formation of multiple valence bonds between atoms in a molecule Most of the evidence for the manner in which atoms are attached to each other in the molecule is circumstantial Yet all the circumstantial deductions of the organic chemist have been substantiated by direct evidence of spectroscopy The structural formula is also a short hand notation for the important chemical reactions of the compound It can be considered as being built up of a group of organic **radicals,** i e, groups of atoms which retain their individuality in the course of certain reactions Each radical has reactions which are characteristic of its presence in the molecule For instance, the **carboxyl** radical $-C\overset{O}{\diagdown\!\!\diagup}OH$ will react with alkali such as **sodium** hydroxide to form salts $-C\overset{O}{\diagdown\!\!\diagup}ONa$, with **phosphorus** pentachloride to form acid **chlorides** $-C\overset{O}{\diagdown\!\!\diagup}Cl$, with **alcohols** to form **esters;** with reducing agents under certain conditions to form successively the **aldehyde** radical $-C\overset{O}{\diagdown\!\!\diagup}H$ and the **alcohol** radical Any compound which undergoes such reactions is said to contain a carboxyl group The number of such carboxyl groups in a molecule can be determined by studying the above reactions quantitatively On the other hand if the compound will react with sodium to give off hydrogen, with phosphorus trichloride to give a halogen substitution product which can be reduced to **hydrocarbon;** with an oxidating agent to give an **aldehyde** or ketone, with organic **acids** to form **esters;** with **alcohols** to form **ethers;** then the molecule is said to contain a hydroxyl group —OH Analogously there are similar characteristic reactions for a variety of radicals It often happens that the presence of one type of a radical near another type mutually influences their reactivity, but one can consider to the first approximation that the radicals act independently of each other The structural formula is considered completely established if one can synthesize the compound by simple clear-cut reactions involving no **rearrangements** on the basis of the proposed formula In the particular example of tartaric acid the third step in the determination of the structural formula would be to determine what radicals are present in the molecule and their number The results show that there are two carboxyl and two hydroxyl groups The only structural formula involving these groups, satisfying valence requirements, possessing the proper molecular formula and consistent with the synthesis of tartaric acid is the following one



To conclude, the structural formula purports to give an idea as to how the individual atoms are attached to each other in the molecule, to give a résumé of the chemical reactions, and suggest methods of synthesis Configurational formulae are discussed in **Isomerism and Stereoisomerism** (R K S)

CHEMICAL NOMENCLATURE AND PRONUNCIATION. Based on the "Report of the Commission on the Reform of the Nomenclature of Organic Chemistry," from the translation published in the Journal of the American Chemical Society, Vol 55, No. 10, p 3905, October, 1933

The subject is treated under the following general headings I General II Hydrocarbons 1 Saturated Hydrocarbons 2 Unsaturated Hydrocarbons 3 Cyclic Hydrocarbons III Fundamental Heterocyclic Com-

pounds IV Simple Functions V Complex Functions VI Radicals VII Numberling

I. General

1 As few changes as possible will be made in terminology universally adopted

2 For the present, only the nomenclature of compounds of known constitution will be dealt with, the question of substances of imperfectly known constitution is postponed

3 The precise form of words, endings, etc, prescribed in the rules should be adapted to the genius of each language by the subcommittees

II Hydrocarbons

4 The ending *ane* is adopted for saturated hydrocarbons Open-chain hydrocarbons will have the generic name *alkanes*

The name "alkane" is better and shorter than "paraffin," especially since the latter term is now so commonly applied to a solid mixture

5 The present names of the first four normal saturated hydrocarbons (methane, ethane, propane, butane) are retained Names derived from the Greek or Latin numerals will be used for those having more than four atoms of carbon

6 Branched-chain hydrocarbons are regarded as derivatives of the normal hydrocarbons, their names will be referred to the longest normal chain present in the formula by adding to it the designations of the side chains In case of ambiguity, or if a simpler name would result, that chain which admits of the maximum of substitutions will be selected as the fundamental chain

If there are two or more choices for the longest chain, then that one should be chosen in which there is the greatest number of substitutions (the reason being that the substituting radicals, while more numerous, will be of simpler structure)

Example $CH_3CH_2CH_2CH_2CHCH_2CH_2CH_2CH_3$
$\quad\quad\quad

the name of the parent hydrocarbon and the suffix *ol* Example CH_2OHCH_2OH, 1,2-ethanediol

22 The name *mercaptan* as a suffix is abandoned, this function will be denoted by the suffix *thiol* Examples CH_3SH, methanethiol, C_6H_5SH, benzenethiol, CH_2SHCH_2SH, 1,2-ethanedithiol

23 Ethers are considered as hydrocarbons in which one or several hydrogen atoms are replaced by alkoxy groups However, for symmetrical ethers the present nomenclature may be retained Examples $CH_3OC_2H_5$, methoxyethane, CH_2OCH_3, methoxymethane or methyl ether.

24 Oxygen linked, in a chain of carbon atoms, to two of these atoms will be denoted by the prefix *epoxy* in all cases where it would be unprofitable to name the substance as a cyclic compound Examples ethylene oxide = epoxyethane, epichlorohydrin = 3-chloro-1,2-epoxypropane, tetramethylene oxide = 1,4-epoxybutane

25 Sulfides, disulfides, sulfoxides and sulfones will be named like the ethers, *oxy* being replaced by *thio, dithio, sulfinyl* and *sulfonyl*, respectively Examples $CH_3SO_2C_2H_5$ methylsulfonylethane, $CH_3SC_3H_7$, methylthiopropane, $CH_3CH_2CH_2SOCH_2CH_2CH_2CH_3$, 1-(propylsulfinyl)butane

26 Aldehydes are characterized by the suffix *al* added to the name of the hydrocarbon from which they are derived, thioaldehydes, by the suffix *thial* Acetals will be named as 1,1-dialkoxyalkanes

27 Ketones will receive the ending *one* Diketones, triketones, thioketones will be designated by the suffixes *dione, trione, thione*

28 The name *ketene* is retained

"Ketene" (or, as spelled by some, "keten") is accordingly recognized as a name for the parent compound $CH_2=CO$

29 For acids the rule of the Geneva nomenclature is retained However, in cases where the use of that nomenclature would not be convenient the carboxyl group will be considered as a substituting group and the name of the acid will be formed by adding to the name of the hydrocarbon the suffix *carbonique* or *carboxylic*, according to the language

This rule on the naming of acids is a frank compromise between two conflicting ideas, whose advantages and disadvantages led to much discussion both in the Geneva Congress and in the International Committee By the Geneva rules aliphatic acids are regarded as derived from hydrocarbons of the same number of carbon atoms (CH_3 being replaced by COOH) The acid name is formed from the hydrocarbon name by adding to it *-oic acid, -dioic acid*, etc Such names are convenient for simple monoacids and diacids, but become less so as the structure grows more complicated In the latter case most chemists will probably prefer the "carboxylic" nomenclature

30 Acids in which an atom of sulfur replaces an atom of oxygen will be named according to the Geneva nomenclature Example ethanethioic, -thiolic, -thionic, -thionothiolic If the carboxyl is considered as a substituent the compounds will be named *carbothioic* acids The suffix *carbothiolic* will be used if it is certain that the oxygen of the OH group is replaced by sulfur, the suffix *carbothionic* if it is the oxygen of the CO group, the suffix *carbodithioic* will be used if both oxygen atoms are replaced Examples of the two systems of names CH_3COSH or CH_3CSOH (either one), ethanethiolic acid, methanecarbothiolic acid, CH_3CSOH, ethanethionic acid, methanecarbothionic acid, CH_3CSSH, ethanethionothiolic acid, methanecarbodithioic acid

31 The existing conventions will be retained for salts and esters Examples Sodium butanoate or sodium salt of butanoic acid, diethyl 1, 2-ethanedicarboxylate or diethyl ester of 1,2-ethanedicarboxylic acid, sodium acetate, methyl succinate

32 Acid anhydrides will retain their present mode of designation according to the names of the corresponding acids For names formed in accordance with the Geneva nomenclature, the amides, amidoximes, amidines, imides and nitriles will be named like the acids by adding to the name of the corresponding hydrocarbon the endings *amide, amidine, amidoxime, imide* and *nitrile*, respectively, while the halides will be named by combining *chloride*, etc, with the name of the radical Examples C_3H_7COCl, butanoyl chloride, $C_3H_7CONH_2$, butanamide, etc

If the carboxyl is considered as a substituent the endings *carbonamide, carbonamidine, carbonamidoxime, carbonimide, carbonitrile* will be used Examples C_3H_7COCl, propanecarbonyl chloride, $C_3H_7CONH_2$, propanecarbonamide, etc

33 The ending *ine* is reserved exclusively for nitrogenous bases The present nomenclature of monoamines is retained For polyamines, the name of the hydrocarbon will be followed by the suffixes *diamine, triamine*, etc

For aliphatic compounds containing quinquivalent nitrogen the ending *ine* will be changed to *onium* For cyclic substances containing quinquivalent nitrogen in the ring the ending *ine* will be changed to *inium*, for those with the ending *ole*, this will be changed to *olium* Examples pyridine, pyridinium, imidazole, imidazolium

In accordance with the first sentence of this rule the spelling of names of non-bases ending in -ine should be changed, thus glycerine becomes glycerol, dextrine becomes dextrin, propine becomes propyne (see rule 9) Examples of names of amines CH_3NH_2, methylamine, $(CH_3)_2NH$, dimethylamine, $(CH_3)_3N$, trimethylamine, $H_2NCH_2CH_2NH_2$, 1,2-ethanediamine, $C_6H_4(NH_2)_2$, benzenediamine

34 The nomenclature of the derivatives of phosphorus, arsenic, antimony and bismuth, being very complicated, will be considered later

Usage in this field needs systematizing but the Committee could not agree upon a plan The scheme proposed by the American Committee for the acids of phosphorus, arsenic and antimony was as follows (with "phosph" and "stib" corresponding to "ars")

Formula	Prefix	Suffix
$RR'AsOH$	Arsinoso	Arsinous
$RAs(OH)_2$	Arsonoso	Arsonous
$RR'AsO\ OH$	Arsino	Arsinic
$RAsO(OH)_2$	Arsono	Arsonic

35 Compounds derived from hydroxylamine by replacement of the hydrogen of the hydroxyl will be regarded as alkoxy derivatives, those in which an atom of hydrogen of the NH_2 group is replaced, as alkylhydroxylamines Oximes will be named by adding the suffix *oxime* to the name of the corresponding aldehyde, ketone or quinone Examples $C_2H_5ONH_2$, ethoxyamine, C_2H_5NHOH, ethylhydroxylamine

36 The generic term *urea* is retained, it will be used as a suffix for the alkyl and acyl derivatives of urea Examples butylurea, $C_4H_9NHCONH_2$, butyrylurea, $C_3H_7CONHCONH_2$ The bivalent radical —NHCONH— will be named *ureylene*

37 The generic name *guanidine* is retained

38 The name *carbylamine* is retained

39 Isocyanic and isothiocyanic esters (RNCO, RNCS) will be named *isocyanates* and *isothiocyanates*

40 The name *cyanate* is reserved for true esters which on saponification yield cyanic acid or its hydration products The name *sulfocyanate* will be replaced by *thiocyanate*

41 Nitro derivatives no change in the present nomenclature That is, the group NO_2 is always indicated by the prefix *nitro*, never by a suffix Nitroso compounds are treated similarly (see rule 52) Examples nitrosobenzene, 2,4,6-trinitrophenol

42 Azo derivatives the forms *azo, azoxy* are retained This rule is rather non-committal, as it does not state how the azo and azoxy names are to be formed By rule 1 familiar terms like azobenzene, $C_6H_5N_2C_6H_5$, would be retained The Geneva name for this substance

is benzeneazobenzene In treating the group $C_6H_5N_2$ as a substituent the Committee does not indicate whether it should be called "benzeneazo" or "phenylazo" (the latter would seem to accord best with rules 23 and 25). The same considerations apply to azoxy compounds. Hydrazo compounds are treated as hydrazine derivatives (rule 44)

43 (a) Diazonium compounds, RN_2X, are named by addition of the suffix *diazonium* to the name of the parent substance (benzenediazonium chloride)

(b) Compounds having the same empirical formula but containing trivalent nitrogen will be named by replacing diazonium with *diazo* (benzenediazohydroxide)

(c) Substances of the type RN_2OM will be named *diazoates*

(d) Compounds in which the two nitrogen atoms are united to a single carbon atom will be designated by the prefix *diazo* (diazomethane, diazoacetic acid)

(e) The term *diazoamino* is retained, however, these compounds may also be regarded as derivatives of triazene

(f) Derivatives of the substances $H_2NNHNHNH_2$, $NH{=}NNHNH_2$, $NH{=}NNHN{=}NH$ will be named *tetrazanes, tetrazenes, pentazdienes*, etc

44 Hydrazines are designated by the name of the alkyl radicals from which they are derived, followed by the suffix *hydrazine* In cases where the amino group of carbonamides is replaced by the hydrazino group, the suffix *hydrazide* will be used Hydrazo derivatives are regarded as derivatives of hydrazine Examples CH_3NHNH_2, methylhydrazine, $C_2H_5NHNHC_6H_5$, 1-ethyl-2-propylhydrazine, $C_3H_7CONHNH_2$, butyrohydrazide or propanecarbohydrazide

45 Hydrazones and semicarbazones are named like the oximes The term *osazone* is retained

46 The name *quinone* is retained

47 Sulfonic and sulfinic acids will be designated by adding the suffixes *sulfonic* and *sulfinic* to the name of the hydrocarbon

The analogous acids of selenium and tellurium will bear the names *alkaneselenonic* and *-seleninic* acids, *alkanetelluronic* and *-tellurinic* acids Examples $C_2H_5SO_3H$, ethanesulfonic acid, $C_{10}H_6(SO_2H)_2$, naphthalenedisulfinic acid

48 Organometallic compounds will be designated by the names of the organic radicals united to the metal which they contain, followed by the name of the metal Examples dimethylzinc, tetraethyllead, methylmagnesium chloride

However, if the metal is united in a complex manner it may be considered as a substituent Example $ClHgC_6H_4CO_2H$, chloromercuribenzoic acid

49 The nomenclature of cyclic derivatives having side chains will be considered later

50 If it is necessary to avoid ambiguity, the names of complex radicals will be placed in parentheses Examples (dimethylphenyl)amine $=$ $(CH_3)_2C_6H_3NH_2$, dimethylphenylamine $=$ $C_6H_5N(CH_3)_2$

V. Complex Functions

51. For compounds of complex function, that is to say, for compounds possessing different functions, only one kind of function (the principal function) will be expressed by the ending of the name The other functions will be designated by appropriate prefixes

This is a definite departure from the Geneva system, since the latter permits functional suffixes to pile up in the names of mixed compounds (as, pentanaloloic acid) In certain cases it seems unavoidable that more than one function be expressed in the ending, as, butenyne, butenol, quinolinesulfonic (*-ene, -yne* and *-ine* have no corresponding prefixes)

52 The following prefixes and suffixes will be used for designating the functions

Function	Prefix	Suffix
Acid and derivatives	carboxy	carbonylic, carbonyl, carbonamide, etc, or oic, oyl, etc.
Alcohol	hydroxy	ol
Aldehyde	oxo, aldo (for aldehyde O) or formyl (for CHO)	al
Amine	amino . .	**amine**
Azo derivative	azo	
Azoxy derivative	azoxy	
Carbonitrile (nitrile)	cyano	carbonitrile or nitrile
Double bond		ene
Ether	alkoxy	
Ethylene oxide, etc	epoxy	
Halide	halogeno [halo]	
Hydrazine	hydrazino	hydrazine
Ketone	oxo or keto	one
Mercaptan	mercapto	thiol
Nitro derivative	nitro	
Nitroso derivative	nitroso	
Quinquivalent nitrogen		onium, inium [olium]
Sulfide	alkylthio	
Sulfinic derivative	sulfino	sulfinic
Sulfone	sulfonyl	
Sulfonic derivative	sulfo	sulfonic
Sulfoxide	sulfinyl	
Triple bond		yne
Urea	ureido	urea

For the order used in the *Chemical Abstracts* indexes, see Patterson and Curran, *Journal of the American Chemical Society*, **39**, 1624 (1917)

53 The names of derivatives of fundamental heterocyclic substances will be formed according to the preceding rules Example Hydroxyquinolinecarbonamide, not quinolinolcarbonamide

VI. Radicals

54 Univalent radicals derived from saturated aliphatic hydrocarbons by removal of one atom of hydrogen will be named by replacing the ending *ane* of the hydrocarbon by the ending *yl*

Examples methyl, ethyl, pentyl (or amyl), etc Since isopropylidene is recognized (rule 56) it was no doubt the intention of the Committee to recognize isopropyl similarly

55 The names of univalent radicals derived from unsaturated aliphatic hydrocarbons will have the endings *enyl, ynyl, dienyl*, etc, the positions of the double or triple bonds being indicated by numerals or letters where necessary

Examples $CH_2{=}CH{-}$, ethenyl (or vinyl), $CH{\equiv}C{-}$, ethynyl, $CH_2{-}CH{=}CH{-}CH_2{-}$, 2-butenyl, $CH_3{=}CH{-}CH{=}CH{-}$, 1,3-butadienyl

56 Bivalent or trivalent radicals derived from saturated hydrocarbons by removal of 2 or 3 hydrogen atoms from the same carbon atom will be named by replacing the ending *ane* of the hydrocarbon by the endings *ylidene* or *ylidyne* For radicals derived from unsaturated hydrocarbons, these endings will be added to the name of the hydrocarbon The names isopropylidene and methylene are retained

57 The names of bivalent radicals derived from aliphatic hydrocarbons by removal of a hydrogen atom from each of the two terminal carbon atoms of the chain will be ethylene, trimethylene, tetramethylene, etc

Only saturated radicals are provided for $-CH_2CH_2-$, ethylene, $-CH_2CH_2CH_2-$, trimethylene, etc

58 Radicals derived from acids by removal of OH will be named by changing the ending carboxylic to

carbonyl or, if the Geneva nomenclature is used, oic to *oyl* Examples CH_3CO, ethanoyl or methanecarbonyl (or acetyl)

59 Univalent radicals derived from aromatic hydrocarbons by removal of a hydrogen atom from the ring will in principle be named by changing the ending *ene* to *yl* However, the radicals C_6H_5 and $C_6H_5CH_2$ will continue provisionally to be named phenyl and benzyl, respectively Moreover, certain abbreviations sanctioned by usage are authorized, as *naphthyl* instead of *naphthalyl*. Examples $CH_3C_6H_4$—, tolyl (instead of toluyl), anthryl (instead of anthracyl), phenanthryl, fluoryl

60 Univalent radicals derived from heterocyclic compounds by removal of hydrogen from the ring will be named by changing their endings to *yl* In cases where this would give rise to ambiguity, merely the final *e* will be changed to *yl* Examples pyridine, pyridyl, indole, indoyl, pyrroline, pyrrolinyl, triazole, triazolyl, triazine, triazinyl

61 Radicals formed by removal of a hydrogen atom from a side chain of a cyclic compound will be regarded as substituted aliphatic radicals Examples $C_6H_5CH_2CH_2$—, (2-phenylethyl), $C_6H_5CH{=}CHCH_2$—, (3-phenyl-2-propenyl)

62 In general, special names will not be given to multivalent radicals, derived from cyclic compounds by removal of several hydrogen atoms from the ring In this case prefixes or suffixes will be used Examples triaminobenzene or benzenetriamine, dihydroxypyrrole or pyrrolediol

63 The order in which prefixes or radicals are stated (alphabetic order or conventional order) remains optional

VII. Numbering

64 In aliphatic compounds the carbon atoms of the fundamental chain will be numbered from one end to the other with the use of arabic numerals In case of ambiguity the lowest numbers will be given (1) to the principal function, (2) to double bonds, (3) to triple bonds, (4) to atoms or radicals designated by prefixes The expression "lowest numbers" signifies those that include the lowest individual number or numbers Thus, 1,3,5 is lower than 2,4,6, 1,5,5 lower than 2,6,6, 1,2,5 lower than 1,4,5, 1,1,3,4 lower than 1,2,2,4

The Committee has left full latitude on the position of numbers The examples in the French version usually show the numbers placed after, the examples in these comments follow the practice of *Chemical Abstracts* in being placed before Each method has certain advantages In Beilstein numbers placed after are in parentheses, those placed before are not, *e g*, "2-methylbutanol-(4)"

65 Positions in a side chain will be designated by numerals or letters, starting from the point of attachment The numerals or letters will be in parentheses with the name of the chain

Examples $(CH_3)_2CH$—, (1-methylethyl) or isopropyl, $CH_3CHClCH_2$—, (2-chloropropyl) The rule equally permits Greek letters, ordinary letters, primed numbers (1′, 2′), numbers with indices (4^1, 4^2) or other designations

66 In case of ambiguity in the numbering of atoms or radicals designated by prefixes, the order will be that chosen for the prefixes before the name of the fundamental compound or side chain of which they are substituents

67 The prefixes, *di, tri, tetra,* etc, will be used before simple expressions (for example, diethylbutanetriol) and the prefixes *bis, tris, tetrakis,* etc, before complex expressions Examples bis(methylamino)propane $CH_3NH(CH_2)_2NHCH_3$, bis(dimethylamino)ethane, $(CH_3)_2NCH_2CH_2N(CH_3)_2$ The prefix *bi* will be used only to denote the doubling of a radical or compound, for example, biphenyl

CHEMICAL SOCIETIES AND PUBLICATIONS.

1663 Royal Society (London) founded
1665 Philosophical Transactions of the Royal Society first published (Volume 200, 1903)
1699 Memoires de l'Académie des Sciences de l'Institut de France, Paris, first published Académie founded 1666, recognized by letters patent 1713
1780 American Academy of Arts and Sciences founded Memoirs 1785– Proceedings 1846–
1785 Chemical Society of the University of Edinburgh in existence Date of founding not known Students of Joseph Black
1789 Annales de Chimie first published
1792 Chemical Society of Philadelphia founded by James Woodhouse
1818 American Journal of Science first published
1831 British Association for the Advancement of Science founded
1835 Comptes rendues de l'Académie des Sciences (Paris) first published (Volume 201, 1935)
1840 Chemical News (London) first published
1841 Chemical Society (London) founded Chartered 1848
1848 American Association for the Advancement of Science founded
1848 Journal of the Chemical Society (London) first published
1857 Société Chimique de France founded Bulletin 1858–
1863 National Academy of Sciences (U S A) founded
1867 Deutsche Chemische Gesellschaft founded
1868 Berichte der Deutschen Chemischen Gesellschaft first published (Volume 68, 1935)
1869 Nature (London) first published
1876 American Chemical Society founded
1876 Analyst (London) first published
1878 Institute of Chemistry (British) founded
1879 Journal of the American Chemical Society first published
1879 American Chemical Journal first published
1879 Philosophical Magazine (London) first published
1881 Society of Chemical Industry (British) founded
1882 Journal of the Society of Chemical Industry first published
1883 Science first published (New series 1895)
1896 Journal of Physical Chemistry first published
1902 Electrochemical Society (U S A) founded Transactions published
1904 Annual Reports of the Progress of Chemistry first published
1905 Journal of Biological Chemistry first published
1905 Transactions of the Faraday Society first published
1907 Chemical Abstracts first published
1908 American Institute of Chemical Engineers founded Transactions published
1909 Industrial and Engineering Chemistry first published (as Journal of Industrial and Engineering Chemistry)
1912 Eighth International Congress of Applied Chemistry, Washington and New York
1915 Société de Chimie Industrielle founded
1916 National Research Council (U S A) founded
1916 Annual Reports of the Progress of Applied Chemistry first published
1918 Chimie et Industrie first published
1919 Proceedings of Chemical Engineering Group of Society of Chemical Industry first published
1923 Chemistry and Industry (London) first published
1923 Institution of Chemical Engineers (London) founded Transactions published
1923 American Institute of Chemists founded
1924 Chemical Reviews first published
1924 Journal of Chemical Education first published

1925 Annual Survey of American Chemistry first published
1929 World Power Congress, Tokio
1933 Journal of Chemical Physics first published
1934 Ninth International Congress of Pure and Applied Chemistry, Madrid
1936 Chemical Engineering Conference of World Power Congress, London

(R K S)

CHEMISTRY. On account of the vast scope of the field of chemistry, the subject has, for convenience, become divided into many branches It should be emphasized that these branches are not, cannot be, and are not desired to be mutually exclusive The field is a unit, covering the composition and changes in composition of matter, and the accompanying energy phenomena The natural tendency is toward unification and removal of artificial barriers, the artificially created demand for systematic treatment has necessitated the erection of boundaries, but the more penetrable the boundaries, the better for the healthy unification and growth of science

I Classification of the subject, wherein the primary emphasis is on *Matter Changes*

II On *Energy Changes*

A *Inorganic Chemistry* Study of chemical elements and their compounds, their properties, chemical behavior, preparation, and applications List of elements accepted by the committee on Atomic Weights of the International Union of Chemistry

Aluminum	Fluorine	Mercury	Silicon
(Ammonium)		Molybdenum	Silver
Antimony	Gadolinium		Sodium
Argon	Gallium	Neodymium	Strontium
Arsenic	Germanium	Neon	Sulfur
	Gold	Nickel	
Barium		Nitrogen	Tantalum
Beryllium	Hafnium		Tellurium
Bismuth	Helium	Osmium	Terbium
Boron	Holmium	Oxygen	Thallium
Bromine	Hydrogen		Thorium
		Palladium	Thulium
Cadmium	Indium	Phosphorus	Tin
Calcium	Iodine	Platinum	Titanium
Carbon	Iridium	Potassium	Tungsten
Cerium	Iron	Praseodymium	
Cesium		Protoactinium	Uranium
Chlorine		Radium	
Chromium	Krypton	Radon	Vanadium
Cobalt		Rhenium	
Columbium	Lanthanum	Rhodium	Xenon
Copper	Lead	Rubidium	
	Lithium	Ruthenium	Ytterbium
Dysprosium	Lutecium		Yttrium
		Samarium	
Erbium	Magnesium	Scandium	Zinc
Europium	Manganese	Selenium	Zirconium

With the following exceptions the compounds of the above elements are treated in this book alphabetically by elements The exceptions are in the cases of bromine, carbon, chlorine, fluorine, hydrogen, iodine, nitrogen, oxygen, phosphorus, sulfur, where the number and variety of substances to be discussed necessitates the extension of the discussion to additional separate articles The titles of the articles related to each element are, however, stated under the given element

B *Organic Chemistry* Among the chemical elements, carbon stands alone in the large number and complexity of its compounds Carbon-containing substances are grouped and treated separately under the heading of **organic chemistry** Traditionally, certain of these substances are commonly treated in inorganic chemistry, namely, the various forms of carbon element, carbon oxides, cyanogen, carbonic acid, formic acid, acetic acid, oxalic acid, hydrocyanic and related acids The sections devoted to organic phases of chemistry are selected by topics, by important groups, and by individual substances See **Carbon, Key to Organic Compounds.**

(a) Hydrocarbons

(b) Oxygen function compounds The following are found under **Oxygen:** Furane, pyrone, alcohols, phenols, aldehydes, ketones, quinones, carboxylic acids The following are found in this book under their individual names

Acetals	Fats	Oils, fatty
Acid anhydrides		Oxides
Aldehydeacids	Glucosides	
Anthocyanins		Phthaleins
	Hydroxyacids	
Benzil	Hydroxyaldehydes	Saccharides
Benzoin	Hydroxyketones	Starch
		Sterols
Carbohydrates	Ketenes	Sugars
Cellulose	Ketoneacids	
Coumarone		Tannins
Esters	Lactones	
Ethers	Lactides	Waxes

(c) Nitrogen function compounds The following are found under **nitrogen.** Nitro-, nitroso-, hydroxylamines, hydrazines, amines, pyrrole, pyridine, amines, amides, cyanides and isocyanides, cyanates and isocyanates, ureas The following are found in this book under their individual names

Acridine	Indazole
Alkaloids	Indigo
Aminoacids	Indole
Aminoazo-compounds	Isoquinoline
Aminoguanidines	
Anilides	Lactams
Azides	Lactims
Azines	
Azo-compounds	Nitrates
Azoles	Nitriles
Azoxy-compounds	Nitrites
	Nitrobenzene
Biuret	Nitrolic acids
	Nucleic acids
Carbamic acid	
Carbazole	Osazones
Chlorophyll	Oxazoles
Cyanamides	Oximes
Cyanuric acid	
	Phenylhydrazones
Diazoamino-compounds	Piperidine
Diazo-compounds	Polypeptides
	Porphyrins
Esters	Proteins
	Purines
Fulminates	Pyrazole
	Pyrrolidine
Guanidines	
	Quinoline
Hydrazo-compounds	
Hydrazones	Semicarbazides
Hydrazoates	Semicarbazones
Hydroferricyanides	
Hydroferrocyanides	Tetrazoles
Hyponitrites	Triazoles
Hydroxyazo-compounds	
	Uredes
Imides	Urethanes
Imines	Uric acid

(d) Sulfur function compounds may be found by reference to the article on **Sulfur.** They include thiophene, penthiophene, thioalcohols, thiophenols, thioic acids, thiocyanates, thioureas, thiocarbonic acid, and related compounds, sulfinic acids, sulfinyl compounds, sulfonic acids, sulfonyl compounds

C *Analytical Chemistry* Qualitative and quantitative analysis of elements, radicals and compounds, or by groups of these See **Analytical Chemistry**

D *Synthetical Chemistry* Qualitative and quantitative synthesis of compounds and radicals, or by groups of these

E *Principles of Chemistry*—Pure Chemistry See below

F *Applications of Chemistry*—Applied Chemistry See below

G *Radioactive changes* and ultimate structure of matter See **Radioactive Changes.**

H *Biochemistry* Plant and animal substances and processes, both normal and abnormal See **Biochemistry.**

I. *Geochemistry* Composition of and changes in the atmosphere (See **Air**), hydrosphere (See **Water**), and **lithosphere** By extension, astral chemistry, See **Geochemistry.**

J *Domestic chemistry* Chemical aspects of **air, water, foods,** clothing, shelter, cleansing, transportation, communication, and sanitation

K *Agricultural Chemistry* **Soils,** crops, **fertilizers,** agricultural **poisons** and live stock

L *Metallurgical Chemistry* Recovery and purification of metals (See each metal), properties of metals and alloys

M *History and Evolution of Chemistry* See **History and Evolution of Chemistry.**

N *Studying and teaching of chemistry*

O *Chemical nomenclature* See **Chemical Nomenclature.**

The PRINCIPLES OF CHEMISTRY have been formed around various nuclei as the following arrangement illustrates

(a) Matter in various physical states (See *Each* of the following states of matter)
  (1) **Gases**
  (2) **Liquids**
  (3) **Solutions**
  (4) **Solids**
  (5) **Colloidal state**

(b) *Chemical composition* of matter (See **Chemical Composition**)
  (1) Elements, symbols, atoms, allotropes, isotopes
  (2) Compounds, formulas, molecules, allotropes, isomers
  (3) Radicals
    (a) in combination
    (b) as ions (See **Reactions involving recombination of ions**)
    (c) free
  (4) Equivalents, valency, graphical formulas

(c) Changes in composition of matter See **Chemical Changes**
  (1) Reactions
    (a) Natural rates of reactions
      Concentration, temperature, pressure, medium
    (b) Artificially controlled rates of reactions
      Catalyzers
    (c) End-point of reactions—Equilibrium reactions
      Concentrations, equilibrium constant, temperature, pressure

(d) Changes in energy in chemical reactions.
  (1) **Thermochemistry**
  (2) **Electrochemistry**
  (3) **Photochemistry**

(e) Grand groups of chemical substances
  (1) Acids, bases, salts (See **Reactions involving recombinations of ions**)
  (2) Metals, non-metals, alloys
  (3) Oxides, chlorides, sulfides (See each, **Thermochemistry, Heat of Formation**)
  (4) Organic (classification given on preceding pages)

(f) Grand groups of chemical reactions
  (1) **Reactions involving recombinations of Ions**—Hydrogen-ion concentration, pH, indicators
  (2) **Reactions involving water**
    (a) Consumption of water—including acid and alkaline mediums—Hydrolysis, saponification of esters
    (b) Production of water—Neutralization, esterification, nitration, sulfonation
    (c) Water as catalyzer
  (3) **Reactions involving oxidation—reduction**
    (a) In solutions of electrolytes
    (b) Not in solutions of electrolytes, including oxygenation and deoxygenation, hydrogenation and dehydrogenation, chlorination and dechlorination, bromination and debromination, nitro-reduction, and sulfonyl-reduction
  (4) **Würtz-Fittig**—sodium-organic halide reaction
  (5) **Friedel-Crafts**- anhydrous aluminum chloride-alkyl-aryl halide-benzenoid hydrocarbon reaction

(g) Grand groups of phenomena and processes
  (1) Isotopy (See **Chemical Composition**), allotropy (See **Chemical Composition**), **Isomerism and Stereoisomerism**
  (2) **Association and polymerization; Dissociation, rearrangement; passivity**
  (3) Role of water, **deliquescence, efflorescence,** desiccation, drying, water as catalyzer (See **Reactions Involving Water**)
  (4) **Equilibrium** including Phase rule
  (5) **Adsorption**
  (6) Vapor Pressure
  (7) Heating of materials
    (a) With access of air roasting (See **Calcination**), smelting
    (b) Without access of air **calcination, destructive distillation;** sublimation (See **Distillation**), **distillation, evaporation and drying**
  (8) Solid-liquid-gas treatments
    Including precipitation, crystallization, sedimentation, filtration, dissolving solids, extraction

APPLICATIONS OF CHEMISTRY Applied chemistry both industrial and non-industrial, concerned with (1) chemical materials, their composition, location, transportation, storage, (2) chemical processes naturally occurring or artificially operated, their matter and energy changes, the conditions, both favorable and unfavorable, of temperature, pressure, concentration, medium and catalyzer for these changes to take place, including apparatus, (3) chemical products, their quality (composition or specifications), quantity, applications, uses, and value

Industrial chemistry, including chemical engineering, economic aspects of chemistry plus industry, embraces a part of the field of applied chemistry Those product industries which have attained large proportions and general recognition are among the following

Abrasives
Acetaldehyde

Acetic acid
Acetone
Acetylene
Acids See Individual acids, e g , **sulfuric, nitric, hydrochloric, phosphoric, oxalic, phthalic**
Adhesives
Alcohols
Alkalis See Individual Alkalis, e g , **sodium** hydroxide and carbonates, **potassium** hydroxide and carbonates, **ammonium** hydroxide, **calcium** oxide and carbonate
Alloys
Aluminum and its compounds
Amines
Ammonia
Ammonium compounds
Aniline
Anthracene
Arsenic compounds
Artificial fibers and films See **Carbohydrates**

Baking powders
Barium compounds
Benzene
Bleaching substances, bleaching and decolorizing
Boron compounds
Bricks See **Ceramics**
Bromine and its compounds

Calcium compounds
Carbon dioxide
Casein See **Aminoacids; Plastics**
Cellulose See **Carbohydrates**
Cement, Portland
Ceramics
Chlorine and its compounds
Chromium and its compounds
Coal See **Fuels; Destructive distillation** products, **Hydrogenation**
Coaltar products and intermediates
Coke See **Fuels, Destructive distillation** products, **Calcium** carbide
Copper and its compounds

Decolorizing See **Bleaching** substances
Destructive distillation products
Dextrin See **Carbohydrates; Adhesives**
Disinfectants See **Poisons**
Drugs
Dyes and dyeing, textile fibers

Earthenware—See **Ceramics**
Essential Oils See **Hydrocarbons,** terpenes
Esters
Ethers See **Alcohols**
Ethyl alcohol
Explosives

Fats See **Esters**
Fertilizers
Flavors See **Esters**
Foods
Formaldehyde
Fuels
Fungicides See **Poisons**

Gases See individual gases, e g , **oxygen, acetylene, ammonia, chlorine, carbon dioxide, hydrogen, nitrous oxide, sulfur dioxide; Fuels**
Gasoline See **Hydrocarbons,** paraffin.
Germicides See **Poisons**
Glass
Glazes See **Glass**
Glycerol
Gold and its compounds

Hydrochloric acid
Hydrogen
Hydrogenation products See **Catalysis**

Inks See **Tannins**
Intermediates See **Coal Tar** products
Insecticides See **Poisons**
Iron and its compounds

Ketones See **Aldehydes**

Lead and its compounds
Leather and tanning See **Tannins**
Lime See **Calcium** oxide
Lubricants

Magnesium and its compounds
Mercury and its compounds
Metals See individual metals, e g , **iron, copper, lead, zinc, aluminum, magnesium, nickel, tin, mercury, silver, gold**
Methyl alcohol

Naphthalene
Nickel and its compounds
Nitric acid
Nitrobenzene
Nitrocellulose See **Explosives**
Nitrogen and its compounds See also **Fertilizers; Explosives**
Nitroglycerine See **Explosives**
Nitrous oxide See **Nitrogen,** oxides

Oils See **Esters** for fatty oils, **Hydrocarbons,** for petroleum products, and for essential oils
Oxalic acid
Oxygen

Paints See **Pigments**
Perfumes
Petroleum See **Hydrocarbons,** paraffin
Phenol
Phosphate rock See **Phosphoric acid, Fertilizers**
Phosphoric acid
Phosphorus and its compounds
Photography
Phthalic acid
Pigments
Plaster See **Calcium** sulfate
Plastics
Poisons
Potassium compounds See also **Fertilizers**
Pottery See **Ceramics**

Rayon See **Carbohydrates**
Rubber and accelerators

Salts See individual salts
Silica See **Silicon,** oxide
Silver and its compounds
Slags See **Glass**
Soaps See **Esters**
Sodium compounds
Solvents
Starch See **Carbohydrates**
Steel See **Iron**
Stoneware See **Ceramics**
Sugars See **Carbohydrates**
Sulfur and its compounds
Sulfur dioxide See **Sulfur,** oxides
Sulfuric acid

Textile fibers See **Dyes**
Tiles See **Ceramics**
Tin and its compounds
Toluene
Turpentine See **Hydrocarbons, Terpenes**

Varnishes See **Pigments**

Waxes See **Esters**

Zinc and its compounds (R K S)

CHEMORECEPTOR. Sense organ.

CHERRY. Rose Family.

CHERT. An impure, flinty hard rock composed chiefly of cryptocrystalline **silica.** Chert varies in color from

gray through brown to black according to the kind and amount of coloring matter. It occurs principally as concretions, nodules or bands in **limestones** and **dolomites**, and unlike **flint** its fracture tends to be splintery instead of conchoidal. A great deal has been written on the occurrence and origin of chert and there is no doubt but that it may be formed in several different ways. Many of the nodular and concretionary cherts have grown around siliceous sponge spicules or **radiolaria**. Chert may be either **sygenetic** or **epigenetic**. The former type is supposed by some authors to be chemically precipitated from river waters on the bottom of the sea as a colloid contemporaneously with the limestones or dolomites. On the other hand certain cherts are obviously secondary although they may have been formed previous to the final lithification of the formations in which they occur. Cherts which contain relatively large amounts of iron are called **Jasper**. (R.M.F.)

CHESTNUT BLIGHT. Ascomycetes.

CHEVROTAIN. Mammalia, Artiodactyla. The mouse-deer of Asia and Africa, a group of several species whose appearance is like that of very small **deer** but whose structure differs in several important details. *Tragulus* is found in Asia, *Dorcatherium* in Africa. (A.W.L.)

CHEWING GUM. Achras sapota.

CHEZY FORMULA. The Chezy formula is an important formula for friction loss in large water conduits. The formula is stated as follows:

$$V = C\sqrt{RS}.$$

R is the **hydraulic radius** of the cross-section of flow. It is the cross-sectional area of flow divided by the wetted perimeter. S is the friction loss, in fractional foot head per foot length of conduit for a conduit running full of water, or it is the slope of the water surface, fractional foot per foot of length for open flow. C is a coefficient. A widely accepted formula for C is Kutter's formula, as follows:

$$C = \frac{41.65 + \frac{1.811}{n} + \frac{.00281}{S}}{1 + \frac{n}{\sqrt{R}}\left(41.65 + \frac{.00281}{S}\right)}.$$

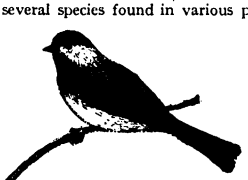
In this formula, R and S have meanings already defined, n is a channel roughness coefficient. Typical values of n are as follows:

Wood stave penstocks	.010
Steel penstocks	.017
Lumber flumes	.014
Earth canal	.030
Natural river channel	.05 to .10

(F.T.M.)

CHIASTOLITE. Andalusite.

CHICKADEE. Aves, Passeriformes. Birds (**Aves**) of several species found in various parts of North America, all quietly colored in grays with some black markings and in some species a little white and brown. The common widely distributed species is also called the black-capped **titmouse**, *Penthestes atricapillus*. (A.W.L.)



Carolina Chickadee.

CHICKENPOX. A specific infectious disease of childhood caused by an unknown **virus**. The disease attacks great numbers of children. Those that escape the disease as children, may develop the disease in adult life in a very severe form. Before 1553 this disease was confused with smallpox.

The incubation period varies from four to twenty-seven days. The average incubation period is from fourteen to sixteen days.

The symptoms of this disease usually begin with the eruption. The eruption generally appears first on the trunk and then spreads to the rest of the body. It consists of small red spots that soon are capped by a small blister containing clear fluid. When this dries up, crust and scab formation replace the area. The lesions appear in crops of different stages of development for three or four days. (R.S.M.)

CHICLE. Achras sapota.

CHICORY. *Cichorium Intybus.* **Composite Family.**

CHIGGER, CHIGOE, JIGGER. 1. Arachnida, Acarina. A harvest **mite** whose **larva** is very irritating to the human skin, causing intense itching. North American, sometimes locally abundant. 2. Insecta, Siphonaptera. A small **flea** found in the tropical parts of Africa and the New World. After mating the female burrows into the skin of a warm-blooded animal and becomes distended as her eggs develop until she is as large as a pea. When they attack man they usually enter the skin of the foot and cause a troublesome sore. (A.W.L.)

CHILARIA. A pair of rudimentary appendages on the first abdominal or pregenital segment in the king crab (**Xiphosura**). (A.W.L.)

CHILBLAIN. Swelling, painfulness and redness of the hands or feet due to previous exposure to cold. (R.S.M.)

CHILDRENITE. The mineral childrenite is a complex hydrous compound of **aluminum**, **iron** and **phosphorus**. **Manganese** may replace the **iron**, this variety being called **eosphorite**. Childrenite is known only in **orthorhombic** crystals; massive sorts have never been found. Its hardness is 4.5–5; specific gravity, 3.18–3.24; luster, vitreous to resinous; color, pale yellowish through yellowish brown to nearly black; streak is white or yellowish, translucent. Childrenite is found in Saxony; Devonshire, England; and Oxford County, Maine. Eosphorite occurs in Branchville, Connecticut; Oxford County, Maine, and Bavaria. Childrenite was named for J. G. Children, an English mineralogist. Eosphorite is derived from the Greek word meaning dawn-bearing, because of the pinkish color of this mineral. (E.S.C.S.)

CHILL. A paroxysm of shaking or shivering, accompanied by a sense of cold and pallor of the skin. During a severe chill the temperature usually becomes elevated. A chill may indicate the onset of some disease or a severe infection.

Nervous chill is shaking or shivering due to excitement, fear or anger, not accompanied by any rise in temperature. (R.S.M.)

CHILOPODA. The centipedes, usually considered as a class of arthropods related to but distinct from the millipedes and a few rare forms, but sometimes ranked as an order in the class Myriapoda, containing all of these forms.

These animals are elongate and slender with numerous segments, most of them bearing a single pair of appendages. They have one pair of **antennae** and the first pair of legs is modified to form a pair of poison claws with which they catch their prey. They are terrestrial, breathing by air tubes (**tracheae**) which open separately on the various segments. The body is flattened and the segments are composed of dorsal and ventral plates connected by softer lateral walls which bear the legs. Centipedes have poison glands opening through the poison claws but there is no evidence to show that they are ever dangerous to man. (A.W.L.)

CHIMACHIMA. Aves, Falconiformes. A bird (**Aves**) of prey found from Panama to southern Brazil. One of the **caracaras.** (A.W.L.)

CHIMANGO. Aves, Falconiformes. A South American bird (**Aves**) of prey found in Tierra del Fuego and the southern part of the continent. A **caracara.** (A.W.L.)

CHIMNEY. A chimney is a vertical tubular structure of masonry, steel, or reinforced concrete, built for the purpose of enclosing a column of hot gas, to produce thereby a draft. Combustion requires **oxygen.** Air is needed to supply it. To move this air through the fuel bed, and to produce a flow of the gaseous products of combustion through the furnace and boiler, or through a stove, requires a difference of pressure, called draft. The chimney is built primarily to produce a certain available draft, although sometimes a chimney may have to be high for reasons entirely foreign to draft. In addition to the useful draft it produces, a chimney must also overcome the friction loss in the chimney itself. These losses are proportional to the cross-sectional area of the stack. Hence the problem of chimney diameter is more than the assumption of a velocity comparable to that used in actual practice; it should be such that the diameter and height it indicates result in a chimney of least cost. Ordinarily, the economic chimney gas velocities range between 20 and 40 feet per second.

A chimney produces a draft by virtue of an extremely simple principle of thermodynamics. When gas is heated it expands in volume and decreases in density, in which condition it may be displaced by a more dense gas. The figure shows how this principle is incorporated in the stack. The light, hot flue-gas is confined by the chimney. The tendency of air or gas to move in the direction shown by the arrows is proportional to the height of the stack, since the difference of weight of air and gas columns (and this is the *draft*) is greater the higher the columns.

The draft of a stack is, in an elementary way, expressed by:

D = Height multiplied by difference in density of flue gas and air.

Many empirical formulae are extant for computing the height of a chimney required for a given boiler. A rational scientific approach would necessarily be based on the above equation, as it truly represents the physical action actually creating the draft. When the elementary equation is written for a chimney of 100 feet, incorporating certain factors needed to convert draft to inches of water, and allowing for cooling and friction in the stack, it has the form:

$$D = K(d_a - d_f) - 0.0148 d_f \frac{V^2}{F}$$

where D = effective draft per 100 feet of stack, in inches of water.
K = 17.3 for masonry stacks, and 15.4 for steel stacks.
d_a = density of air, in pounds per cubic foot.
d_f = density of flue gas, in pounds per cubic foot.
V = gas velocity in the stack, in feet per second.
F = gas flow, in cubic feet per second.

The second term in this equation allows for friction in the stack itself, so that D represents the effective draft per 100 feet of stack. The actual height of a chimney is obtained by dividing required draft by D and multiplying by 100. The required stack draft is the sum of all friction losses external to the stack, plus the impact loss (of gas discharged from stack), and less the effective draft furnished by fans or jets. The impact loss is $0.003V^2 d_f$ inches of water, the symbols having meaning as given above.

The use of perforated radial brick has found much favor in chimney construction. Their dead air space acts somewhat as heat insulation, and they are lighter than ordinary bricks. Comparatively short stacks are frequently made of plate steel. These are lined for a portion of their height with refractory lining, and, unless very short, are braced by suitable guy wires. A tall masonry chimney must have sufficient area in any transverse section to distribute the superimposed weight sufficiently to prevent the unit pressure from exceeding the safe bearing power of the masonry material. The effect of a transverse applied load due to wind pressure can not be neglected. The effect of wind pressure is to increase the compression in the masonry on the leeward side and decrease it on the windward side. Since tension is not permissible in masonry, not only the thickness of the wall, but the external diameter of the chimney, must be selected with due respect to strength and stability under the condition of maximum wind load. It is very important that the foundation of a tall chimney be absolutely firm and unyielding, as a very small settling on one side would throw the top of a tall chimney several inches out of line and induce an unexpected eccentric loading in the structure.

To be satisfactory, chimneys for residences must, like all other chimneys, have sufficient height for the required draft, and sufficient area to carry off the volume of gases produced. Deficiencies in either or both of these needed characteristics will be sure to cause lazy fires and smoky furnaces. Insofar as possible, a chimney should be straight and perpendicular. Necessary bends should be reduced to the minimum, and corners should be well rounded. The use of a flue lining made of jointed sections of tile is an aid to draft as well as a safeguard against the risk of fire due to defective brickwork in the chimney. (F.T.M.)

CHIMPANZEE. Mammalia, Primates. One of the large man-like **apes** of tropical Africa. This species has been found the most easily kept and tractable of the apes in captivity and for this reason has been a favorite subject for the study of these near relatives of the human species. A number of chimpanzees have become famous for their ability to learn human habits and have displayed the rudiments of true intelligence. (A.W.L.)

CHINA-CLAY. A commercial term, more or less identical with **kaolin,** as applied to the relatively pure clay concentrated by washing from a thoroughly kaolinized **granite.** England is the chief exporter of China clay. France has unique clays from which are made the famous Sèvres and Limoges potteries. At the present time the United States imports only about one-third of the China-clay which it consumes, most of its domestic supply coming from the **Cretaceous** clays of New Jersey. (R.M.F.)

CHINCH BUG. Insecta, Hemiptera. A small black **bug,** *Blissus leucopterus,* with whitish wing membranes. Although its total length is only one quarter of an inch it is one of the most serious pests of wheat and damages other cereals as well. The methods of control are complex, including means of trapping the bugs during migration from field to field, the destruction of rubbish in which they spend the winter, and the use of decoy plots planted at such a time as to be most attractive when the eggs are being deposited. These plots are later plowed under to destroy the insects. (A.W.L.)

Chinch bug.

CHINCHILLA. Mammalia, Rodentia. Small squirrel-like **rodents** related to the porcupines. They live at high altitudes in the mountains of South America. The fur of the common chinchilla is valuable. There are two genera, *Chinchilla* and *Lagidium.* (A.W.L.)

CHINOOK. Pisces, Teleostei The king or quinnat **salmon,** most important of all North American food fishes It is found from California to Alaska (A W L)

CHIPMUNK. Mammalia, Rodentia Small burrowing **rodents** of squirrel-like appearance but with the tail shorter and not bushy They are brown or grayish with longitudinal stripes on the back or sides They are omnivorous and while not usually troublesome they sometimes destroy flowering bulbs during the winter

Chipmunks belong to several genera and numerous species and subspecies Some of the western species are called golden chipmunks or rock squirrels and others antelope chipmunks or ground squirrels They are related to the ground squirrels and gophers While predominantly North American, chipmunks are also found in Siberia. (A W L)

CHIROPTERA. The **bats** An order of mammals highly specialized for flying (A W L)

CHIRU. Mammalia, Artiodactyla The Tibetan **antelope,** *Panthalops hodssoni,* a species of moderate size with long horns, ringed in the basal half (A W L)

CHISEL-JAW Pisces, Teleostei A small fish (**Pisces**) of West African rivers It has very strong teeth (A W L)

CHISEL-MOUTH Pisces, Teleostei A North American fish (**Pisces**), *Acrocheilus alutaceus,* related to the carps and dace, found in the lower Columbia River and its tributaries (A W L)

CHITAL Mammalia, Artiodactyla The Indian spotted **deer** or axis deer, *Axis axis* (A W L)

CHITIN. An essential constituent of the **cuticula of arthropods** Also found to a lesser extent in most of the invertebrate groups A material of variable and intricate chemical composition, this substance has been the subject of habitual misstatement especially among entomologists It is a principal component of the insect exoskeleton and appears in both the rigid and flexible parts, which are usually said to be chitinized or not chitinized, the degree of rigidity has recently been said to depend upon other materials deposited with the chitin Chitin is inelastic, hence the arthropods shed the exoskeleton at intervals during growth to permit expansion during the formation of a new covering Chitin is chemically very inactive (A W L)

CHITRA Chital (A W L)

CHIVES Allium

CHLAMYDOSPORE A single spore or reproductive cell enclosed in a spore case, formed by some of the **slime molds** (A W L)

CHLOANTHITE. Smaltite-chloanthite.

CHLORAL HYDRATE (CCl_3 CHO H_2O) A valuable and powerful sedative prepared by passing **chlorine** gas through absolute alcohol (See **Ethyl Alcohol**) and precipitating by water It occurs in crystalline form, is soluble in water and has a bitter caustic taste and a penetrating odor

With therapeutic doses, quietness and drowsiness are produced Pain is not diminished With poisonous doses there is profound stupor, coma and collapse which may result fatally

Chloral should never be given with alcohol as the alcoholic solution which is formed constitutes the well-known powerful "knockout drops," a quick-acting and dangerous depressant

Chloral is used medically to quiet nervousness, irritability, and to produce sleep It is contraindicated in threatened failure of the circulation or respiration (See **Acetaldehyde,** and **Drugs**) (R S M)

CHLORENCHYMA CELLS. Parenchyma.

CHLORIC ACID AND CHLORATES. Chloric acid ($HClO_3$) is a colorless solution, fairly stable but slowly decomposes into (a) **perchloric** and **hydrochloric acids,** (b) chlorine dioxide and **oxygen,** (c) hydrochloric acid and oxygen, (d) **chlorine** and oxygen (when of strength as high as 40% $HClO_3$) Can be concentrated in vacuum up to 52% $HClO_3$ with considerable decomposition A powerful oxidizing agent, e g, **sulfur** and all forms of sulfur compounds (other than **sulfates**) to **sulfuric acid**—but **persulfates** oxidize chlorate to perchlorate

Prepared by reaction (1) of **barium** chlorate solution and sulfuric acid, and filtering off barium sulfate, (2) **potassium** or **sodium** chlorate and sulfuric acid

Potassium chlorate is formed (1) by electrolysis of potassium chloride solution, stirring and heating over some hours, (2) by heating potassium hypochlorite solution

Metallic chlorates are solids, soluble in water, except that those of bismuth, tin and mercury require a little free acid Chlorates, when heated, evolve oxygen and leave the chloride (or oxide) as residue The process of evolution of oxygen from chlorates liberates heat and may take place with explosive violence The addition of a **catalyzer,** e g, **manganese** dioxide, causes a rapid evolution of oxygen at the melting point of the chlorate Potassium chlorate explodes violently, upon friction or percussion, with sulfur, phosphorus, charcoal, sugar and many organic substances When potassium chlorate (melting point about 350° C) or sodium chlorate (melting point 260° C) is heated for some time somewhat above the melting point, the respective perchlorates and chlorides are formed

Upon addition of hydrochloric acid, chlorate liberates chloric acid, which reacts with hydrochloric acid to form chlorine (R K S)

CHLORIDE. Chlorine.

CHLORINE. Symbol Cl Atomic number 17 Atomic weight 35 457 Density 3 214 grams per liter, 0° C, 760 mm or 2 486 when air equals 1 000 Formula of chlorine gas Cl_2 Melting point —100 6° C Boiling point —34 6° C Critical temperature 144 0° C Critical pressure 76 1 atmospheres Isotopes 35 (76%), 37 (24%), have been separated by diffusion, and have been identified and quantitatively estimated by the mass spectroscope

Chlorine is a pale greenish-yellow gas, of marked odor, irritating to the eyes and throat, poisonous Somewhat soluble in water, soluble in carbon tetrachloride to a colorless solution Discovered by Scheele in 1774, but identified as a chemical element by Davy in 1810

Chlorine occurs as sodium chloride in ocean water (2% Cl), in salt beds, salt brines, salt lakes, e g, Stassfurt, Germany, the Dead Sea, the states of New York, Michigan, Louisiana, Utah, and many other places Practically all the chlorine manufactured in the United States is made by electrolysis of sodium chloride solution under special conditions Chlorine is marketed as liquid in steel cylinders up to large sizes, or as "bleaching power" (calcium hypochlorite), and is used (1) for the purification of drinking water, (2) as a disinfectant, (3) in the preparation of many chemicals, (4) for bleaching paper pulp and textiles

Chlorine does not react with oxygen gas, but is reactive with explosive violence with **hydrogen** gas when exposed to sunlight, reacts vigorously with many metals such as **copper, iron, aluminum, arsenic, antimony,** with some non-metals such as **phosphorus, sulfur,** with many organic compounds such as **ethylene, acetylene** to form ethylene dichloride, acetylene tetrachloride, respectively, with warm **turpentine** to form **carbon** plus **hydrogen chloride** violently, with benzenoid

compounds to form chloro-benzenoid substitution products plus hydrogen chloride Chlorine reacts with **sulfurous acid** to form **sulfuric acid**, with **hydrosulfuric** acid in deficiency of chlorine to form **sulfur**, in excess of chlorine to form sulfuric acid.

Azide chlorazide (ClN_3)

Acids hydrochloric acid (HCl), hypochlorous acid (HOCl), chlorous acid ($HClO_2$), chloric acid ($HClO_3$), perchloric acid ($HClO_4$) See each acid. Also chloro-organic acids, see below

Bromide chlorine bromide (ClBr).

Chlorate· See **Chloric acid**

Chlorides Chlorides are known of many elements Metallic chlorides are (1) Soluble, e g, **sodium, potassium, ammonium** chlorides (NaCl, KCl, NH_4Cl), (2) Reactive with water, e g, **aluminum** chloride anhydrous, **magnesium** chloride crystals when heated, titanium tetrachloride, **stannic** chloride anhydrous, (3) Insoluble, e g, **silver** chloride (AgCl), **lead** chloride ($PbCl_2$) (soluble in hot water), **mercurous** chloride (HgCl), and (4) organic chlorides are noteworthy, e g, methyl chloride (CH_3Cl), chlorobenzene (phenyl chloride, C_6H_5Cl), carbon tetrachloride (CCl_4), carbonyl chloride ("phosgene," $COCl_2$) Hydrochloric acid and soluble chlorides are important chemical reagents for the precipitation of insoluble chlorides See **Hydrochloric acid** Organic chloro-compounds, see Chlorine, organic compounds, below

Chlorites See **Chlorous acid.**

Hydride hydrogen chloride (HCl), colorless gas, of characteristic odor, melting point — 111° C, boiling point — 85° C, density 1 27 (air equal to 1 00), very soluble in water yielding hydrochloric acid Formed by reaction of (1) sodium chloride and concentrated sulfuric acid upon heating, (2) hydrogen and chlorine gases under regulated conditions (explosive in sunlight or magnesium light) Reacts with ammonia gas to yield ammonium chloride, white smoke

Hypochlorites See **Hypochlorous acid**

Iodides Chlorine iodide (ClI), trichloroiodine (Cl_3I)

Oxides Chlorine monoxide (Cl_2O), pale orange-yellow gas, boiling point 5° C, odor resembling but distinguishable from chlorine, soluble in water to yield hypochlorous acid, reactive with explosive violence with sulfur, phosphorus, and many carbon compounds Formed (Hazard!) by reaction (1) of chlorine gas and dry finely divided mercuric oxide at 400° C, (2) chloroamine and water in the presence of **calcium** chloride, chlorine dioxide, chlorine peroxide (ClO_2), reddish-yellow gas, melting point — 79° C, boiling point 11° C, unpleasant odor, soluble in water and upon cooling chlorine dioxide octahydrate crystallizes, dangerously explosive alone as solid, liquid, gas or with organic matter or phosphorus, reactive with sodium hydroxide solution to form sodium chlorite plus sodium chlorate Formed by reaction of **potassium** chlorate and concentrated sulfuric acid (Hazard!) and slight warming (chlorine dioxide gas and perchloric acid are formed), chlorine heptoxide (Cl_2O_7), colorless volatile oil, formed by reaction of perchloric acid and phosphorus pentoxide at — 10° C, for one day, and then distilling at the boiling point 82° C of the heptoxide, explosive by percussion or by flame, but unreactive with paper or wood, reactive with water to yield perchloric acid

Perchlorates See **Perchloric acid**

Sulfides See **Sulfur**, chlorides

SCHEME SHOWING THE INTERRELATIONSHIPS OF CHLORINE-CONTAINING SUBSTANCES

Hydrogen chloride	Chlorine	Chlorine monoxide		Chlorine dioxide	Chlorine heptoxide
Hydrochloric acid		Hypochlorous acid	Chlorous acid	Chloric acid	Perchloric acid
Metallic chlorides Of sodium, potassium, magnesium in nature		Metallic hypochlorites	Metallic chlorites	Metallic chlorates	Metallic perchlorates
Organic chlorides See below.		Organic hypochlorites			

Organic Chloro-compounds

Paraffin and benzenoid **hydrocarbons**, e g, **ethane** and **benzene**, respectively, react with chlorine by *substitution* of chlorine for hydrogen (hydrogen chloride also formed), e g, ethane to yield ethyl chloride (C_2H_5Cl) plus further substitution products, benzene, in the presence of a catalyzer, e g, iodine, phosphorus, iron, to yield chlorobenzene (C_6H_5Cl) plus further substitution products, toluene, under like conditions to benzene, to yield ortho-chlorotoluene and para-chlorotoluene ($CH_3C_6H_4Cl$) plus further substitution products, but, at the boiling temperature, in sunhght, dry, and in the absence of a catalyzer, to yield paraffin-side-chain substitution products, benzyl chloride ($C_6H_5CH_2Cl$), benzal chloride ($C_6H_5CHCl_2$) and benzotrichloride ($C_6H_5CCl_3$)

Olefin, acetylene and benzenoid **hydrocarbons**, e g, **ethylene, acetylene,** and **benzene**, respectively, react (A) with chlorine by *addition*, e g, ethylene dichloride ($C_2H_4Cl_2$(1,2)), acetylene tetrachloride ($C_2H_2Cl_4$(1,1, 2,2)), benzene hexachloride ($C_6H_6Cl_6$), also carbon monoxide yields carbonyl chloride ($COCl_2$), (B) with hypochlorous acid by *addition* to form, for example, ethylene chlorohydrin (CH_2ClCH_2OH).

Oxygen-function compounds, e g, **ethyl alcohol, acetaldehyde, acetone, acetic acid**, react (A) with chlorine, to form *chloro-substituted* corresponding or related *compounds*, e g, ethyl alcohol or acetaldehyde to yield chloral (CCl_3CHO), acetone to yield chloroacetone ($CH_3ClCOCH_3$), acetic acid to yield, at the boiling temperature, dry, and in the absence of a catalyzer, monochloroacetic acid (CH_2Cl COOH), dichloroacetic acid ($CHCl_2COOH$), trichloroacetic acid (CCl_3COOH), the substitution taking place on the alpha-carbon (the carbon next to the carboxyl group (—COOH)), (B) with phosphorus chlorides, to form corresponding *oxygen-function chlorides*, e g, ethyl chloride (C_2H_5Cl), ethylidene dichloride (CH_3CHCl_2), acetone chloride ($(CH_3)_2CCl_2$), acetyl chloride (CH_3COCl)

Chloroform is made by reaction of **acetone** or **ethyl alcohol** with calcium or sodium hypochlorite, carbon tetrachloride by reaction of carbon disulfide (CS_2) plus chlorine (Cl_2) in the presence of iron heated (sulfur monochloride, S_2Cl_2, boiling point 130° C, also formed, and separated by fractional distillation), trichloroethylene by reaction of acetylene tetrachloride and dilute alkali The diazo-reaction (See **Azo and Related Compounds**) may be used to introduce chlorine into benzenoid compounds

Many of the chloro-compounds are used as reagents or as intermediate compounds in organic chemistry, and as non-inflammable solvent liquids for the extraction of fats and oils, and in cleaning textile materials

SCHEME SHOWING THE INTERRELATIONSHIPS OF CHLORINE-FUNCTION ORGANIC COMPOUNDS

Related to	Methane	Ethane or Propane	Toluene	Benzene
—CH_2OH >CHOH >COH of alcohols and phenols	Methyl chloride	Ethyl chloride Ethylene dichloride Chloroalcohols Ethylene chlorohydrin	Benzyl chloride Ortho-chlorotoluene Para-chlorotoluene 2,4-Dichlorotoluene 2,4,6-Trichlorotoluene	Phenyl chloride (chlorobenzene) Ortho-dichlorobenzene Para-dichlorobenzene 1,2,4-trichlorobenzene 1,2,3,5-tetrachlorobenzene Hexachlorobenzene Benzene hexachloride Ortho-chlorophenol Para-chlorophenol 2,4-Dichlorophenol 2,4,6-Trichlorophenol
—CHO >CO of aldehydes and ketones	Methylene chloride	Acetylene tetrachloride Aldo- and keto-chlorides Acetaldehyde chloride (ethylidene dichloride) Acetone chloride Chloroaldehydes and -ketones Chloral Chloroacetone	Benzal chloride	
H—COOH Carboxylic acids	Chloroform	Hexachloroethane Acid chlorides Acetyl chloride Chloroacids Monochloroacetic acid Dichloroacetic acid Trichloroacetic acid	Benzotrichloride Acid chlorides Benzoyl chloride Chloroacids Meta-chlorobenzoic acid	
HO—COOH Carbonic acid	Carbon tetrachloride Carbonyl chloride			

ORGANIC COMPOUNDS OF CHLORINE

	Organic Compounds of Chlorine	Formula	Melting Point °C	Boiling Point °C
1	Methyl chloride	CH_3Cl		−24
2	Ethyl chloride	C_2H_5Cl		12
3	Normal-propyl chloride (1-chloropropane)	$C_2H_5\ CH_2Cl$		46
4	Iso-propyl chloride (2-chloropropane)	$CH_3\ CHCl\ CH_3$		37
5	Vinyl chloride (chloroethylene)	$CH_2\ CHCl$		−12
6	Allyl chloride	$CH_2\ CH\ CH_2Cl$		45
7	Chloroacetylene	$CH \cdot CCl$		Expl
8	Alpha-chlorostyrene	$C_6H_5CCl : CH_2$		199
9	Omega-chlorostyrene	$C_6H_5CH\ .\ CHCl$		199
10	Bornyl chloride	$C_{10}H_{17}Cl$	161	
11	Benzyl chloride (phenyl chloromethane)	$C_6H_5\ CH_2Cl$		179
12	Cinnamyl chloride	$C_6H_5CH\ \ CH\ CH_2Cl$		
13	Glycol chlorohydrin (ethylene chlorohydrin)	$CH_2Cl\ CH_2OH$		120*
14	Alpha-glycerol chlorohydrin	$CH_2Cl\ CHOH\ CH_2OH$		139 (18 mm)
15	Beta-glycerol chlorohydrin	$CH_2OH\ CHCl\ CH_2OH$		146 (18 mm)
16	Chloroacetic acid	$CH_2Cl\ COOH$		190
17	Alpha-chloropropionic acid	$CH_3\ CHCl\ COOH$		186
18	Beta-chloropropionic acid	$CH_2Cl\ CH_2\ COOH$	61	203
19	Chloromalonic acid	$CHCl(COOH)_2$	133	
20	Ethyl chloroformate	$ClCOOC_2H_5$		94

*Constant boiling mixture, 42 5% water, 96° C

(Continued on next page)

ORGANIC COMPOUNDS OF CHLORINE (*continued*)

	Organic Compounds of Chlorine	Formula	Melting Point °C	Boiling Point °C
21	Alpha-chloroacrylic acid	$CH_2 \cdot CCl\ COOH$	65	
22	Beta-chloroacrylic acid	$CHCl\ CH\ COOH$	85	
23	Acetyl chloride	$CH_3\ COCl$		51
24	Benzoyl chloride	$C_6H_5\ COCl$		197
25	Chloroacetone	$CH_2Cl\ CO\ CH_3$		121
26	Alpha-epichlorohydrin (chloropropylene oxide)	$CH_2Cl\ CH{-}CH_2$ (O)		117
27	Cyanogen chloride	$CN\ Cl$		13
28	Chlorofurane	$C_4H_3Cl(2)O$		77 (744 mm)
29	Furoyl chloride	$C_4H_3O\ COCl(2)$	0	170
30	Furfuryl chloride	$C_4H_3O\ CH_2Cl(2)$		49 (26 mm)
31	Chlorofuroic acid (3)	$C_4H_2Cl(3)O\ COOH(2)$	149	
32	Chlorofuroic acid (5)	$C_4H_2Cl(5)O\ COOH(2)$	179	
33	Chlorobenzene (phenyl chloride)	C_6H_5Cl		132
34	Ortho-chlorotoluene (1,2)	$C_6H_4(Cl)(2)(CH_3)(1)$		160
35	Meta-chlorotoluene (1,3)	$C_6H_4(Cl)(3)(CH_3)(1)$		162
36	Para-chlorotoluene (1,4)	$C_6H_4(Cl)(4)(CH_3)(1)$	8	162
37	Ortho-chlorobiphenyl	$(2)Cl\ C_6H_4\ C_6H_5$	34	267
38	Meta-chlorobiphenyl	$(3)Cl\ C_6H_4\ C_6H_5$	89	
39	Para-chlorobiphenyl	$(4)Cl\ C_6H_4\ C_6H_5$	75	282
40	Alpha-chloronaphthalene	$C_{10}H_7\ Cl(1)$		259
41	Beta-chloronaphthalene	$C_{10}H_7\ Cl(2)$	56	265
42	Ortho-chlorophenol (1,2)	$C_6H_4(Cl)(2)(OH)(1)$		175
43	Meta-chlorophenol (1,3)	$C_6H_4(Cl)(3)(OH)(1)$	28	214
44	Para-chlorophenol (1,4)	$C_6H_4(Cl)(4)(OH)(1)$	41	217
45	Ortho-chloroaniline (1,2)	$C_6H_4(Cl)(2)(NH_2)(1)$	0	210
46	Meta-chloroaniline (1,3)	$C_6H_4(Cl)(3)(NH_2)(1)$	−10	230 (767 mm)
47	Para-chloroaniline (1,4)	$C_6H_4(Cl)(4)(NH_2)(1)$	71	231
48	Ortho-chloronitrobenzene (1,2)	$C_6H_4(Cl)(2)(NO_2)(1)$	32	245
49	Meta-chloronitrobenzene (1,3)	$C_6H_4(Cl)(3)(NO_2)(1)$	44	236
50	Para-chloronitrobenzene (1,4)	$C_6H_4(Cl)(4)(NO_2)(1)$	83	242
51	Ortho-chlorobenzoic acid (1,2)	$C_6H_4(Cl)(2)(COOH)(1)$	141	
52	Meta-chlorobenzoic acid (1,3)	$C_6H_4(Cl)(3)(COOH)(1)$	158	
53	Para-chlorobenzoic acid (1,4)	$C_6H_4(Cl)(4)(COOH)(1)$	242	subl
54	Ortho-chlorobenzaldehyde (1,2)	$C_6H_4(Cl)(2)(CHO)(1)$	11	208 (748 mm)
55	Meta-chlorobenzaldehyde (1,3)	$C_6H_4(Cl)(3)(CHO)(1)$	18	213
56	Para-chlorobenzaldehyde (1,4)	$C_6H_4(Cl)(4)(CHO)(1)$	48	213 (748 mm)
57	Alpha-chloroanthraquinone	$(1)Cl\ C_6H_3(CO)_2C_6H_4$		
58	Beta-chloroanthraquinone	$(2)Cl\ C_6H_3(CO)_2C_6H_4$	208	
59	Methylene chloride	CH_2Cl_2		42
60	Ethylene dichloride (1,2-dichloroethane)	$CH_2Cl\ CH_2Cl$		84
61	Acetylene dichloride (1,2-dichloroethene)	$CHCl\ CHCl$		48
62	Ethylidene chloride (1,1-dichloroethane)	$CH_3\ CHCl_2$		58
63	Benzal chloride (benzylidene chloride)	$C_6H_5CHCl_2$		214
64	Acetone chloride (2,2-dichloropropane)	$(CH_3)_2CCl_2$		70
65	Dichloroacetic acid	$CHCl_2\ COOH$		194
66	Chloroacetyl chloride	$CH_2Cl\ COCl$		105
67	Carbonyl chloride (phosgene)	$COCl_2$		8
68	Ortho-dichlorobenzene (1,2)	$C_6H_4Cl_2(1,2)$		179
69	Meta-dichlorobenzene (1,3)	$C_6H_4Cl_2(1,3)$		172
70	Para-dichlorobenzene (1,4)	$C_6H_4Cl_2(1,4)$	53	174
71	Dichlorophenol (2,4)	$HO{-}C_6H_3\ Cl_2(2,4)$	45	210
72	Dichloroanthracene (9,10)	$C_6H_4(CCl)_2C_6H_4$	209	
73	Chloroform	$CHCl_3$		61
74	Methylchloroform (1,1,1-trichloroethane)	$CH_3 \cdot CCl_3$		74
75	Benzotrichloride (phenyl chloroform)	$C_6H_5\ CCl_3$		221
76	Trichloroethylene	$CHCl \cdot CCl_2$		88
77	1,2,3-Trichloropropane	$CH_2Cl\ CHCl\ CH_2Cl$		158
78	Trichloroacetic acid	$CCl_3\ COOH$	58	195
79	Trichlorophenol	$C_6H_2(OH)(Cl)_3(2,4,6)$	68	
80	Chloral (trichloroacetaldehyde)	$CCl_3\ CHO$		98 (768 mm)
81	Chloral hydrate	$CCl_3\ CH(OH)_2$	52	96
82	Carbon tetrachloride	CCl_4		76
83	Acetylene tetrachloride (1,1,2,2-tetrachloroethane)	$CHCl_2\ CHCl_2$		146
84	Tetrachloroethylene	$CCl_2 \cdot CCl_2$		121
85	Naphthalene tetrachloride	$C_{10}H_8Cl_4(1,2,3,4)$		
86	Hexachloroethane	$CCl_3\ CCl_3$	187 (sealed tube)	185 (777 mm)
87	Benzene hexachloride, alpha, trans	$C_6H_6Cl_6$	158	
	" " beta, cis	$C_6H_6Cl_6$	297 (decom)	
88	Hexachlorobenzene	C_6Cl_6	230	309 (742 mm)

* Constant boiling mixture, 42.5% water, 96° C

CHLORITE SCHIST. A schist whose color and foliation is chiefly due to the mineral chlorite Other minerals common in this type of schist are **quartz** and **epidote. Garnet** and **magnetite** sometimes occur as **idiomorphic** crystals giving the schist a **porphyroblastic** texture (R M F)

CHLORITOID. A mineral which occurs as tabular crystals, probably triclinic, foliated masses or scattered scales and plates of a greenish gray to greenish black mineral that is characteristic of the less intensely altered **metamorphic** rocks such as **phyllites** and **quartzites** Chemically it is a hydrous **iron aluminum silicate** Ottrelite contains some manganese as well Chloritoid was originally noted as from the Ural Mountains and named for its greenish color from the Greek word meaning green Ottrelite was named from Ottrez in Luxemburg (E S C S)

CHLOROFORM. Chlorine, and **Anaesthesia**

CHLOROMONADINA An order of single-celled animals of green color See **Mastigophora.** (A W L)

CHLOROPHYLL. Pyrrole and Related Compounds, and **Pigments in Plants**

CHLOROPLASTID Pigments in **Plants.**

CHLOROPLATINIC ACID. Platinum

CHLOROUS ACID AND CHLORITES. Chlorous acid ($HClO_2$) is a yellow solution, unstable, and of characteristic odor of chlorine dioxide A strong oxidizing agent

Formed by the spontaneous decomposition of **chloric acid** into chlorous and **perchloric acids**

Sodium chlorite is slowly formed by the reaction of chlorine dioxide (ClO_2) and **sodium** hydroxide, with the simultaneous formation of sodium chlorate

Chlorites are generally yellow The chlorites of **sodium** and **potassium** are deliquescent, those of **lead, silver, mercurous, mercuric** (red) are insoluble (R K S)

CHOANOCYTE The collar cell of **sponges,** bearing a high ridge surrounding a **flagellum** at the free end They are located in cavities in the sponge and produce currents of water through the passages in the body wall (A W L)

CHOCOLATE. Theobroma Cacao.

CHOKE COIL. A coil with an air core having much **inductance** and relatively small **resistance** can produce a counter electromotive force opposing an impressed **alternating current** voltage The counter voltage will depend on the frequency of the inducing current This fact is made use of in the choke coil, which is a simple air core reactor such as that placed between lightning arresters and the apparatus to be protected The reactance at normal frequency is negligible, but at the very high frequencies of transient discharges, the coil will choke back the lightning disturbance and cause it to discharge through the path provided by the arrester (F T M)

CHOLANGITIS. An acute infection of the **bile** ducts, usually associated with acute infection of the **gall-bladder** This results from infection with the pyogenic **bacteria** similar to those seen in **cholecystitis** while it may occur with cholecystitis or **cholelithiasis,** it may complicate **pneumonia, typhoid fever,** or other acute illnesses

The symptoms of cholangitis are those of an acute cholecystitis with sepsis **Jaundice** is present due to the obstruction of the common bile duct **Leukocytosis,** chills, high intermittent fever, colic, vomiting, and severe pain in the abdomen are present **Septicemia** may complicate the picture

The prognosis is bad and the mortality is high The best treatment is surgical drainage of the common bile duct (R S M)

CHOLECYSTECTOMY. Removal of the **gall-bladder** This is usually done when **cholelithiasis, cholecystitis,** or **cancer** of this organ is present It is sometimes done in **typhoid** carriers, when the gall-bladder is the focus of infection (R S M)

CHOLECYSTITIS Infection of the **gall-bladder** occurring in an acute and chronic form Cholecystitis rarely develops as a primary infection It is usually secondary to **cholelithiasis,** or is part of a general **cholangitis**

The **bacterial** organisms usually found in cholecystitis are of the colon-typhoid group Less frequently the *Streptococcus, Staphylococcus* and *Pneumococcus* are found The organisms gain access to the organ either by the blood stream or ascend from the **duodenum** through the bile

The acute form is accompanied by fever, generalized abdominal pain, vomiting and severe prostration Jaundice is not seen unless the common bile duct is involved with the acute infection (cholangitis) In severe infections of the gall-bladder, perforation may occur This usually results fatally unless surgical intervention is done early

Chronic cholecystitis is the more common form It may follow the acute form, or progress insidiously over a period of time Usually, stones are present in the gall-bladder and predisposed to infection sooner or later

The symptoms of chronic cholecystitis are practically the same as cholelithiasis and are those of vague intestinal disorders

Diagnosis is verified by means of cholecystography (x-ray visualization of the gall-bladder)

The treatment of cholecystitis is surgical This is usually done in the chronic stage, and consists of removal of the infected gall-bladder At times operation becomes imperative in the acute stage when danger of perforation, or **empyema** of the gall-bladder occurs (R S M)

CHOLECYSTOGRAPHY. X-ray visualization of the **gall-bladder** This procedure is of routine use in diagnosis of gall-bladder disease It is accomplished by giving the halogen salts of **phthaleins** by mouth, or less often by vein The salts are excreted by the liver into the **bile** and concentrated in the gall-bladder This renders the gall-bladder opaque to the x-ray By this method the position, size, shape and often the presence of stones can be demonstrated Later a fat meal is given This causes the gall-bladder normally to contract causing a disappearance or diminution of the shadow on the x-ray plate When inflammation of the gall-bladder or obstruction of the cystic duct is present, the gall-bladder shadow may be absent With stones in the gall-bladder and inflammation, **cholecystitis** is present, the size of the gall-bladder may be altered, and the emptying of the bladder after ingestion of fat is impaired or absent Shadows of stones are often seen (R S M)

CHOLECYSTOSTOMY. Surgical drainage of the **gall-bladder** This is sometimes done when the patient is too ill to allow removal of the organ It is usually necessary to remove the gall-bladder at a later date. (R S M)

CHOLELITHIASIS (GALL-STONES, BILIARY CALCULUS). Gall-stones usually form as the result of infection, stasis of **bile,** or changes in the **metabolism** of the body causing an increase in the **cholesterol** content of the blood, or other changes in the composition of the bile In other cases stones form without the above factors being observed It is believed by some

that in certain cases infection follows stone formation

Certain predisposing factors are definitely known. Age evidently plays a part, since 5% to 10% of all cases coming to autopsy show stone formations Women are prone to cholelithiasis, probably due to pregnancy when there is increased cholesterol formation in the blood **Typhoid** infection seems to dispose to stone formation The majority of patients are obese, and are usually over thirty-five or forty years of age

The chemical contribution, number, size, and structure of gall-stones varies greatly The largest number reported in one **gall-bladder** is said to be 7802 Some stones are very large In shape, gall-stones may be round, irregular or sharply faceted Solitary stones are often found Chemically the stones are commonly of four types (1) Pure cholesterol Such stones present, in section, a radiating crystalline structure (2) Alternate layers of cholesterol and calcium salts (3) Mixtures of cholesterol and bilirubin-calcium Such stones are usually soft, non-crystalline, and small in size (4) Pure bilirubin-calcium The symptoms caused by gall-stones depend on their position, and the amount of infection (**cholecystitis**) present The common symptoms seen in most cases are usually vague digestive disturbances, such as dull pains, sour eructation, fullness and flatulence of the upper abdomen These symptoms are aggravated by eating rich foods, especially those of a fatty nature

The severe pain or colic that occurs in recurring attacks is due to a stone lodging in the cystic, or common bile duct, to spasm of the gall-bladder walls due to irritation by stones or the infection, or to distension and stretching of the gall-bladder by the obstructed bile If the common bile duct becomes obstructed so that no bile can pass, **jaundice** develops

The pain accompanying a stone impacted in the system of biliary ducts is often excruciating, and is accompanied by repeated vomiting and fever—the latter depending on the amount of infection present A large gall-stone escaping into the intestine may cause intestinal obstruction The paroxysms of biliary colic tend to recur at more frequent intervals, and to become more severe

Complications of cholelithiasis are chronic cholecystitis, pancreatitis (inflammation of the **pancreas**), perforation of the gall-bladder with resulting **peritonitis**, intestinal obstruction from large gall-stones, infection of the **liver** (hepatitis), and adhesion formation around the gall-bladder and neighboring organs

Cholelithiasis without marked infection is not often fatal The severe pain that is seen with it makes the victim's life miserable

Medical measures are not of much assistance in a frank case Surgery is safe, and consists of removal of the damaged gall-bladder, together with all stones, including those in the duct system as well as those in the gall-bladder itself (R S M)

CHOLESTEROL. Alcohols and Ethers.

CHONDRIOCONT. A structure found within some **cells** (A W L)

CHONDRIOSOME. A structure within the **cell** (A W I)

CHONDRITE. A term proposed by Rose in 1864 for **meteoric** stones which contain spheroidal aggregates of basic minerals (**pyroxene** and **olivine**), **oligoclase feldspar**, and varying proportion of **nickel-iron**. The percentage of free nickel increases as the percentage of nickel-iron decreases (R M F)

CHONDROSTEI The **paddle-fishes** and **sturgeons**. An order with the skeleton made up largely of **cartilage** but with some bony components (A W L)

CHONOLITH. A term proposed by R. A. Daly in 1905 for irregular **igneous** intrusions which according to their shapes and field relationships cannot be classified as **dykes, laccoliths, batholiths, bysmaliths, etc.** (R M F)

CHORD. The word chord has three well-defined engineering meanings In railroad and highway practice a chord is a straight line joining the ends of an arc of any given curvature The sharpness of **circular curves** used on railroad lines is defined by the number of degrees in a central angle subtended by a chord of 100 feet

The principal boundary members of the framed **truss** used in bridges or buildings are designated as chord members or chords Refer to **bridges** for an illustration of chord members

In aviation terminology, the dimension of an **airfoil** surface parallel to the air stream is called the chord. (F T M)

CHORDATA. The **vertebrates** and a few marine animals of simpler form, including the **tunicates, salpians** and **lancelets** Although the true vertebrates make up most of this phylum the inclusion of the other forms is scientifically accurate With these limits the distinctive characters of the phylum are few The animals are **triploblastic, coelomate,** and **metameric** like the higher invertebrates but differ from them in three points· 1 The skeleton is internal In its primitive state it consists of a slender longitudinal rod lying above the alimentary tract and called the **notochord** This structure is present at some stage in development in all of the included species 2 The **nervous system** is entirely dorsal in position, lying in the body wall above the notochord 3 The alimentary tract includes a chamber, the **pharynx**, just behind the oral cavity, whose walls are perforated by openings associated with respiration and called the gill slits or pharyngeal clefts These openings appear or are indicated only in the **embryos** of terrestrial species

It is difficult to estimate the relative importance of the phylum since man himself is one of the included species The chordates include the most highly developed animals from the scientific point of view, and from the practical point of view they are equally important as the source of most of our animal foods, furs, feathers, wool, leather, and as beasts of burden Man has depended on the vertebrates, indeed, for much of his progress, and has taken his domestic animals from this group

The classification of the phylum is briefly as follows·

Subphylum **Hemichordata** Worm-like marine animals **Balanoglossus** Also named Enteropneusta

Subphylum **Urochordata** Sessile or free-swimming forms, marine, with larvae resembling tadpoles in which the characters of the phylum are evident. Also named Tunicata

- Class **Larvacea** Small floating animals with the larval form of the subphylum
- Class **Ascidiacea** The tunicates Sessile or free, named from the investing test or tunic which encloses them
- Class **Thaliacea** The **salpians** Free-swimming

Subphylum **Cephalochordata** The lancelets Small fish-like animals which swim freely and also burrow in the sand

Subphylum **Vertebrata** The skeleton includes cartilaginous or bony components in addition to the notochord Also named Craniata

- Class **Cyclostomata** The round-mouthed **eels** lampreys and hags
- Class **Pisces** The fishes Sometimes placed in two classes Elasmobranchii, containing the **sharks, rays**, etc, and Pisces containing the remaining fishes
- Class **Amphibia** The **salamanders, frogs, toads**, etc

Class **Reptilia** The **lizards, snakes, turtles, crocodiles,** etc
Class **Aves** The birds
Class **Mammalia** Popularly called animals without further qualification They secrete milk for the nourishment of their young and the skin usually bears some hair, often a complete coat which may be in the form of fur or wool Mice (**mouse**), **horses** and **cattle, monkeys,** man, and many other forms (A W L)

CHORDOTONAL ORGAN. An organ for the perception of vibrations, found in the insects where it may exist singly or in association with complex auditory organs It consists of a nerve ending with accessory cells connected directly to the body wall or to some modified derivative of the body wall in an organ of hearing (A W L)

CHORION 1 An accessory structure formed during embryonic development in **mammals** It provides the connection with the tissues of the mother through which all interchange of materials between her blood and that of the **embryo** is carried on prior to birth

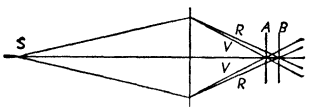
The chorion is a composite structure formed of the **serosa** and the **allantois,** although the name is sometimes erroneously applied to the serosa alone In some mammals a specialized **placenta** develops from part of the chorion as the persistent connection with the mother Like all other extraembryonic membranes, this structure is discarded at birth

2 The shell of an insect egg (A W L)

CHOROLOGY. Zoogeography.

CHOUGH Aves, Passeriformes *Pyrrhocorax* Eurasian birds (**Aves**) related to the crows and resembling them in form and color A few other Asian birds are known as chough-thrushes (A W L)

CHROMATIC ABERRATION The indistinct color effects observed along the edges of images formed by a simple **lens** constitute what is known as the chromatic aberration of the lens This aberration is due to the fact that the glass, or any other substance, out of which the lens is constructed produces **dispersion** (i e, refracts light of different colors by different amounts) In a convergent glass lens the focal length is greater for red light than for blue, while in a divergent (concave surface) glass lens the blue focus is longer than the red The effect for the convergent (convex surface) lens is



Chromatic Aberration

shown, highly exaggerated, in the figure, in which the location of the image of a source, S, is shown for red light, R, to be in the plane, B, and for blue light, V, to be in the plane, A An observer using an **eyepiece** focused for the plane A will see a sharp image of the source in blue light surrounded by the margin of a confused set of images of greater size in other colors

Chromatic aberration is very bothersome to users of lenses either for telescopic, microscopic, or photographic purposes and ever since optical instruments came into use attempts have been made to design "achromatic" lenses For relatively short focus instruments, such as **cameras** or field glasses, practically complete achromatism can be obtained by using, instead of a simple convex lens, a combination of a convex and a concave lens, the two lenses being constructed of glasses of different dispersive powers Prospective purchasers of field glasses, opera glasses or binoculars should always examine them carefully to determine whether or not the lenses are properly achromatised A simple test is to examine the edge of a white building, which is in full sunlight, through the instrument under consideration Move the image of the edge well over to one side of the field of view, and, if the lenses are properly figured, no color effects will appear If, however, chromatic aberration is present, the image of the edge of the white building will be found to be bordered with a bright colored fringe which increases in width as the image is moved closer to the edge of the field In passing it might be said that the same test will indicate whether or not the field glasses are properly corrected for **spherical aberration**' and other aberrations, for in a poor lens the image of the edge will become blurred and curved when moved to the side of the field of view

In long focus instruments, such as astronomical **telescopes,** complete achromatism is virtually impossible Partial achromatism may be obtained in such instruments by employing the combination of the divergent and convergent lenses of glass of different dispersive powers (See **Dispersion**) Two types of partial achromatism are employed, depending upon the purposes for which the telescope is designed In a telescope to be used for photographic purposes the colors which are most active photographically, i e, the greens and blues, are all brought to the same focal point, whereas the reds and oranges are thrown well out of this focal plane

In a so-called visual telescope the yellowish-green light is all brought to one sharp focus, while the blues and violets are bent well inside this visual focus On looking at the image of a very bright object, such as the **moon,** a **planet,** or a bright **star,** a halo of bluish light can be observed due to the out of focus photographic light, but this halo is so diffuse that it is not objectionable when working with objects of the brilliance for which the instrument is designed Instruments designed for visual observing (visual refractors) cannot be used satisfactorily for celestial photography without employing yellow sensitive plates and color filters to eliminate the out of focus blue and green light

The image formed by a concave metal or silver on glass mirror is free from chromatic aberration since all colors are reflected in the same direction This is the most important optical advantage of the reflecting telescope over the refracting type (W K G)

CHROMATIN. A substance found in the **nucleus** of the **cell,** named for its pronounced affinity for biological stains It is the bearer of **hereditary** qualities of the organism It usually occurs in the form of small granules distributed throughout the nucleus When the nucleus is about to divide the chromatin particles mass together to form the **chromosomes**

Chromatin of special qualities has received special names in several cases Basichromatin takes basic stains, oxychromatin acid stains Trophochromatin governs the vegetative activities of the cell and idiochromatin its reproductive functions (A W L, R M W)

CHROMATOPHORE. The chromatophore, also called a chromoplastid, is a definite body occurring in the **protoplast** It is characteristic of a chromatophore that it should have a definite color, due to the pigment or **pigments** present in it

In plants the most common chromatophore is the **chloroplastid** Other chromatophores are of various colors, including yellow, brown, orange, and red Not all plant pigments are found in chromatophores, however Many occur dissolved in the cellsap

Chromatophores found in the skin of animals of several groups, including **arthropods, mollusks,** and **vertebrates,** are large cells, often extensively branched They are well developed in the **octopus** and **squid,** in many **amphibians** and fishes, and in **reptiles.**

Rapid changes in color such as those of squids and some lizards have been ascribed to a contraction of the chromatophores but it now seems evident that the cell itself does not contract although the pigment within it may undergo a considerable change in distribution, revealing itself when widely distributed and otherwise concealed from view (R M W, A W L)

CHROMIDIA. Granules in the cytoplasm of **cells** which stain deeply with basic stains and are derived from the nucleus In some cells they constitute a nucleus of scattered parts, as in **bacteria.** (A W L)

CHROMIOLE. A granule within a **chromomere** (A W L)

CHROMITE. The mineral chromite corresponds to the formula $FeCr_2O_4$ but **magnesium** frequently replaces **iron,** and **aluminum** and **ferric** iron frequently replace the **chromium** It is **isometric,** in **octahedrons,** although commonly massive, granular to compact Chromite is brittle with an uneven fracture, hardness, 5 5, specific gravity, 4 1–4 9, luster, metallic, black to brownish black, streak, brown, opaque to rarely translucent Chromite may at times be slightly magnetic It is found in basic rocks of the **peridotite** type, also in veins and masses in serpentines derived from **peridotite** Important foreign chromite localities are in Asia Minor, Rhodesia, New Caledonia and the Ural Mountains Other occurrences are in Austria, France, and Cuba In the United States it is found in New Jersey, Pennsylvania, Maryland, North Carolina, Montana, and California It is used as a source of metallic chromium and chromium compounds used as pigments, also in the manufacture of refractory bricks, and in hardening **steel** (R M P)

CHROMIUM. Symbol Cr Atomic number 24 Atomic weight 52 01 Density 7 1 Hardness 9 Melting point 1615° C Boiling point 2200° C

Chromium is a slightly grayish metal, hard, and capable of taking a brilliant polish, not appreciably ductile or malleable, soluble in **hydrochloric** or **sulfuric acid** (dilute), made passive by **nitric acid** (dilute or concentrated) or sulfuric acid (concentrated), not affected by air or water at ordinary temperatures, not affected by fused alkalis, when heated to 200° C in air forms chromic oxide Discovered by Vauquelin in 1798 (**Isotopes** page 238)

Chromium metal is used (1) in special steels—less than 1% Cr in chrome or nickel-chrome steels greatly increases the hardness, (2) in corrosion resistant or "stainless" steels—8%–14% Cr, (3) in electroplating, as a protective and ornamental coating for less resistant metals—electrodeposited chromium is the hardest form of the metal, being almost as hard as diamond, and very resistant to corrosion, (4) in special alloys, e g, wire of high electrical resistance for heating units, nichrome or chromel wire (11%–25% Cr, 50% or more nickel, remainder iron)

Chromium occurs chiefly as chromite (ferrous **chromite,** $Fe(CrO_2)_2$) in southern Rhodesia, New Caledonia, India, and California (1) Heating chromite in the **electric furnace** with **carbon** yields ferrochrome for alloys, and (2) when chromite is heated with **sodium** carbonate and nitrate, **sodium** chromate is formed, which is then extracted with water This is the substance from which chromium compounds are obtained

Acetates chromous acetate ($Cr(C_2H_3O_2)_2$), brownish-violet solid, chromic acetate ($Cr(C_2H_3O_2)_3 \cdot H_2O$), grayish-green solid Both are soluble and used as mordants in dyeing and printing **textiles,** and in tanning

Alum See Sulfate

Chlorides chromous chloride ($CrCl_2$), white solid, by heating chromic chloride in dry **hydrogen** gas, and obtained as a blue solution by reduction of chromic chloride solution with **zinc** metal, or by reaction of chromium metal and **hydrochloric acid** in the absence of air, chromic chloride ($CrCl_3$), exists in two forms, (1) green, deliquescent crystals, soluble in water, formed by reaction of chromium hydroxide and hydrochloric acid and subsequent crystallization, (2) reddish-violet crystals, anhydrous, insoluble in water or dilute or concentrated acids, although the presence of a very small amount of chromous or stannous chloride renders the chromic chloride soluble, formed by heating chromic oxide in sulfur chloride above 400° C Solutions of chromic chloride, concentrated or acidified, are green, when diluted violet, chromyl chloride (CrO_2Cl_2), red liquid, boiling point 118° C, by heating anhydrous sodium or potassium dichromate with sodium chloride and concentrated sulfuric acid

Chromates and dichromates· **sodium** chromate (Na_2CrO_4), **potassium** chromate (K_2CrO_4), **ammonium** chromate ($(NH_4)_2CrO_4$), **calcium** chromate ($CaCrO_4$), are yellow soluble solids, **barium** chromate ($BaCrO_4$), pale yellow, **strontium** chromate ($SrCrO_4$), pale yellow, **lead** chromate ($PbCrO_4$), yellow (used as a pigment, "chrome yellow"), **zinc** chromate ($ZnCrO_4$), yellow, used as a pigment, **mercurous** chromate (Hg_2CrO_4), yellow to red to brown, **silver** chromate (Ag_2CrO_4), reddish-brown, are insoluble solids **Sodium** dichromate ($Na_2Cr_2O_7$), **potassium** dichromate ($K_2Cr_2O_7$), readily crystallized, ammonium dichromate ($(NH_4)_2Cr_2O_7$), are red soluble solids, of important application as oxidizing agents, e g, sulfurous acid causes reduction to chromic, silver dichromate ($Ag_2Cr_2O_7$), red insoluble solid, changing to silver chromate (Ag_2CrO_4) upon boiling with water Solutions of chromate in the presence of acid are changed to the corresponding dichromate

Dichromates See Chromates Solutions of dichromate in the presence of alkali are changed to the corresponding chromate

Hydroxides chromous hydroxide ($Cr(OH)_2$), brown precipitate, formed by reaction of chromous salt solution with **sodium** hydroxide solution, chromic hydroxide ($Cr(OH)_3$), grayish-green precipitate, formed by reaction of chromic salt solution with sodium or ammonium hydroxide or sulfide solution, soluble in excess of sodium hydroxide but reprecipitated upon boiling, soluble in acids

Oxides chromic oxide, chromium sesquioxide (Cr_2O_3), green solid relatively insoluble in acids after having been heated to 500° C, a good **refractory** material, formed by ignition of ammonium dichromate or chromium hydroxide, reduced to chromium metal (1) by heating with carbon in the electric furnace, or (2) by ignition with **aluminum** powder, chromium trioxide, chromic anhydride, "chromic acid" (CrO_3), brownish-red crystals, soluble in water forming chromic acid (H_2CrO_4 or $H_2Cr_2O_7$), formed by addition of concentrated **sulfuric acid** to dichromate solution, forms chromic oxide and oxygen upon being heated to 190° C, a powerful oxidizing agent in which reaction chromic compound is formed Used as a mordant in dyeing wool and silk

Sulfate chromium sulfate, chromic sulfate ($Cr_2(SO_4)_3 \cdot 18H_2O$), violet crystals, formed by reduction of dichromate with sulfurous acid in sulfuric acid solution, and crystallization Used as a mordant in the textile industry, in the photographic fixing bath, in tanning, and in ceramics, chromium potassium sulfate, "chrome alum" ($Cr_2(SO_4)_3 \cdot K_2SO_4 \cdot 24H_2O$) Used as chromium sulfate

Sulfide chromium sulfide (Cr_2S_3), brownish-black powder, formed by heating chromium metal in **carbon disulfide** vapor, not formed by wet methods because with water forms chromium hydroxide plus hydrogen sulfide

Chromic acid and chromates are detected by the formation with lead acetate solution of a yellow precipitate (lead chromate) soluble in nitric acid, but insoluble in acetic acid

For the detection of chromous and chromic compounds see **Analytical Chemistry.** (R K S)

CHROMOMERE. One of the masses into which the chromosome is differentiated longitudinally See **Cell.** (A W L)

CHROMONEMA. A thread of **chromatin** in the resting **cell.** (A W L)

CHROMOPHORE. **Dyes.**

CHROMOSOME. A unit into which the **chromatin** of the cell forms during **cell division.** Important in **heredity.** (A W L)

CHROMOSPHERE. The chromosphere is the layer of **atmosphere** of the sun which is composed principally of hydrogen, helium and calcium It lies at a distance of several hundred miles above the **photosphere** and merges into the **reversing layer** below and the **corona** above Since the elements which compose the chromosphere contain strong spectral lines in the red, it is usually visible at a total **eclipse** of the sun as a brilliant red envelop about the sun, and gets its name from this fact The chromosphere may be observed with specially designed instruments, similar to those used in the study of **prominences,** even without a total eclipse (W K G)

CHRONOGRAPH. As the word itself implies, a chronograph is an instrument for writing time In the usual type of instrument a drum carrying a sheet of paper is rotated by clockwork at the rate of one revolution per minute A pen, attached to the armature of an electromagnet, is carried parallel to the axis of the drum by a screw and rests on the paper, tracing a spiral line The electromagnet is connected in an electric circuit with a standard clock in such a manner that every second the pen makes a short lateral movement which graduates the spiral line into seconds A key is connected in the circuit in such a manner that each time the key is closed an extra graduation is made on the spiral When the sheet is removed from the drum a scale may be used to measure the distance of the marks made by pressing the key from the marks made by the clock In this way the time pressing the key may be readily measured to 0 01 of a second Where observation times are required with greater accuracy, the drum may be rotated more rapidly and a tuning fork used to make the time graduations Other types of chronograph use a steadily moving strip of paper on which the pen traces its record On the printing type of instrument a set of type wheels is rotated by a standard clock and each time a key is pressed a piece of paper is pressed against the type and the instant printed to the nearest hundredth of a second Chronographs have many uses, for example, in apparatus designed to record vibrations from **earthquakes.** (W K G)

CHRONOLOGY. The study of the measurement of time This term is used by the geologist to include the methods employed in determining the age of the earth, and also the sequence of events The principal methods that are employed are (1) **Salinity** of the Oceans Assuming that the oceans were originally fresh water and that their present saltiness is due to river-borne solutions, it is computed that the oceans are from ninety million to six hundred million years old (2) **Erosion.** It has been estimated that, to produce a major **unconformity,** having an approximate area of three million square miles, would take nine million years Therefore the **unconformity** (plan of erosion) which forms the boundary between the Archeozoic and the Proterozoic is a fundamental factor in the computation of **pre-Cambrian** time alone (3) **Deposition.** The rate of deposition or time which it has taken to produce the stratigraphic sequence of sedimentary formations may be taken as a measure of the age of the earth It is estimated that the **post-Proteozoic** stratigraphic column is approximately 350,000 feet. If this amount of sediments was the result of continuous depositions, at the present rate of deposition for the Nile delta, it would intimate that the earth was only twelve million years old (Compare with "radioactive methods") (4) **Radioactive** elements The study of the radioactive minerals offers a method of determining the time at which the minerals crystallized from the **magma.** Since igneous rocks intrude sedimentary **formations** which may be dated by **stratigraphic** methods, it is possible to date both the intrusive and the intruded sedimentary rocks in terms of the appropriate period of the **geologic time-scale.** According to the radioactive method the oldest known rocks were formed approximately 1800 million years ago (R M P)

CHRONOMETER For many types of field observing where accurate time is required, the use of the pendulum clock is not practicable This is particularly true on shipboard or in countries like Japan, where earthquakes frequently disturb the pendulum The chronometer is an accurate type of escapement timekeeper which is spring driven The movement is similar to that in the ordinary pocket watch but much more massive Various devices to compensate for changes in temperature and for changes in the tension of the spring are incorporated in the instrument When properly handled, the rate of a chronometer may be relied upon to within a few hundredths of a second per day With modern methods of obtaining clock comparisons by radio at frequent intervals the chronometer may be used for all except the most refined astronomical observations Many chronometers are equipped with devices for making or breaking an electric circuit so that they may be used in conjunction with the **chronograph.** (W K G)

CHRYSALIS, CHRYSALID. The third stage in the development of **butterflies,** also properly called the pupa The caterpillar of a butterfly spins no cocoon but hangs itself by a silken button or by a belt and button The skin of the pupa into which it changes is often brightly colored or protectively colored and marked, unlike the mahogany-colored pupae of most moths Although some moths form similar naked pupae the term chrysalis is applied only to those of the butterflies (A W I)

CHRYSOBERYL. (CYMOPHANE — GOLDEN BERYL) The mineral chrysoberyl, an **aluminate** of **beryllium** corresponds to the formula $BeAl_2O_4$, crystallizes in the **orthorhombic** system with both contact and penetration twins common, often repeated resulting in rosetted structures Hardness 8 5, specific gravity, 3 5 – 3 84, luster vitreous, color various shades of green, sometimes yellow A variety which is red by transmitted light is known as **alexandrite** Streak colorless, transparent to translucent, occasionally opalescent

Chrysoberyl occurs in granitic rocks, **pegmatites** and mica **schists,** often is found in alluvial deposits The Ural Mountains yield **alexandrite;** other localities for chrysoberyl are Czechoslovakia, Ceylon, Southern Rhodesia, Brazil and Madagascar where it occurs of gem quality in the pegmatites of that island In the United States it is found in Maine, Connecticut and New York The word chrysoberyl is derived from the Greek words meaning golden, and beryl **Cymophane** has its derivation also from the Greek words meaning wave, and appearance, in reference to the opalescence exhibited at times (E S C S)

CHRYSOCOLLA. This mineral, a hydrous **silicate** of **copper** probably corresponding to the formula $CuSiO_3\ 2H_2O$, is perhaps a mineral gel for it usually appears as an amorphous mass, in veins, or as incrustations It is very rarely found in small acicular crystals which are either **hexagonal** or **tetragonal**

Its color is generally some shade of blue or green but if impure may be brown or black It has a characteristic conchoidal fracture, hardness, 2–4; specific

gravity, 2–2 2, vitreous, to dull luster, translucent to opaque

Chrysocolla is a secondary mineral and associated commonly with other copper minerals of similar origin Among the localities for excellent specimens may be mentioned Cornwall and Cumberland, England, Belgian Congo, Chile, Lebanon and Berks Counties, Pennsylvania, the Clifton-Morenci Globe and Bisbee districts in Arizona, Dona Ana County, New Mexico and the Tintic district, Utah

The word chrysocolla is derived from the Greek words meaning gold, and glue, formerly the name for gold solder Chrysocolla is one of the less important ores of copper and has a minor use as a gem stone (E S C S)

CHRYSOLITE. Olivine.

CHRYSOMONADIDA. One-celled animals of yellow or brown color, or colorless, constituting an order of **Mastigophora.** (A W L)

CHRYSOPRASE. Chalcedony.

CHRYSOTILE. A delicately fibrous variety of **serpentine** which separates easily into silky flexible fibers of greenish or yellowish color Its name is derived from the Greek words meaning gold, and fibrous Most of the common asbestos of commerce is chrysotile It is mined in Thetford, Province of Quebec, and in South Africa (E S C S)

CHUB. Pisces, Teleostei A European fish (**Pisces**), *Leuciscus cephalus,* related to the dace, and several North American species One, an excellent food and game fish, is the fallfish, *Leucosomus corporalis,* or chub of northeastern streams and lakes Another, the horned dace, *Semotilus atromaculatus,* creek chub, or common chub, is widely distributed in the United States and Canada with the exception of the far west In small streams it becomes abundant and sometimes rises to the fly as freely as the game fishes Its flesh is usually lacking in flavor Other species of the group are sometimes called chubs (A W L)

CHUB SUCKER. Pisces, Teleostei A small **sucker,** *Erimyzon sucetta,* of rather stout build, common throughout the eastern half of the United States (A W L)

CHUCK. A chuck is a device for holding a tool or work on a machine Power **drills** and machine **lathes** are common examples of machines employing chucks The chuck of a **drill press** rotates with the spindle The chuck is ordinarily used to hold round straight shank drills, and does so by the pressure of its three fingers, which can be tightened firmly against the shank of the drill by the mechanism of the chuck A lathe chuck is screwed to the spindle, and has adjustable radial jaws which can be screwed against the work to hold it in place for turning or other machining operations Often it is necessary to center a round piece exactly on the center of rotation This is somewhat tedious in the four-jawed chuck, in which each jaw is separately adjusted, but may be accomplished very easily in the three-jaw automatic chuck, in which one operating motion brings all jaws in simultaneously until they grasp the piece, which is, of course, perfectly centered The chuck as a tool holder is only one of many forms of tool holders which may perform the function quite differently, since the work is held in vises or clamps in some machine tools, as, for instance, in the shaper.

A collet chuck is a special attachment for a lathe, and is a quantity production accessory A separate collet chuck must be provided for each diameter of stock to be held Since the stock may be released and advanced for another cut very rapidly with the collet chuck, it is used to speed up production where stock of limited diameter is being worked. (F.T M)

CHUCK-WALLA. Reptilia, Sauria A common **lizard,** *Sauromalus obesus,* of the southwestern deserts, ranging into Utah and Nevada It attains a length of eleven inches and is sometimes eaten (A W L)

CHUCK-WILL'S-WIDOW. Goatsucker.

CICADA Insecta Homoptera Large **insects** of many species They are stoutly built and have two pairs of membranous wings which are folded roof-like over the body when at rest They are best known for the loud songs of the males, which are produced by a pair of elaborate organs located on the under surface at the base of the abdomen These organs have a vibrating structure controlled by special muscles and thin resonating parts which result in a peculiarly penetrating sound

The female has a powerful **ovipositor** with which she punctures the twigs of trees and shrubs to deposit her eggs The young cicada does not remain in the twig but drops to the ground and burrows, feeding on the roots of plants In the case of one species, *Tibicina septendecim,* the duration of the larval period is unusually long and has resulted in the name seventeen-year locust Locust is inaccurately but very commonly applied to these insects and some are called harvest-flies

Great damage is sometimes done to young orchard trees by the breaking of twigs where the eggs have been deposited, especially after one of the great broods of the seventeen-year locust, or periodical cicada, has passed The only effective protection is to cover young trees with inexpensive cloth when such a brood is imminent, the years of emergence are known by economic entomologists and can readily be learned for any part of the country (A W L)

CICATRIX. The scarring or connective tissue formation, which occurs after the healing of a wound or sore A cicatricial deformity is one that occurs through excessive scarring, such as following a severe **burn** (R S M)

CICHLID. Pisces, Teleostei Fishes (**pisces**) of a large family, including several hundred species, found in tropical and subtropical waters of India, Africa, and the New World They occur in both fresh and brackish water

A number of species of cichlids are offered by dealers in tropical fishes for aquaria They include beautifully colored fishes and are interesting for their breeding habits, the eggs are carried in the mouth or **pharynx** until they hatch (A W L)

CICONIIFORMES. An order of long-legged wading birds (**Aves**) including the **herons, flamingoes, bitterns, storks** and others (A W L)

CIDAROIDA. An order of sea-urchins without gills around the mouth (A W L)

CIENEGA. A type of spring which occurs in intermontane basin deposits or **bolsons,** especially of semiarid to arid regions When the underground waterbearing statum, or **aquifer,** is blocked by cemented gravels the water may be forced by hydrostatic pressure to the surface forming the type of spring called a cienega (R M F)

CILIARY JUNCTION. An association of separate **gill filaments** in certain **bivalve** molluscs, which is characterized by interlocking **cilia.** (A W L)

CILIATA. One-celled animals which have **cilia** during adult life but are without suctorial tentacles They constitute a class of this name in the subphylum **Ciliophora.** (A W L)

CILIOPHORA. A subphylum of the phylum **Protozoa** containing species which have cilia or cirri dur-

ing some stage of life. They vary greatly in form and habits Some are sessile, some free swimming, and some parasitic

The following is a brief summary of a classification of ciliates now widely used

Class Ciliata With cilia or cirri throughout life
- Subclass Protociliata Leaflike species with two to many nuclei Parasitic in the intestines of fishes and amphibians *Opalina* and related forms
- Subclass Ciliata (Euciliata) With two kinds of nuclei, large and small (macronucleus and micronucleus)
- Order Holotrichida **Cilia** uniformly distributed *Paramecium* and many other genera
- Order Heterotrichida With a zone of cilia of larger size, or membranelles, associated with the mouth *Stentor*
- Order Oligotrichida With cilia about the mouth but few on the body
- Order Hypotrichida Flattened, with cilia or cirri on the under surface *Stylonychia,* etc
- Order Peritrichida Oral end of body enlarged, ciliated, many species stalked *Vorticella,* etc

Class Suctoria With cilia only during early life Adults sessile, with tentacles for ingesting food and for piercing (A W L)

CILIUM. A slender hair-like process of minute size on the surface of a cell It is part of the living **cytoplasm** In association with their minute size cilia occur in relatively large numbers and act in unison to produce aggregate effects They are capable of waving movement Commonly they bend consecutively in the same direction so that a wave of movement passes along the ciliated surface, followed by the return of the cilia to the resting position and this again by their bending This type of movement is said to be metachronal The successive waves follow each other closely so that several may be apparent at the same time

Cilia are found in many species of Protozoa and give the name Ciliophora to one subdivision of the phylum Among the multicellular animals they occur on the surface of the body in a few groups (e g, **coelenterates, turbellarian** worms and **molluskans**) during adult life and in many larvae such as those of the **echinoderms,** the **annelid** worms, coelenterates, and others They are also found on epithelia of limited distribution in many complex animals, as in the mantle cavity of molluscs and the trachea of man

Cilia on the surface of small animals, such as the **Protozoa** and **larvae** of greater complexity, are able by their action against a surrounding liquid to propel the animal and so serve as organs of locomotion In animals of larger size, in those which are not surrounded by a liquid medium, on sessile forms, and where the direction of their movement is contrary to the movements of propulsion, they act to set up currents either in liquids secreted by the body or in the surrounding medium Thus some cilia in Protozoa, coelenterates, and molluscs direct a current bearing food and oxygen into the gullet and in man cilia carry toward the throat the mucus secreted by glands in the lining of the trachea This secretion may bear foreign particles which have been inhaled (A W L)

CINCHONA. *Cinchona calisaya* Rubiaceae This is a small tree (thirty to forty feet high) with light green leaves and pink flowers It is native in Bolivia There, because of the destructive habit of chopping the trees down in order to obtain the bark, the wild tree has almost disappeared In 1859 the plant was introduced into the East Indies, where it was so widely cultivated as to produce a tremendous decrease in the price of the bark

The bark is the **source** of the drug quinine, a bitter **alkaloid** used as a preventive and cure for **malaria.** When the trees are seven or more years old, they are felled, and the bark removed Production for world trade at present is centered largely in the Dutch East Indies, particularly in Java (R M W)

CINCHONIDINE. Alkaloids.

CINGULUM. 1 A girdle, such as the outer ciliated ring at the anterior end of a **rotifer.** 2 A bundle of association fibers in the mammalian **brain,** partially encircling the corpus callosum not far from the median plane 3 The basal ridge of a tooth (A W L)

CINNABAR. The mineral cinnabar, mercuric sulfide (HgS) occurs in small and often highly modified hexagonal crystals, usually of rhombohedral or tabular habit It is found chiefly in crystalline crusts, granular or simply massive The fracture of cinnabar is subconchoidal, hardness, 2–2 5, specific gravity, 8–8 2, luster, adamantine tending toward metallic, sometimes dull This mineral has a characteristic cochineal red color which, however, may be brownish at times, occasionally dull lead gray The streak is scarlet, it is transparent to opaque

Cinnabar occurs in veins or may be in masses in **shales, slates, limestones** and similar rocks due to the impregnation by mineral bearing solutions or as replacements Russia, Czechoslovakia, Bohemia, Bavaria, Italy and Spain have furnished excellent specimens The most important of the world's mercury deposits is at Almadin in Spain Italy, Peru, Dutch Guiana, China and Mexico have commercially valuable occurrences of cinnabar In the United States this mineral is found in California (most important deposit), Nevada, Utah, Texas and Oregon Cinnabar is the chief ore of mercury Its name is supposed to be of Hindu origin (E S C S)

CINNAMON. Cinnamomum zeylanicum. Lauraceae Cinnamon is obtained from a small tree native to Ceylon and India, where the plant is now extensively grown in cultivation The trees grow from twenty-five to forty feet high, have shining dark green leathery leaves, small whitish flowers having a rather disagreeable odor, and dark purple fruits The bark of young twigs is smooth and somewhat mottled, in older branches and the main stem, the bark becomes thick, rough and of little value To insure the desideratum of many young branches, the limbs are severed so that many slender branches will form, a practice known as coppicing From these slender stems the bark is removed by lengthwise splitting and partial loosening from the stem, as it dries it rolls back It is then removed from the stem, the dry useless **periderm** scraped off, and the inner bark remaining allowed to dry completely During drying its color changes from pale yellow to deep brown The tight rolls of dried bark are packed together in bundles, called pipes, and are ready for marketing

This bark contains considerable amounts of a powerful drug which in large doses is a dangerous poison The principal use of cinnamon is as a spice for pastries By distillation of cinnamon stems and leaves there is obtained oil of cinnamon (See **Valuable Oils**), used in flavoring candy and soap (R M W)

CIRCLE. A circle is a plane curve such that all of its points are at a fixed distance, called the radius, from a fixed point called its center

The length of the circumference of a circle of radius r is given by $C = 2\pi r$, its area by $A = \pi r^2$

The area of a circular sector is given by $A = \frac{1}{2}r^2\theta$, where r is the radius of the circle and θ is the **radian measure** of the angle of the sector

The area of a segment of a circle (between a circle and a chord) is given by $A = \frac{1}{2}r^2(\theta - \sin\theta)$, where r is the radius of the circle and θ is the radian measure of the angle of the segment

In **rectangular coordinates,** the equation of the circle of radius r with center at the origin is

$$x^2 + y^2 = r^2;$$

and the equation of the circle of radius r with center at the point (h, k) is

$$(x - h)^2 + (y - k)^2 = r^2.$$

Any equation, in rectangular coordinates, of the form $Ax^2 + Ay^2 + Bx + Cy + D = 0$ represents a circle For the circle whose equation is $x^2 + y^2 + Dx + Ey + F = 0$, the center is $(-\frac{1}{2}D, -\frac{1}{2}E)$ and the radius is $\frac{1}{2}\sqrt{D^2 + E^2 - 4F}$ if this latter expression is real A circle is determined by three conditions

In **polar coordinates**, if the center is on the polar axis and the circle passes through the pole, its equation is $r = 2a \cos \theta$ (if the center is to the right of the pole) or $r = -2a \cos \theta$ (if the center is to the left of the pole), where a is the radius of the circle If the center is on a line perpendicular to the polar axis through the pole and the circle passes through the pole, the equation of the circle is $r = \pm 2a \sin \theta$, where the + or − sign is to be used according as the center is above or below the pole If the center is at the pole, the equation of the circle is $r = a$ If the circle passes through the pole and has X- and Y-intercepts a and b, its polar equation is $r = a \cos \theta + b \sin \theta$

The simplest **parametric equations** of a circle are $x = a \cos \theta$, $y = a \sin \theta$, where a is the radius and θ is the angle XOP, and P is the point (x,y)

If $C_1 = 0$ and $C_2 = 0$ are the equations of two given circles, then $C_1 + kC_2 = 0$ is the equation of the system of all circles passing through the intersections of the given circles, if k takes all positive and negative values

If $x^2+y^2+D_1x+F_1y+F_1=0$ and $x^2+y^2+D_2x+E_2y+F_2 = 0$ are the equations, in rectangular coordinates, of two given circles, then the straight line whose equation is $(D_1 - D_2)x + (E_1 - E_2)y + (F_1 - F_2) = 0$ is called the radical axis of the given circles It is perpendicular to the line of centers of the given circles If the given circles intersect (or touch) each other, the radical axis is their common chord (or common tangent) The radical axis of two circles is the locus of all points from which the lengths of the tangents to the circles are equal

If three circles are given, and the three radical axes of these circles taken in pairs are found, it will be found that they intersect in a common point, which is called the radical center of the three given circles

The length along the tangent from a point (x_1, y_1) to a circle of radius r and center (h, k) is given by

$$t^2 = (x_1 - h)^2 + (y_1 - k)^2 - r^2$$

The length along the tangent from a point (x_1, y_1) to the circle $x^2 + y^2 + Dx + Ey + F = 0$ is given by

$$t^2 = x_1^2 + y_1^2 + Dx_1 + Ey_1 + F$$

The equation of the **tangent** to the circle $x^2 + y^2 = a^2$ at the point (x_1, y_1) is $x_1x + y_1y = a^2$

The equation of the tangent of **slope** m to the circle $x^2 + y^2 = a^2$ is $y = mx \pm r\sqrt{1 + m^2}$

The circles $x^2 + y^2 + 2D_1x + 2F_1y + F_1 = 0$ and $x^2 + y^2 + 2D_2x + 2E_2y + F_2 = 0$ are orthogonal (intersect at right angles) if $2D_1D_2 + 2E_1E_2 = F_1 + F_2$

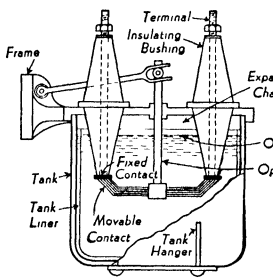
(L L S)

CIRCLE OF POSITION Line of Position.

CIRCUIT BREAKER. A circuit breaker is a device constructed primarily for the interruption of an **electric circuit** under infrequent abnormal conditions It is a safety device installed in those portions of an electric circuit where it is desired to open the circuit under load upon presence of abnormal current, abnormal voltage, high temperature, grounds, etc There is no more important element of an electrical power system than the circuit breakers and their control equipment They are used in generator leads, feeders, bus ties, large motor leads, etc

Circuit breakers may be classified as air break or oil break, types The air break type, commonly a carbon circuit breaker, consists of stationary contacts mounted on a vertical panel, a movable contact which is closed against a heavy spring by a handle, a trip to release the latch, and carbon auxiliary contacts which take the arc when the breaker opens These breakers are mostly closed by hand, and opened by series overload trip coils They are infrequently used above 600 volts In recent years, a type of air circuit breaker called the Deion breaker has been developed By means of magnetic fields the arc which tends to follow upon opening of a circuit under load, is blown into a deionizing chamber where it is broken up into a number of short arcs which are deionized and quenched during two or three cycles The Deion breaker is applicable to alternating current circuits

The carbon circuit breaker is a type used principally for direct current circuits The oil immersed circuit breaker is standard with alternating current because the arc can be oil quenched as the voltage passes through

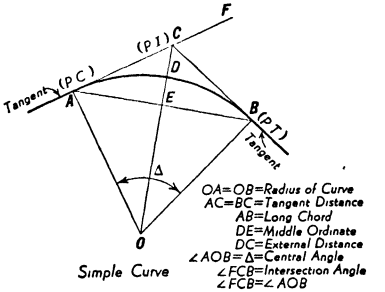


Oil circuit breaker

the zero point The accompanying figure shows the elements of an oil circuit breaker The contacts are opened under oil by means of a rod extending through the cover of the case The operating arm is actuated by hand, motor, or solenoid, and when in closed position is tensed by a heavy spring whose purpose is to produce a rapid opening of the contacts when the operating arm is released The latch which locks the operating arm in closed position against spring pressure may be tripped free by energizing a small solenoid called the trip coil, and the breaker has a protective device which is intended to be automatically opened by a trip coil actuated either directly by the current passing through the breaker, or indirectly by special trip circuits utilizing **relays** (F T M)

CIRCULAR CURVES. From a mathematical standpoint a circular curve is an arc having a constant radius but it is used in Civil Engineering as a general heading to cover simple, compound and reversed curves

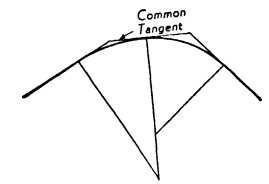
A circular arc joining two tangents (straight lines) is



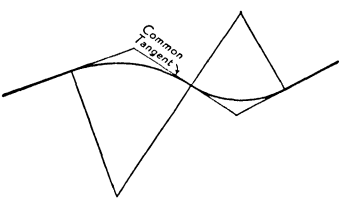
called a simple curve Large radius simple curves are used in **highways** to provide a means of gradually changing the direction of the center line of a roadway.

Simple curves connected by tangents were formerly used on railroads but they have been superseded by the combination of **spiral** and simple curves The accompanying figure shows the elements of a simple curve Point *A* is called the point of curvature (P C) and point *B* the point of tangency (P T) Point *C* is known as the point of intersection (P I) of the tangents In highway practice the length of the curve is generally represented by the length of the circular arc but in railroad practice it is given in terms of *chord* lengths

A curve made up of two or more simple curves, each having a common tangent point at their junction and lying on the same side of the tangent, is called a compound curve Compound curves have an advantage over simple curves since they may be easily adapted to the natural **topography** of a particular location



Compound Curve



Reversed Curve

A curve made up of two simple curves, having a common point of tangency at their junction and lying on opposite sides of the common tangent is called a reversed curve This type of curve is advantageous for use in connection with railroad cross-overs and spur tracks but should never be employed for main lines Reversed curves are used in highway location when the alignment requires an abrupt reversal in direction (C W C)

CIRCULAR FUNCTIONS. Trigonometric Functions.

CIRCULAR INSANITY. Manic-depressive insanity. (R S M)

CIRCULAR MEASURE OF ANGLES. Radian Measure of Angles.

CIRCULAR MILL. This is a unit of area, employed to designate the cross-sectional area of round electrical conductors It replaces measurement in square inches, and is more convenient since it is not necessary to multiply by the factor π A mill is 1/1000 of an inch The area of a circle whose diameter is *M* mills is simply M^2 circular mills

Wires are sized by their area in circular mills or by the American wire gauge Despite the arguments in favor of one system using diameters in mills as size numbers, the American wire gauge is commonly used for wires sized from 40 to 000 American wire gauge Wires larger than 000 (212,000 circular mills) are always sized in circular mills (F T M)

CIRCULAR POLARIZATION. Polarized Light.

CIRCULAR SECTOR. Circle.

CIRCULAR SEGMENT. Circle.

CIRCULATION. The distribution through the body of a liquid medium known as **blood** or haemolymph which conveys necessary materials to the tissues and carries wastes away from them

In the simplest animals materials are merely transmitted from cell to cell but in the more complex forms the bulk of tissues which is removed from direct contact with the centers of interchange with the environment is too great to be served adequately by this method In such animals a special **circulatory system** is developed for the more rapid distribution of materials Circulation in such a system may be accomplished by the mixing of liquid contents in open cavities such as the **coelom** or it may be the function of special organs in closed tubular systems

In a closed tubular system such as that of the **vertebrates,** including man, pressure is applied to the blood stream by a muscular organ, the heart, and by the muscular walls of the larger vessels The blood leaves the **heart** under its greatest pressure and enters the arteries whose elastic walls expand and then, returning to their contracted state, partially equalize the fluctuating pressure supplied by the heart The blood is at a lower pressure in the minute capillaries where some of it escapes into the spaces between the cells of other tissues, vessels of this kind occur in abundance at all points where interchange between the blood and the tissues takes place From the capillaries the blood flows back to the heart in veins In total the pressure diminishes steadily from the time the blood leaves the heart until it returns again, a necessary condition according to the laws of hydraulics

The relations existing at any point in the body between the liquids in the cells and intercellular spaces and the blood itself make possible osmotic (See **osmosis**) interchange in both directions which serves the needs of the tissues and maintains a normal concentration of materials in solution in the blood

The paths of circulation in the bodies of various animals involve the discussion of the **circulatory system** (A W L)

CIRCULATORY SYSTEM. The system of passages and chambers through which materials are distributed in the body in a liquid mixture called **blood** or haemolymph

Animals of very simple structure and small size secure adequate distribution by the diffusion of materials from cell to cell and so have no need for a special circulatory system In more complex bodies, however, the principal centers of interchange, such as the alimentary tract, respiratory organs, and excretory system, are far removed from some of the parts that they serve, here more rapid transportation is necessary

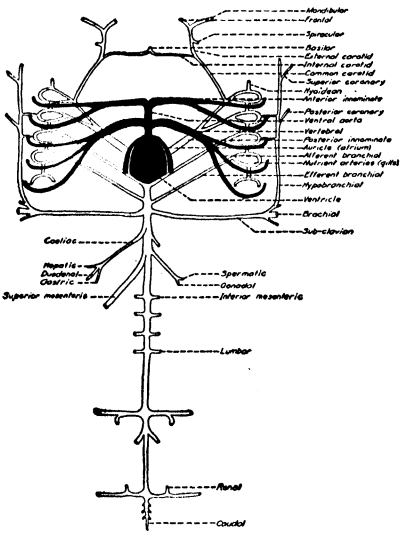
This need is met in some animals by the extension of centers of interchange In the flatworms, for example, the alimentary tract branches through the body and no other structure is far from some part of it

Other forms, as the roundworms, have extensive spaces within the body in which liquid contents are moved to some extent by the movements of the body This type of circulation extends to animals with a true body cavity or **coelom** but here it is associated with the development of a closed tubular circulatory system, a condition which exists in the earthworm

In this simple state the tubular system consists of a longitudinal vessel above the alimentary tract and others at different levels in the ventral part of the body Other tubes running around the alimentary tract associate the longitudinal vessels, and muscular walls of certain regions, together with valves in the cavities of the tubes, propel the blood which they contain In the earthworm the contractile vessels are principally the dorsal vessel and

a series of five pairs encircling the **oesophagus** and known as hearts. The blood flows forward in the dorsal vessel, down through the hearts, and back in the ventral vessels, reaching the dorsal vessel again after following various routes through the tissues which it serves.

In such systems as this several types of vessels are developed. Those which lead from the central pumping organ receive the blood under its highest pressure and have the strongest walls, containing elastic and muscle fibers. These vessels are called arteries. They lead into smaller branches known as arterioles and these in turn into minute vessels with very delicate walls made up chiefly of a single layer of thin cells. In the human body these delicate **capillaries** are from 1/200 to 1/90 of a millimeter in diameter. Some of the blood-fluid



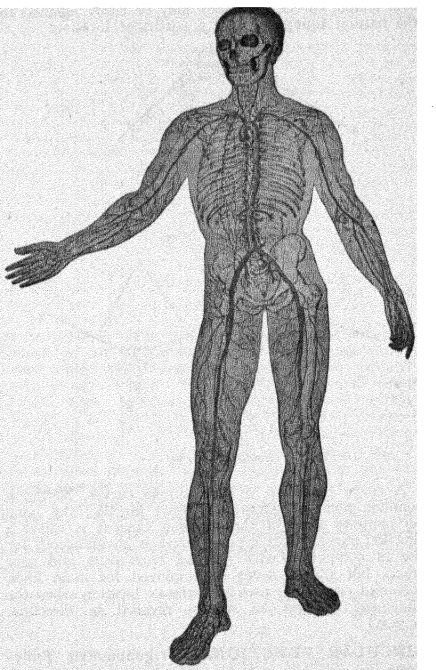
Arterial circulation of skate. (Drawn by W. J. Moore.)

passes between the cells of their walls into spaces in the surrounding tissues where interchange with the various cells is possible. In some parts of the body, as in the **liver** of vertebrates, the ultimate tubular passages are even simpler than the capillaries and are called sinusoids. Their walls are, at least in part, merely the surrounding tissues; whether a special lining exists in some parts is disputed. From such small vessels the blood is collected into veinlets and these converge to form veins which carry it to the heart. The veins have strong walls of complex structure but in vessels of the same caliber the walls are thinner in veins than in arteries.

Some of the fluid from tissue spaces is gathered into a type of vessel resembling veins but more delicate; it flows into trunk vessels which rejoin the veins. This system of vessels is known as the lymphatic system.

In the vertebrates the fishes present the basic plan of the circulatory system. The **heart** has two principal chambers, an **atrium** which receives the blood and a ventricle which pumps it out to the body. A single large artery, the ventral aorta, leads forward and branches into a series of afferent branchial arteries which break up into capillaries in the gills. Efferent branchial arteries lead out of the gills to the dorsal aorta which runs back to the body. The head is supplied by extensions of the dorsal aorta, the carotid arteries. From the arterial system branches conduct the blood to the capillaries of all parts of the body. The blood from the alimentary tract is collected into a hepatic portal vein which breaks up into sinusoids in the liver, and is carried thence to the heart by a hepatic vein. In a like manner some of the blood from the caudal part of the body is conveyed to the **kidneys** by a renal portal vein before entering the veins which carry it to the heart. From all other regions of the body the blood is collected by veins which flow directly to the heart.

The **vertebrate** heart is a specialized region of the tubular system whose subdivision into chambers is com-



Circulatory system.

plicated above the fishes by some degree of longitudinal splitting. In the **amphibians** the atrium has become two, right and left, in the **reptiles** the splitting involves the ventricle, and in the birds (**Aves**), and **mammals** the division into four chambers is complete. Blood entering the right atrium comes from the body and passes on into the right ventricle to be pumped to the lungs. It returns by the pulmonary veins to the left atrium, enters the left ventricle, and is pumped to the body. In other respects the most striking difference between the circulatory system of the fish and that of man is the elimination of the renal portal system in the higher classes of vertebrates.

The circulatory system of **arthropods** differs from that of other complex animals in the limited extent of the closed tubes and their association with extensive blood spaces constituting a haemocoele or blood cavity. **Insects** have a single longitudinal tube lying in the dorsal region of the body. It pumps the blood into the head and is known as the heart or dorsal vessel. (A.W.L.)

CIRCUMCISION. The excision of the foreskin or prepuce which covers the head of the **penis** in the male or the **clitoris** in the female It is done more commonly in the male and is indicated when the foreskin becomes too tight, although it is often done solely for cosmetic purposes Circumcision is performed as a religious rite on both sexes by some races (R S M)

CIRQUE. Topographic feature produced by a mountain glacier A mountain **glacier** usually starts in some sheltered ravine, slightly below the top of the mountain Névé (firn) is the name of the granular ice which gradually develops from the original snow The névé or accumulation of ice is restricted to that altitude at which the average summer temperature is 32° F This line (summer **isotherm**) may vary from sea level, in the polar regions, to 20,000 feet in the tropics After the accumulation of granular ice on a slope reaches a certain thickness, the melting at the contacts of the granules (due to pressure) causes the granules to rotate, the rotation of the granules producing glacial motion Ice, therefore, moves down a slope, but not in the same manner as a stiff or viscous liquid In the névé region, where the snow and ice bank rests against the sloping cliff, the ice tends to work away from the rock, forming a crevice called the bergschrund Frost action in the region of the bergschrund causes the recession of the cliff, the broken material from which is frozen into the base of the ice and serves as tools to scour out circular basins called cirques Small lakes and ponds which occur in cirques are called tarns Where several cirques are developed near the summit of a mountain, the side walls of the cirques are called combs, the ridges between the cirques, cols, and the elevated terminations of the comb ridges, monuments A triangular mountain peak, such as a Matterhorn, results from the complete cirquation of what was originally a relatively smooth-topped mountain (R M F)

CIRRHOSIS. A disease of the liver which, in general, is characterized by an increase in the connective tissue of the organ The disease is chronic and occurs in several forms There are however, two principal forms·

(1) Portal cirrhosis There are several theories as to the cause of this form of cirrhosis It is a disease of middle life usually and seen in men more often than in women (two to one) Some believe that it is due to a slow infection ascending into the liver by means of the **bile** channels. Others believe that most cases are due to excessive alcohol consumption acting directly on the liver cells Still others believe that impurities in alcoholic liquors may be the cause of this factor Cirrhosis sometimes occurs in individuals who have never touched alcohol Even highly seasoned foods have been cited as a cause **Syphilis** causes a cirrhosis similar to the picture seen in portal cirrhosis In general, there are probably several causes of this condition The disease occurs usually in those individuals who possess the common factor of having livers that are easily damaged

Symptoms may be absent during life and signs of cirrhosis be found on examination after death Usually there is some history of nausea or vomiting and other digestive disturbances Due to obstruction of the liver channel from overgrowth of fibrous tissue, there is back flow of blood, which is unable to get through the liver, causing engorgement of accessory channels serving as a by-path around this organ Because of this, hemorrhage occurs in the stomach with vomiting of blood or passage of it by rectum Some patients die from persistent hemorrhage The obstruction also causes an accumulation of fluid in the abdomen (**ascites**) in about half of the cases **Toxemia** is present at some time during the disease

The average duration of life after symptoms are manifest, is about two years

(2) Biliary cirrhosis Two forms of biliary cirrhosis occur, a primary and secondary form The first is uncommon and is characterized by enlargement of the liver and the **spleen** with the presence of **jaundice.** Infection is the most probable cause The disease cannot be arrested and the average duration of life is five or six years.

The secondary biliary cirrhosis is an obstructive type of cirrhosis caused by destruction of the bile duct by **gall stones** or **tumor** formation Jaundice is present with recurring attacks of chills and high fever Treatment is surgical (R S.M)

CIRRIPEDIA. **Crustaceans** of which the only commonly known representatives are the **barnacles.** The name applies to a subclass characterized by adaptations for sessile life, the included species are unlike other crustaceans in appearance

Economically the barnacles are important because they attach themselves to the bottoms of ships and necessitate occasional removal

Classification

Order Thoracica The common **barnacles.**

Order Acrothoracica Small forms of which the females live in cavities in the shells of molluscs

Order Apoda One simplified form, parasitic in a common barnacle

Order Rhizocephala Parasitic, usually on crabs and related crustaceans The adult forms root-like growths in the body of the host and is otherwise degenerate in form

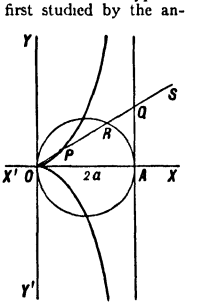
Order Ascothoracica Parasitic in corals, less degenerate than the preceding (A W L)

CIRRUS. 1 In Protozoa a spine-like organ of locomotion formed of aggregated **cilia.** 2 In **annelid** worms a slender fleshy process on the **parapodia.** (A W L)

CISCOE. Pisces, Teleostei *Leucichthys* Important food fishes (**Pisces**) of the Great Lakes and a few smaller lakes Also known as the lake herrings Included are two species known as **long-jaws,** the **bluefin** or blackfin, one species which is called the cisco, *Leucichthys hoyi,* and the **tullibee** which is found in smaller lakes in the Great Lakes region (A W L)

CISSOID OF DIOCLES. The cissoid is a type of mathematical curve which was first studied by the ancient Greek mathematician Diocles

The cissoid is a **plane curve** which may be defined geometrically as follows Draw a circle of radius a with its center on the X-axis and passing through the origin of a system of **rectangular coordinates.** Draw the **tangent** to the circle at A, where the circle cuts the X-axis Let any secant line OS cut the circle at R and the tangent at A in the point Q, then lay off $OP = RQ$ The locus of the point P as the secant rotates about O is the cissoid.



Cissoid

In **polar coordinates,** the equation of the cissoid is $r = 2a \sin^2\theta/\cos\theta$ In **rectangular coordinates,** the equation is

$$y^2 = \frac{x^3}{2a - x} \text{ or } x^3 + xy^2 - 2ay^2 = 0.$$

The cissoid can be used to "duplicate a cube," i e, to find the edge of a cube whose volume is twice that of a given cube. (L L S)

CITRAL. Aldehydes, Ketones, and Related Compounds.

CITRIC ACID AND CITRATES. Citric acid (H_3 $C_6H_6O_7$ or COOH CH_2 C(OH)(COOH) CH_2 COOH H_2O) is a white solid, water of crystallization lost at 130°, melting point 153° C, decomposes at higher temperatures, soluble in water or alcohol, slightly soluble in ether Citrates (like tartrates) in solution change silver of ammonio-**silver** nitrate into metallic silver **Calcium** citrate on account of its solubility characteristics, is of importance in the separation and recovery of citric acid Calcium citrate plus dilute sulfuric acid yields citric acid plus calcium sulfate, and the latter may be separated by filtration Citric acid may be obtained by evaporation of the filtrate Citric acid may be obtained (1) from some natural products, e g, the free acid in the juice of citrus and acidic fruits, often in conjunction with **malic** or **tartaric** acid, and the juice of unripe lemons (approximately 6% citric acid) is a commercial source, (2) by the **fermentation** of **glucose;** (3) by synthesis Citric acid is a tribasic acid, that is, three series (mono-, di-, tri-) of salts and esters are known Citric acid is used (1) in effervescent beverages, and effervescent medicinal salts, e g, "citrate of magnesia," consisting of citric acid, sodium hydrogen carbonate and magnesium sulfate, (2) as ferric ammonium citrate in **blue-printing** (R K S)

CITRINE The mineral citrine is a yellow variety of **quartz** sometimes used as a gem It is often marketed under the name topaz and may mislead the unwary Brazil and Madagascar have furnished material of excellent quality (F S C S)

CITRONELLA. Volatile oils.

CITRONELLAL. Aldehydes, Ketones, and Related Compounds.

CITRUS FRUITS. Rutaceae The various Citrus fruits are obtained from thorny shrubs or small trees, having smooth leathery evergreen leaves with numerous internal resinous glands which contain an aromatic oil In most of the species the **petiole** of the leaf has winged margins and is articulated both to the branch and to the blade The flowers are extremely fragrant and are usually pure white, or in some species purplish pink They are borne singly or in small **cymes** in the axils of the leaves The **calyx** has three to six small teeth, the **corolla** is composed of four to eight thick petals, while there are numerous **stamens** and a many-celled **ovary** The fruit of these plants is a modified **berry,** known as a hesperidium

The roots of Citrus plants lack root hairs entirely, absorption being directly through the fine terminal fibrous roots The wood is hard and fine grained

All Citrus plants are native to the Old World The principal species in cultivation are as follows

Citrus trifoliata, or the trifoliate orange, has trifoliate leaves, and hairy useless fruit Its importance is due to its hardiness, making it valuable for hybridizing with more desirable species It can be grown outdoors as far north as southern New York State

Citrus sinensis, the Orange, originating in China, and with many varieties, is widely cultivated In this country two principal growing regions exist, with characteristic varieties in each Florida produces sweet, thin-skinned juicy oranges, which ripen in early winter They are picked before fully ripe and matured in storage California produces thick-skinned Navel oranges, which have a pleasing acid pulp, and ripen during the winter and spring months The source of these navel oranges was a sport arising in Brazil, and later carried to California, where it was developed California also produces the many-seeded Valencia oranges, which ripen from June through October, producing a crop when other varieties are not in bearing

Citrus limonia, the Lemon, is probably a native of India The trees are small and have many stout thorns The flowers are large and purplish The plants are not at all hardy, so are grown only in regions entirely free from frost The fruits are produced continuously throughout the year and are picked green To allow them to ripen on the tree causes them to become bitter and unmarketable As soon as they attain the size demanded by the market they are picked and stored, often for several months Coloring gradually develops during storage, or may be hastened by placing them in rooms heated above 90° F, where the yellow color develops in four to five days

Citrus grandis, Grapefruit, is probably derived from a bitter-fruited Malaysian tree This is the largest fruited of all the Citrus plants The trees are somewhat hardier than orange trees, and are principally grown in Florida

Citrus nobilis, King oranges, Mandarin oranges, Tangerines This species is characterized by the ease with which the skin or rind is removed from the sweet pulp

Citrus aurantiifolia, Lime, are very thorny shrubs or small trees, which are not at all hardy, and so are grown mainly in tropical countries and, in the United States, in California and the southern tip of Florida The white flowers are small, as is the very acid thin-skinned fruit

Citrus medica, Citron, is rarely grown in the United States The rind of the fruit is treated with brine to remove the bitter oil it contains, then boiled in a sugar solution to which glucose (See **Carbohydrates**) has been added The glucose is used to keep the product from becoming brittle After boiling for a short time the rind remains in the syrup for a few weeks It is then removed, boiled once more in pure sugar solution and dried It is now the commercially-marketed citron

Citrus Aurantium, Bitter or Sour Orange, is an ornamental tree, which is cultivated as a stock on which to bud other more desirable forms

Citrus bergamia, bergamot

Related to the Citrus group is the genus *Fortunella,* with several species They are the kumquats They are small evergreen shrubs often planted for ornament and because of the small yellow fruits, which are either eaten raw or used in preserve making In addition to the species enumerated, many hybrids have been developed

The citrus industry of the United States has received many setbacks during its history An ever-present source of worry is the danger of frosts, which are fatal to the present crop, and often do serious damage to the growing trees At times frost injury is so serious as to menace the success of the industry The use of smudge pots, producing clouds of smoke, increasing the humidity of the air by irrigation and other procedures are a partial insurance against damage

Recently Florida has been beset with the Mediterranean **fruit fly,** which attacks a variety of fruits, in addition to the citrus varieties This pest is now declared to be eradicated Citrus canker, a bacterial scourge, is another source of destruction of the Florida crop In California, very undesirable **scale insects** are present

The uses of citrus fruits are many and varied A very large part of the crop is consumed as raw fruit or as a drink The rich **vitamin** content they possess has done much to further their consumption Citrus oils and **citric acid** are byproducts from culled fruit, which are becoming of commercial importance in the United States The oils are largely used in flavoring extracts, and to some extent in perfumes and soaps (R M W)

CIVET Mammalia, Carnivora Animals of slender build with long tails and short legs, somewhat like the weasels in appearance They occur in Africa, southern Europe, and southeastern Asia and constitute the family Viverridae including, in addition to the true civets, species known as **genets, linsangs,** palm-civets, the **binturong,** the mongooses, hemigales, and a few related forms

The name is also applied to the **cacomistle** and locally to the small spotted **skunk** of North America. (A.W.L.)

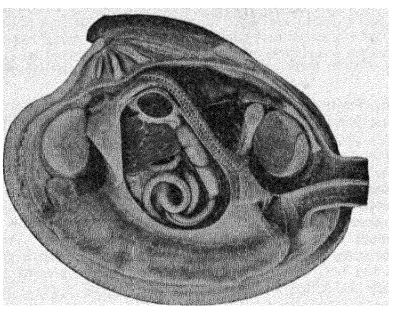
CLADOCERA. The water-fleas, an order of small **crustaceans.** (A.W.L.)

CLADOSELACHE. Fossil Fishes.

CLADOSICTIS. Miocene.

CLAIRAUT'S DIFFERENTIAL EQUATION. Ordinary Differential Equations of First Order and Higher Degree than the First.

CLAM. Mollusca, Pelecypoda. Any member of numerous species of **bivalve** mollusks; a mussel. Some species are commonly called mussels, others clams, and in some



Anatomical model of hard shell clam. (Courtesy of *American Museum of Natural History.*)

cases the names are freely interchanged. Thus the edible mussel and other members of the same family receive this name only, the little-neck clam is always a clam, and the fresh-water species are called freely both clams and mussels.

The clams are moderately important as food. Occasionally valuable pearls are found in them and the shells of fresh-water species are the foundation of the important pearly button industry of the Mississippi Valley. (A.W.L.)

CLAM WORM. Annelida, Polychaeta. Marine worms of the genus *Nereis.* (A.W.L.)

CLARAIN. A term proposed by Marie Stopes in 1919 for a finely banded variety of "bright" or shiny bituminous **coal.** In thin sections, under the microscope clarain is seen to be composed of disintegrated plant substances including bands of **spore** cases, which impart a yellowish to reddish color to the substance. (R.M.F.)

CLARIFICATION. Filtration.

CLARK CELL. Standard Cell.

CLASS. The second subdivision of the animal kingdom: major subdivisions or **phyla** are divided into **classes.** (A.W.L.)

CLASSIFICATION. The description of kinds of living things and their arrangement in categories of various rank according to relationship of varying degrees as determined by the available knowledge of their structure and functions.

The classification of animals is the function of the science of **taxonomy.** By common agreement under the principles of this science the organic world is now divided into plant and animal kingdoms, and in the animal kingdom the following series of subdivisions is recognized:

Phylum
Class
Order
Family
Genus
Species

Various other divisions are introduced into some classifications to express other degrees of relationship. Terms used in this way are subclass, suborder, section, superfamily, subfamily and group.

Agreement is lacking on a few small divisions of the animal kingdom, but most of the phyla into which it is divided are generally accepted. The following is a classification commonly used.

Phylum **Protozoa.** The one-celled animals.
Phylum **Porifera.** The **sponges.**
Phylum **Coelenterata.** The **hydroids, jellyfishes, coals, sea anemones,** etc.
Phylum **Ctenophora.** The comb jellies and **sea** walnuts.
Phylum **Platyhelminthes.** Flatworms, including flukes and tapeworms.
Phylum **Nemertea.** The nemertine worms.
Phylum **Nemathelminthes.** Roundworms, including horsehair worms.
Phylum **Rotifera. Rotifers** or wheel animalcules.
Phylum **Bryozoa.** The moss animals.
Phylum **Brachiopoda.** Lamp shells.
Phylum **Phoronidea.** Phoronids.
Phylum **Chaetognatha.** Arrow worms.
Phylum **Echinodermata.** Starfishes, brittle stars, sea urchins, sea cucumbers, sea lilies, basket stars.
Phylum **Mollusca. Snails, chitons,** mussels, **squids,** cuttlefish, **nautilus.**
Phylum **Annelida.** The segmented worms.
Phylum **Arthropoda. Crustaceans, spiders, scorpions, insects,** etc.
Phylum **Chordata.** Fishes (**Pisces**), **amphibians, reptiles,** birds (**Aves**), **mammals,** and a few other forms. (A.W.L.)

CLASTIC ROCK. A **sedimentary** rock that is entirely or chiefly composed of fragmental material. **Sandstones** and **conglomerates** are typical clastic rocks. (R.M.F.)

CLAVICLE. The collar bone of man. The ventral anterior bone of the **pectoral girdle** of **vertebrates.** (A.W.L.)

CLAY. Clay is a very fine grained unconsolidated rock material which is plastic when wet, but becomes hard and stony when heated to redness. Mineralogically, clay consists chiefly of hydrous **silicates** of **aluminum** together with numerous impurities, as **hematite, limonite,** etc., which often impart various colors to it. (E.S.C.S.)

CLAY GALLS. Thongallen.

CLEARANCE. The distance by which one object clears or misses another is called the clearance. Although this term might be applied to almost any number of situations, there are some cases of special importance.

Clearance in a piston and cylinder mechanism, such as found in the **engine,** is the space left in the end of the cylinder when the piston is in dead center position towards the end of the cylinder for which the clearance is determined. This space in volumetric units of measurement is the clearance volume. Clearance is commonly stated as a percentage, being the ratio of the clearance volume to the piston displacement during a stroke. The percent clearance is a characteristic of no little importance to the performance of steam engines and internal combustion engines. See **ratio of expansion.**

The clearance of gear teeth is that small distance by which the tip of a gear tooth clears the root of one

with which it is mating; and is the amount by which the dedendum of a gear exceeds the addendum of a mating gear. See **Gear Teeth.**

The unobstructed space which must be allotted for the occasional removal of parts of physical equipment such as the rotors of motors or turbines, the tubes of a boiler, etc., may be accurately referred to as clearance. (F.T.M.)

CLEAR-WINGED MOTH. Insecta, Lepidoptera. A **moth** whose wing membranes are largely free from scales and therefore transparent. A majority belong to the families Aegeriidae, containing the squash-borer and other borers of economic importance, and Sphingidae or hawk-moths, of which the genus *Hemaris* includes such species. (A.W.L.)

CLEAVAGE. In biology, cleavage is the subdivision of the fertilized **ovum** which precedes the formation of **germ layers** as the first stage of **embryonic** development. In the simplest type of cleavage the egg and each cell thereafter split completely through; this process is called holoblastic cleavage. With the accumulation of yolk in the egg its division is hampered until in the eggs of birds and reptiles the living matter lies on one side of the yolk and cleavage merely subdivides this small mass into a layer of cells; this is meroblastic cleavage. In still other eggs with much yolk, such as those of the insects, cleavage gives rise to a layer of cells completely enclosing the yolk. The last type is called superficial cleavage.

In geology, cleavage is the tendency of crystalline minerals to split more easily in certain definite directions, with the development of more or less smooth surfaces called cleavage planes. Cleavage planes can only be developed parallel to some possible crystal face. Cleavage may be described either in terms of the ease with which it is developed, or its direction. **Slaty cleavage,** as the term implies, is the tendency for slaty rocks to split in relatively thin, flat plates. Slaty cleavage is the result of the **metamorphism (foliation)** of a sedimentary rock (**shale** or mudstone) and is not to be confused with mineral cleavage. (A.W.L., R.M.F.)

CLICK BEETLE. Insecta, Coleoptera. **Beetles** with a peculiar junction between the first and second thoracic segments which permits them to be moved with a convulsive snap. When laid on its back the beetle uses this method of righting itself, throwing itself into the air by these snapping movements of the body. Most members of the family Elateridae and some of the Eucnemidae are click beetles. (A.W.L.)

CLIMACTERIC. That time or portion of a person's life during which the body undergoes a radical change. The term refers particularly to puberty and the menopause. (R.S.M.)

CLIMBING PERCH. Pisces, Teleostei. An Indian fish, (**Pisces**), *Anabas scandens,* not related to the true perch, which is able to move along the ground by using its paired fins. It and allied species secure oxygen from the air by means of a special organ associated with the gills. It has been said to climb low trees but it climbs rarely, if at all. (A.W.L.)

CLITELLUM. A swollen glandular region occupying several segments near the anterior end of the **earthworm.** It is an accessory reproductive structure. (A.W.L.)

CLITORIS. The organ in the female corresponding to the penis in the male. It is a small cylindrical organ about an inch long, situated in the anterior angle of the **vulva,** capable of erection. Unlike the penis the clitoris is not traversed by the **urethra.** (R.S.M.)

CLOACA. A chamber at the end of the gut which receives the ducts of the reproductive, excretory, and alimentary systems. A cloaca occurs in the **rotifers** and in many **vertebrates** but in most **mammals** it is present only during **embryonic** life. (A.W.L.)

CLONE. The descendants of a single individual produced through continued asexual reproduction. As parts of the parental body, these individuals may be expected to have the same heritage. (A.W.L.)

CLOT. Coagulation. The process of changing from a fluid or semi-fluid state to a semi-solid soft mass. This occurs in **blood** or lymph when it escapes from the blood or lymph vessels. (R.S.M.)

CLOTHES-MOTH. Insecta, Lepidoptera. A **moth** whose **larva** eats dead and dry animal matter, especially

A, clothes moth. B, larva of clothes moth. (After Riley. U. S. Dept. Agr.)

fur, feathers, and wool. Three species are known. The case-bearing clothes-moth larva, *Tinea pellionella,* lives in a case made of bits of the material on which it lives, spun together with silk. The tube-building or tapestry moth, *Trichophaga tapetiella,* makes a gallery of silk and fragments as it works. The common or naked clothes-moth larva, *Tineola biselliella,* does not spin until it makes its cocoon. The adults of all three species are small, expanding usually about one-half inch. As in the case of the **buffalo carpet-moth** good housekeeping is the best remedy for these pests. When present they may be killed by the use of commercial sprays or in heavy infestations by fumigation.

Frequently when moths become over abundant in a house it is due to some forgotten breeding place, such as feathers or old garments in storage. A search in unexpected places is often the best cure for such attacks. (A.W.L.)

CLOUD CHAMBER. An enclosure containing air or other gas saturated with water vapor, the cooling of which by a sudden expansion results in the formation of fog droplets upon particles of dust or other nuclei. That **ions** in the gas are capable of serving as condensation nuclei, even when no dust is present, was demonstrated by the experiments of C. T. R. Wilson. Thus the clouds produced are much more dense if the gas is traversed by some ionizing emission like **x-rays** or **alpha rays.** Sir J. J. Thomson utilized this effect in his early measurements of the electronic charge. One of the most striking phenomena of the Wilson cloud chamber is exhibited when single ionizing particles, such as alpha or beta particles, are allowed to traverse it just before the expansion. The path of each particle is marked by a visible white streak or "track" of mist, sometimes several centimeters in length, which soon diffuses and disappears. The study of photographs of such cloud tracks has in recent years afforded much information as to the nature and the movements of the particles producing them. (L.D.W.)

CLOUD TRACK. Cloud Chamber.

CLOUDED LEOPARD. Mammalia, Carnivora. A **cat,** *Felis nebulosa,* of southeastern Asia, neither closely related to the true leopard nor like it in markings. (A.W.L.)

CLOVES. Eugenia aromatica. Myrtaceae. Cloves are the dried flower buds of a beautiful evergreen tree growing twenty-five to forty feet high. Its native home is the Molucca Islands. In cultivation it has spread throughout tropical Oriental islands. The trees grow best when near the coast. The clove tree has thick shining

leaves, a smooth gray bark and flower buds and flowers of deep red color The fragrant oil is located mainly in the leaves and flower buds, and causes the air surrounding the tree to be richly scented Flower buds are first formed when the tree is four or five years old In gathering the branches are pulled down and the flower buds picked off by hand, or they may be pounded from the trees with bamboo sticks After gathering, the pedicels, or short flower stems, are picked off, and the buds dried These buds may now be used as a spice, either whole, or ground to a powder They are also used to improve the breath, indeed, in ancient times it is recorded that their use for this purpose was required before royalty could be addressed, a commendable requirement In addition to their use as spice, an oil is distilled off and condensed by cooling This oil, which is rich in eugenol, is much used in making artificial vanilla Clove oil (See **Volatile Oils**) is also used in scenting soaps and perfumes, in dentistry, where it is applied to kill nerves in teeth, and as an antiseptic for sterilizing root canals It is also much used in the preparation of sections which are to be examined by the microscope, it being a means of clearing the sections (R M W)

CLUB FOOT (Talipes) A deformity of the foot, usually congenital in origin, characterized by a condition of marked flexion, extension, inversion, or eversion of the foot

Heredity is a factor in some cases In others the condition results from an intra-uterine accident or maldevelopment such as, faulty implantation of the **ovum,** firm pressure or constriction due to deficient **amniotic** fluid, or tumor formation in or around the **uterus,** interlocking of the feet, constriction of the umbilical cord, pressure of twins, etc

The most frequent cause of acquired club-foot is **infantile paralysis.**

Treatment is effective in childhood In older children the prognosis for a useful foot is not as good Treatment may be manipulative or operative, depending on the type of deformity and the age of the patient (R S M)

CLUB MOSSES. **Lycopodiales;** also **Paleobotany.**

CLUSTERS. An examination of the night sky will indicate at once that the stars are not uniformly distributed Certain clusters may be readily distinguished by the unaided eye, such as the **Pleiades,** the **Hyades,** the **constellation** of Coma Berenices, Praesepe, and the double cluster in **Perseus.** The application of the **telescope** to astronomy revealed a number of other clusters and the application of photography further augmented the number until at present several hundred such objects are listed Star clusters are studied under two main types galactic clusters and globular clusters

A galactic cluster contains between a few hundred and a thousand stars far enough apart to be distinguished as individuals The name galactic is derived from the fact that all except two or three of the brightest and closest of these objects lie within fifteen degrees of the **galactic** plane The method of determination of the distances and sizes of those galactic clusters which are close enough to be classified as **moving clusters** are discussed elsewhere For the more distant ones the **spectral classes** of individual stars are plotted as abscissae and apparent **magnitudes** as ordinates and the resulting diagram compared with that obtained for **giant and dwarf stars.** From this comparison an approximate determination of **absolute magnitudes** may be made and the distance determined From the distance and observed angular diameter of a cluster its linear diameter may be found By such methods a few galactic clusters are found to be within a few hundred **light years** of the sun, while the great majority are between 1500 and 15,000 light years away The shapes of the galactic clusters are quite irregular.

The globular clusters contain thousands of stars and are characterized by their globular form and concentration of stars in their central regions In a moderately large telescope these objects are strikingly beautiful objects Many attempts have been made to determine the total number of stars contained within a globular cluster, but the concentration at the center is so great that the images all run together Certainly, in the brighter objects of this class there are more than fifty thousand stars Shapley finds, from an extensive study of a number of clusters, that there are stars of all spectral types, but there is a very definite correlation between spectral class and brightness, with the fainter stars all being redder than the brighter ones.

The distances of globular clusters may be approximately determined from the cluster type **Cepheid variables** which are found in large numbers in these objects Shapley finds that the globular clusters are all contained within a vast ellipsoid with a maximum diameter of approximately 250,000 light years, having its center about 75,000 light years from the sun in the direction of the constellation of **Sagittarius.** While the principal plane of this ellipsoid practically coincides with the **galactic plane,** nevertheless practically none of the globular clusters are observed close to the milky way The only plausible explanation seems to be found in the hypothesis that there is some sort of absorbing material in this region of space

A study of the shapes of the globular clusters indicates that they are somewhat ellipsoidal as though they were rotating, but no rotation has ever been definitely observed From the estimated distances and angular diameters the diameter of the clusters is found to be of the order of magnitude of 100 light years In the central dense portion of a globular cluster there must be about 1500 times as many giant stars as there are in an equal volume of space in the vicinity of the sun However, even with this relatively close packing of stars, the average distance between the individuals must be of the order of magnitude of one light year (W K G)

CLUTCH. The function of a clutch is to effect the coupling of two working parts in such a way as to permit connection or disconnection at will, and without the necessity of bringing both parts to rest Almost always a clutch is a coupling between two **shafts** which are in line, one being the driving, the other the driven, shaft Under these conditions the function of the clutch upon being engaged is to pull the driven member up to the speed of the driving member, and to transmit the required amount of power without **slip.**

Clutches may be classified according to the method of transmitting the torque.

1 Friction clutches are operated by the surface friction created when two surfaces are pressed together

2 Magnetic clutches make use of the attraction of a magnet for its armature This type has attractive features, but has made little headway because of the development of the friction clutch

3 Jaw clutches are those in which positive drive is obtained by the use of projecting lugs If this type of clutch is engaged when the drive is in motion, there will be a sudden shock to the driven mechanism unless some degree of flexibility is imposed between clutch and driven machinery by the use of springs, rubber, or the like

Most clutches are of the friction type, since it has been possible to build this type to transmit almost any amount of power desired with moderate-sized clutches which are comparatively trouble-free The friction clutch may be engaged either by an axial or by radial movement Cone and disk clutches are the former type, internal-expanding shoe and external-contracting bands are examples of the latter

The **internal combustion engine** is not easily started under load, and therefore when used to power self-propelled vehicles, it must be disengaged from the axle for starting purposes. For this reason every automobile, truck, or bus must have a clutch. The two clutch forms frequently used for this service are the cone clutch and the disk clutch.

In explanation of the cone clutch, the reader is asked to refer to Figure 1. In this figure at *A* the clutch is "in"; at *B* it is "out." The flywheel is connected to and rotates with the engine crankshaft. A conical surface is machined on the inside of the rim, and into this the male member of the clutch, also conical, is pressed by the action of the spring *S*. The rim of the external

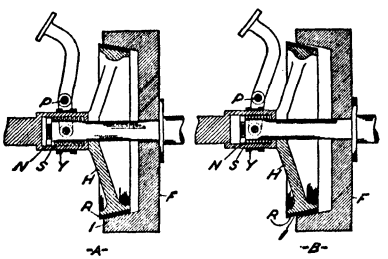


Figure 1. Cone clutch.

cone is faced with a friction material such as leather. Other friction surfaces employed are asbestos fiber, steel with cork insets, or plain steel against steel, or steel against bronze. In *B* the foot pedal is shown depressed, and by means of the collar *Y*, the friction cone is withdrawn, compressing the spring *S*. The spring pressure required is that needed to produce the force at the friction surface which is necessary to transmit the required horsepower. If the mean diameter of the friction surface is *D* feet, and *P* horsepower is to be transmitted at *N* r.p.m., then the sum of all the friction forces acting in the friction surface can be expressed by the following formula:

$$F = \frac{33{,}000P}{2\pi N \times \frac{D}{2}} = \frac{33{,}000P}{\pi ND}.$$

The fundamental law of friction states that frictional force equals coefficient of friction times pressure normal to the surface, hence, calling the pressure normal to the surface *Q*,

$$Q = \frac{F}{f},$$

in which *f* is the coefficient of friction of the contacting surfaces.

The conical clutch surface is used because a small spring pressure acting along the axis of the shaft will produce a large force if the cone angle is small. If the central angle of the cone is α and the force exerted axially by the spring is *S*,

$$Q = \frac{S}{\sin \alpha}.$$

The cone clutch is either metal to metal running in an oil bath, or leather to metal, running dry. Since the leather must be kept soft and pliable, but free from grease, necessitating a certain amount of inspection and maintenance, this type of clutch has been superseded, for automotive uses at least, by the disk clutch. The dry plate disk clutch operates without lubrication, gaining thereby so high a coefficient of friction that one plate held between two disks usually will develop sufficient friction force. Figure 2 shows a multiple disk clutch of the type frequently used in the automobile. *F* is an extension of the crankshaft to the engine, and carries with it the series of disks similar to *R*. The driven shaft, *T*, is expanded inside the clutch to a large diameter drum having mounted internally a series of disks similar to *I*, alternating with the *R* disks. In each case the disks

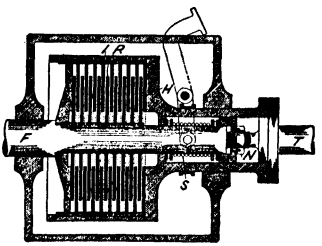


Figure 2. Multiple disc clutch.

must move with their respective shafts, but are permitted some endwise movement through the method of attachment. The clutch is shown in disengaged position. Should the clutch pedal be released, the spring *S* will push on the member *H* and press together the fixed and moving disks. The friction set up thereby will pull the driven shaft up to speed, and then transmit to it the power for which the clutch is designed. Such clutches are sometimes metal to metal, immersed in oil, or metal to friction material if run dry. (F.T.M.)

CNIDOBLAST. A stinging cell of the **coelenterates,** found in all forms, **polyps, jellyfishes,** and **sea-anemones.** It produces **nematocysts** which are discharged in defense and in securing food. (A.W.L.)

CNIDOCIL. A projection on the free surface of a **cnidoblast** which is sensitive to external stimuli. (A.W.L.)

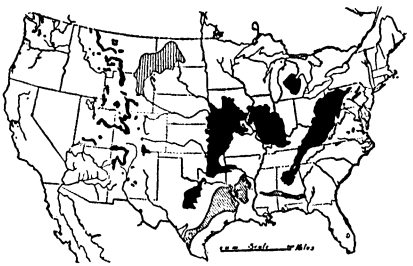
COAGULATION. (1) The clotting of **blood** or **lymph.** (2) The changes produced in tissue by the application of certain increased temperatures or by certain chemicals. (R.S.M.)

COAITA. Mammalia, Primates. The red-faced spider-monkey of the Lower Amazon. (A.W.L.)

COAL. A combustible substance of organic origin which occurs as beds or "seams" and which has a variable physical and chemical composition, including variable amounts of mineral or non-combustible matter. Although the combustible constituents of coal are of organic origin, the geological processes involved in its formation act so slowly and over such a long period of time that coal is, economically speaking, non-reproductible.

It is known that the origin of coal is to be sought in the vast and luxuriant vegetation which flourished over portions of the earth's surface in past geological ages, for the imprint of leaves of giant tree ferns of a form similar to those now found only in tropical jungles, can often be seen on the face of blocks of coal at the mine. (See **Paleobotany.**) Undoubtedly the somewhat higher mean temperature of the earth, coupled with the prevalence of a more steamy atmosphere, produced conditions which led to very rapid growth of vegetation. Such conditions are today approximated in hot houses, so it is probable that the coal-forming epochs are definitely of the past, and that such coals as are used constitute a depletion of a fixed natural resource. Through the centuries of the **carboniferous** age there was produced a rapidly accumulating mass of decaying vegetation, a great deal of which was undoubtedly also preserved from complete decay by having air excluded

from it either by its being partially submerged or being covered with a considerable thickness of superimposed matter. The process of decay soon converted the **cellulose, lignin,** and **proteins** of the original vegetable debris into peat bogs which, due to some subsequent earth movements, were either rapidly or gradually covered with inorganic material which, in time, produced sedimentary rocks such as shale or sand stone. Coal is found today in bedded deposits, or seams, in company with **shale, sandstone, limestone,** and other sedimentary products. The pressure of the overlying strata, together with some possible small amount of residual decay, created an increase of temperature in the peat which slowly accomplished its conversion into coal. The fact that under conditions of controlled pressure and temperature a material of vegetable origin may today in the laboratory be converted into a black powder resembling coal, lends credence to this theory of the origin of coal. It is entirely conceivable that the variations in overlying strata, in condition of the bed when overlaid, and in subsequent rise of temperature, are accountable for the differences in coal as it is brought from the mines today. During the process of this chemical change, percolation of water through the incipient coal seams probably carried into the coal many of the minerals which, in the aggregate, produce the ash which is common to all coals. (Of course, some of the ash can be attributed to the minerals present in the vegetation from which the coal was formed.) The classification of coal is primarily in terms of its origin both as to (a) composition, or the original types of vegetable material composing it, and (b) the degree of **metamorphism** which it has undergone since burial. A simple but practical classification of coal according to its origin and chemical composition is as follows: (1) Peat. Partially carbonized vegetable matter, such as accumulates in a bog. Because of its high water content, peat is not an economical fuel when either lignite or coal is available. (2) Lignite. Brown coal and lignite are formed by the burial and consequent compression of peat by overlying sediments (formations), the peat substances being thus compacted and changed, first to brown coal or lignite, and then to black lignite or sub-bituminous coal. Although lignites are thus the parent forms of the higher grades of coals, even pure lignite is a relatively poor form of fuel because of its high water content and consequent low calorific value. Calculated on an ash-free basis, lignite yields moisture, 43.4 per cent; volatile matter, 18.8 per cent; fixed carbon, 37.8 per cent; heat value in **British Thermal Units,** 7,400 B.T.U. per pound. (3) Bituminous Coal. Soft Coal (bituminous) varies in heating value from 9,720 to 15,360 B.T.U. per pound. The various ranks of bituminous contain roughly 70–80 per cent of fixed carbon and 30–20 per cent of volatile matter. When most bituminous coals are heated in a closed retort this volatile matter is driven off as gas and **coal tar.** The residue of fixed carbon may form a coherent porous mass called **coke.** Coking coals are particularly valuable as they yield the essential fuel for the smelting of iron ores. Other by-products of bituminous coals are a great series of organic compounds which are used extensively in the dye and other industries. (4) Anthracite (Hard Coal). When bituminous coals have been heated and compressed (by natural geological causes) so that they have changed from the finely jointed and crumbly "Soft Coals" to the massive and hard form, they are called anthracite, which is relatively hard, clean and moisture free; low in volatile matter and high in fixed carbon. Anthracite grades (through **metamorphism**) to **graphite** which is high in fixed carbon, combustible only at high temperatures, and classed as a refractory. High grade anthracite, calculated on the ash-free basis yields moisture, 3.2 per cent; volatile matter, 1.2 per cent; fixed carbon, 95.6 per cent, and heat value, 14,400 B.T.U. per pound. **The geologic distribution of coal is as follows: Pre-Paleozoic.** No coal beds but abundance of graphite in the **Archeozoic** crystalline rocks. **Paleozoic.** Important bituminous and anthracite coal deposits in England and eastern United States of Pennsylvanian age. **Mesozoic.** A few beds of **cannel** and bituminous coals occur in the **Triassic.** In the **Cretaceous** occur a great series of bituminous coal beds second only in importance



Map of the United States showing the principal coal fields. The lined areas represent lignitic coals. All solid black areas east of the Rocky Mountains, excepting the very small ones of Triassic age in Virginia and North Carolina, represent fields of Pennsylvania coal. All coal in the western United States is Cretaceous and Tertiary. (Modified after U. S. Geological Survey.)

to those of Pennsylvanian age in the eastern United States. **Cenozoic.** Poor grades of lignite and bituminous coals occur in the **Tertiary.** These coals are of some value for local use only. The chief coal reserves of the world are located in the United States, England and the territory contiguous to Germany and France.

Coal contains **carbon, hydrogen, oxygen, nitrogen, sulfur,** and various mineral substances such as **silica, alumina,** and iron (ferric) oxide. All of the mineral substances are included in the descriptive term ash. Hydrogen is present in coal in two forms, called *free* and *combined,* although actually it is in two methods of combination. Hydrogen is combined with oxygen forming the moisture in coal, and all coal contains more or less moisture. Hydrogen is also combined with carbon, forming the hydrocarbon, or volatile portion of coal. A very important difference, however, exists in these two combinations of hydrogen. In one, water, it is completely oxidized, and must be considered incombustible; in the other, the hydrocarbons, the hydrogen is combustible. There may be, and usually is, some free oxygen dissolved in the coal. Its occurrence in coal is more or less accidental. Coal rarely contains more than 4% of sulfur, or 2% of nitrogen. Only a small portion of the carbon content of coal is accounted for in the volatile portion (the hydrocarbons); in fact, the largest portion of the heating value of coal is obtained from the free or "fixed" carbon. Anthracite coal is high in fixed carbon, and low in volatile material and moisture. Bituminous coal has a much higher volatile-material content, and accordingly, a lower amount of fixed carbon. Lignite is very much higher in moisture content than either bituminous or anthracite coal, and has correspondingly lower proportions of volatile and fixed carbon. Ash is not typical. A sample analysis of anthracite coal is: 2% moisture, 5½% volatile material, 86½% fixed carbon, 6% ash. Typical semi-bituminous coal, the principal steaming coal, would be covered by the following analysis: 3% moisture, 18% volatile material, 75% fixed carbon, 4% ash.

The analysis of coal on the basis just described is known as the **proximate analysis,** but studies in combustion, which is essentially a chemical reaction, necessitate analyzing the coal into its elements. This analysis is known as the **ultimate analysis.** Since the heating value of hydrogen is roughly five times that of carbon,

it follows that the coal high in volatile material is possessed of higher calorific value.

The combustion of free carbon liberates 14,500 B.T.U. per pound, of free hydrogen 62,000 B.T.U. per pound, and of sulfur 4,000 B.T.U. per pound. One pound of coal has a theoretical heating value of

$$HV = \frac{14{,}540C + 62{,}000H + 4{,}000S}{100} \text{ (B.T.U.)}$$

C = the percent of carbon in the coal. S = percent of sulphur in the coal. H = percent "free" hydrogen in the coal, understood to be that portion of the total hydrogen in an ultimate analysis which is not already combined with oxygen. The actual heating value of coal as determined by calorimeter may be slightly different from that yielded by the above formula, because of exothermic or endothermic reactions that take place during combustion such as the heat of decomposition of hydrocarbons, etc. Since, for coal, the endothermic or heat absorbing reactions are usually of greater magnitude than the exothermic, the actual heating value is less than that determined by the formula.

The commercial production of coal is a vast and highly intricate business. In recent years it has suffered from the considerable competition of oil and natural gas, and, in general, the industry has suffered from intensive competition. The seams which are worked are usually less than ten feet thick, and are generally overlaid with a rock cap which is shored up as the coal is removed. Some coal is mined by the open or strip method, in which the overlying earth is stripped off by power shovel. Coal is undercut or blasted out of the face of a seam and loaded onto cars which convey it to the plant, where the slate is removed before the coal is broken and graded.

Bituminous coals are produced in the following sizes:

Run of Mine. This coal is mined, unscreened, and varying in size from large lumps to slack.
Lump. Coal which passes over a 1¼" screen.
Nut. Cut coal of a size which passes through a 1¼" screen, but is retained on a ¾" screen.
Slack. All coal passing the ¾" screen.
Anthracite coal, in addition, is produced in the finely graded sizes called Pea and Buckwheat.

The firing qualities are very important characteristics of coals when selection of coal or coal burning equipment is under consideration, for, if it were not for the effects of firing qualities and impurities, coal could be purchased on the basis of heating value alone. The firing characteristics of coal result from (1) its volatile content, (2) moisture content, (3) sulfur content, (4) ash composition. Some coals retain their original shape during combustion, being gradually reduced in size as combustion proceeds; others soften and fuse into a mat or crust which blankets off the air supply; others soften but do not form a crust. This quality influences the stoker selection. The sulfur and ash content will have much to do with the types of clinkers that are formed. The fusion temperature of the ash becomes an important characteristic when low excess air and high furnace temperatures are employed. The hardness and way in which a coal shatters when pulverized may influence the selection of pulverized fuel equipment. Some coals are fast burning, others slow. That characteristic influences shape and thickness of fuel bed carried, or type of burner installed. The tendency of a coal to disintegrate and become slack will affect the type of grates and the draft used.

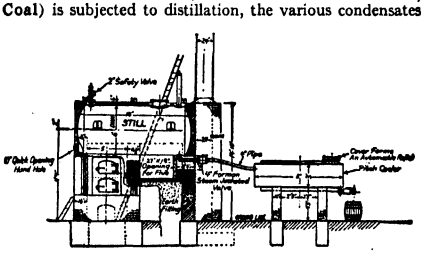
The bulk of coal is transported by boat or railroad, although these are supplemented, to a limited extent, by trucks and wagons. The individual user of coal usually puts considerable quantities of it in storage as insurance against complete shut-down of a plant occurring from failure of normal fuel supplies to arrive. Storage permits some choice in the date of purchase, allowing the purchaser to take advantage of seasonal market conditions. When coal is piled in storage it "weathers." It has a tendency to become slack; the surface oxidizes and heat is liberated. When loosely piled in shallow piles or large lumps, natural circulation of air currents carries the heat away rapidly enough so that the temperature does not rise dangerously. Fines with their larger surface exposure must be watched more carefully than coarse lumps. Two methods of preventing spontaneous combustion are practiced. One of them is to promote sufficient circulation of air to carry off heat at low temperatures. This is done by shallow piling and by use of ventilating ducts. The other is to store in such a way that the oxidizing air is excluded from the coal. This is perfectly accomplished by underwater storage, but few care to attempt that unless some special topographic condition is conducive to low cost wet storage.

Coal is the source of a great many important and useful by-products which are derived either from distillation or carbonization of bituminous coal. Amongst the more important of these might be mentioned the following: illuminating and fuel gas, coke, ammonia, analine and other dye stuffs, explosives, pitch, cresoline and paint compounds, antiseptics, tar. (R.M.F., F.T.M.)

COAL BALLS. Concretions composed of mineralized plant fragments preserved as **petrifactions.** Because the original structure of the plants has been so well preserved, the coal ball flora has been of great aid to **Paleobotanists** in determining the character of the **carboniferous** flora. (R.M.F.)

COAL MEASURES. Upper Carboniferous.

COAL TAR PRODUCTS AND INTERMEDIATES. When coal tar (See **Destructive Distillation, Coal**) is subjected to distillation, the various condensates



Drawing of tar still used in the United States of America.

contain substances of value for intermediates, which with the light oil recovered from coal gas, may be considered the immediate raw materials for making dyestuffs. While the exact treatment may vary with each coal tar obtained, general results are probably satisfactorily summarized as follows:

Fraction Collected	Name of Fraction	Percentage of Coal Tar
Up to 170° C.	Light oil	0.2
170–230° C.	Carbolic oil	10
	½ phenol	
	½ cresylic acid	
230–270° C.	Creosote oil	10
270–350° C.	Anthracene oil	25
Residue at 350° C.	Pitch	55
Residue at 1200° C.	Retort carbon	17

The light oil fraction plus light oil recovered from coal gas (the latter the main source of **benzene** and **toluene**) contains:

Fraction of Light Oil	Fraction Collected	Distillation Characteristics
Crude benzene...	Up to 95° C	90% recovered at 100° C.
Crude toluene ..	95–125° C.	5% " " 100° C
		90% " " 120° C.
Crude solvent naphtha ..	125–170° C.	5% " " 130° C.
		90% " " 160° C.
Heavy naphtha..	170–200° C.	5% " " 160° C.
		90% " " 200° C.

Residue· Wash oil (for benzene absorption from coal gas), naphthalene and phenols Drawn off and cooled, whereupon naphthelene crystallizes, and is separated by filtration

When these fractions are further fractionally distilled, pure benzene, pure toluene, xylenes and solvent naphtha are recovered See also **Hydrocarbons.**

Benzene, toluene, xylene, naphthalene, anthracene, are the important hydrocarbons used for intermediates

In addition to phenol there are used as intermediates the following **phenols:** cresols, resorcinol, alpha- and beta-naphthol In addition to aniline, the following amines ortho- and paratoluidine, dimethyl aniline, diethylaniline, diphenylaniline, benzidine, toluidine, alpha- and betanaphthylamine, acetanilide, in addition to chlorobenzene: paradichlorobenzene, benzyl chloride, in addition to **benzoic acid: phthalic acid,** phthalic anhydride, dibutylphthalate, **salicylic acid,** cresylic acid (See **Acids, Carboxylic**), also diphenylguanidine, orthoditolylguanidine (See **Guanidine**), phenyl glycine, phenylglycocoll, $C_6H_5NHCH_2COOH$ (See **Aminoacids**), tricresylphosphate, benzaldehyde

There are about five largely used processes for producing intermediates The products may be classified as

1 *Sulfonated products* Wherein sulfuric acid concentrated is used to produce sulfonic acid products (group $—SO_3H$) by elimination of water (—OH from sulfuric acid plus H— from the benzenoid compound taken react to form H_2O) Sulfanilic acid (1-amino-4 benzene sulfonic acid) naphthionic acid (1-amino-4-naphthalene sulfonic acid and others) See **Thioalcohols.**

2 *Nitrated products* Wherein nitric acid concentrated (usually with sulfuric acid concentrated) is used to produce nitro-compounds (group $—NO_2$) by elimination of water (—OH from nitric acid plus —H from the benzenoid compound taken react to form H_2O) See **Nitrocompounds** (nitrobenzene, 2- and 4-nitrotoluene, meta-dinitrobenzene, 2,4-dinitrochlorobenzene, 2,4-dinitrochlorotoluene, 2,4-dinitrophenol, nitroanilines), **Nitrobenzene; Toluene; Phenol.**

3 *Chlorinated products* Wherein chlorine is used to produce chloro-compounds by elimination of hydrogen chloride (—Cl from chlorine plus H— from the compound taken react to form HCl) See **Chlorine,** organic compounds.

4 *Hydroxylated products* See **Phenols.**

5 *Aminated products* See **Amines; Aniline.** (R K S)

COATI. Mammalia, Carnivora *Nasua* Animals related to the raccoons but with a long snout They occur in Mexico, Central America, and South America (A W L)

COBALT. Symbol Co Atomic number 27 Atomic Weight: 58 94 Density. 8 9 Melting point 1480° C Boiling point· 2900° C

Cobalt is a silver-white metal, harder and stronger than iron or nickel, not very malleable but a small amount of carbon markedly increases the malleability and ductility, magnetic below 1150° C, soluble in nitric acid Compact cobalt is not oxidized on exposure to air at ordinary temperature, and does not react with alkalis Discovered by Brandt in 1735

Cobalt occurs as arsenide and sulfide (**smaltite,** $CoAs_2$; **cobaltite,** CoAsS), generally associated with iron, nickel, copper and silver minerals, the principal sources being Ontario and Belgian Congo The ore is treated in a **blast furnace** and recovered as arsenide of the above contained metals, which product is roasted with sodium chloride or treated with sulfuric acid, cobaltic hydroxide is obtained by a succession of treatments and then ignited to tricobalt tetroxide From the oxide cobalt metal is obtained by heating with carbon

Cobalt is used in alloys, (1) ferro-cobalt (35% Co) as a permanently magnetized steel, (2) "carboloy," tungsten carbide and cobalt, of high hardness and used as in cutting steel, (3) "stellite," cobalt-chromium alloy used in cutting steel

Acetate cobalt acetate, cobaltous acetate ($Co(C_2H_3O_2)_2\ 4H_2O$), red-violet solid, soluble, used as a dryer for paint and varnish oils

Chloride cobalt chloride, cobaltous chloride ($CoCl_2$), red crystals, soluble

Cobaltinitrites sodium cobaltinitrite ($Na_3Co(NO_2)_6$) soluble, and potassium cobaltinitrite, "cobalt yellow" ($K_3Co(NO_2)_6$), insoluble, are yellow solids, the latter used as a pigment

Hydroxides cobalt hydroxide, cobaltous hydroxide ($Co(OH)_2$), rose-red precipitate by reaction of boiling cobalt salt solution and **sodium** hydroxide solution, cobaltic hydroxide ($Co(OH)_3$), brownish-black precipitate by reaction of cobalt salt solution and sodium hypochlorite solution

Nitrate cobalt nitrate, cobaltous nitrate ($Co(NO_3)_2\ 6H_2O$), red crystals, soluble

Oxides cobalt monoxide, cobaltous oxide (CoO), gray to greenish solid, formed by heating cobaltous hydroxide or carbonate, used in the production of various colors with other oxides in ceramics such as blue, purple, green, red, yellow, cobalt sesquioxide, cobalt oxide (Co_2O_3), black solid, formed by heating cobaltous nitrate at 180° C, tricobalt tetroxide, cobalto-cobaltic oxide (Co_3O_4), black solid, formed by heating in air to a red heat any of the other oxides or compounds which yield these oxides by heating

Sulfate cobalt sulfate, cobaltous sulfate ($CoSO_4 \cdot H_2O$), red crystals, soluble

Sulfide cobalt sulfide, cobaltous sulfide (CoS), black precipitate, formed by reaction of cobalt salt solution with **ammonium** sulfide solution, relatively insoluble (after precipitation) in **hydrochloric acid.**

Cobalt soluble salts are pink, in solid or solution, but when heated gently to dehydration the hydrated salts preferably chloride turn blue, and the blue turns pink upon absorption of water vapor from the atmosphere (R K S)

COBALTITE. The mineral cobaltite is a sulfarsenide (See **Sulfur** and **Arsenic**) of **cobalt** corresponds to the formula CoAsS crystallizing in the isometric system as cubes or pyritohedrons, also may be massive Cobaltite has a very good cleavage parallel to the cube faces, uneven fracture, brittle, hardness, 5 5, specific gravity, 6–6 4, metallic luster, color, silvery white to reddish, sometimes steel gray or violet to grayish black, streak, grayish black Cobaltite is found with cobalt and **nickel** minerals deposited commonly by metasomatic processes It is found in Sweden, Norway, England and the Province of Ontario. It is an ore of cobalt. (E S C S)

COBEGO. Dermoptera.

COBIA. Pisces, Teleostei A fish (**Pisces**) of the family Elacatidae, especially the species *Elacate canada* This species is taken on the Atlantic Coast of North America. Also called the crab-eater and the sergeant-fish (A W L)

COBRA. Reptilia, Sauria Poisonous **snakes** of several species found in Africa and southern Asia Distinguished by the ability to inflate the neck when aroused The common cobra of India, *Naja naja,* is the best-known species It attains a length of six feet, half the

size of the giant cobra or hamadryad, *Naja hannah*, which is less common. The asp or Egyptian cobra, *Naja haje*, occurs in Africa.

As is true of other poisonous snakes, the effect of the bite of a cobra depends on its own supply of venom, on the location of the bite, on the condition of the victim when bitten, and on his tolerance for poison. If the fangs penetrate well, however, and the snake has a good supply of venom, the bite of any of these species is said to be almost certainly fatal. The venom acts upon the nervous system. (A.W.L.)

COCA. *Erythroxylon Coca.* Erythroxylaceae. Coca is a drug which is found in leaves of a shrub, *Erythroxylon coca*, growing wild in Peru. This shrub grows about six feet high, and has small ovoid leaves which are whitish on the under side, small yellow flowers growing in the axils of the leaves, and scarlet fruit. Cultivation has been carried on in Peru and adjacent regions since prehistoric days. The trees have been introduced into Java where they are now extensively cultivated. The leaves of the plant are highly prized by the native South American Indian for chewing. For this purpose they are mixed with lime, or ashes, and when chewed in this form enable the masticator to endure hunger and fatigue. The active principle is a poisonous alkaloid, **cocaine**, which is extracted from the leaves. (R.M.W.)

COCAINE. One of the alkaloids **obtained** from coca leaves. It is one of the vicious, habit-forming drugs when used for a period of time. It is a valuable local anesthetic when painted or sprayed on mucous membrane. It is not used for injection beneath the skin to obtain local anesthesia as there are other drugs such as novocaine, etc., which do not produce habit formation and which are less toxic.

The cocaine habit is quite common among those who have easy access to the drug. The addicts take the drug as snuff, by application to the gums, by mouth or hypodermically. Mania and chronic dementia and other forms of insanity result from its continued habitual use. (R.S.M.)

COCCIDIA. An order of parasitic Protozoa. See **Sporozoa**. (A.W.L.)

COCCIDIOMORPHA. An order of parasitic Protozoa in some classifications, including **Coccidia** and **Haemosporidia**. See **Sporozoa**. (A.W.L.)

COCCOSTEUS. **Fossil fish.**

COCCUS. One of a family of the order of *Eubacteriales* which includes **bacteria** whose cells are spherical in form. (R.S.M.)

COCCYGODYNIA. Pain in the region of the **coccyx** usually due to injury. (R.S.M.)

COCCYX. The lower end of the spinal column. It is composed of four rudimentary small segments which are usually fused together. (R.S.M.)

COCHLEA. The auditory portion of the inner **ear** of **vertebrates**. (A.W.L.)

COCKATIEL. Aves, Psittaciformes. A small Australian **parrot** related to the cockatoos. (A.W.L.)

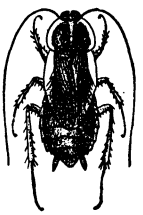
COCKATOO. Aves, Psittaciformes. Any member of a family of crested **parrots** whose beaks are transversely ridged on the under surface of the hook. The tail is short and broad. Cockatoos occur in the Australian and Oriental regions. (A.W.L.)

COCKCHAFER. Insecta, Coleoptera. A European **beetle**, *Melolontha vulgaris*, related to the May beetles of North America. (A.W.L.)

COCKLE. Mollusca, Pelecypoda. *Cardium.* Marine **bivalve** mollusks of several species. (A.W.L.)

COCK OF THE ROCK. Aves, Passeriformes. *Rupicola.* Birds (**Aves**) of several species found in tropical South America. The males are crested and brilliantly colored. See **Chatterers**. (A.W.L.)

COCKROACH. Insecta, Orthoptera. Flattened oval **insects**, usually brown in color. The head is almost concealed by the broad margins of the **thorax** and in winged species the wings overlap above the body.


Cockroach.

Cockroaches are widely known from a few species which inhabit houses, especially where quantities of food are available. They eat almost anything used by man as food and often damage other things, such as articles made of cloth containing sizing or paste. They are especially troublesome in restaurants. The two most important pests are the Croton-bug, *Blatella germanica*, and the Oriental cockroach, *Blatta orientalis*. They can be destroyed by sprinkling borax (See **Boron**), **sulfur**, or **pyrethrum** powder liberally about their hiding places or by the use of commercial roach pastes.

The cockroaches gain their greatest development in the tropics, where species with a normal length of more than two inches are found. (A.W.L.)

COCOA. **Theobroma Cacao.**

COCOA BUTTER. **Theobroma Cacao.**

COCONUT. *Cocos nucifera.* Palmaceae. To the natives of tropical islands the coconut is a most valuable tree; it provides him with shelter, with dishes, with food and drink. To the inhabitant of north temperate regions, the plant is equally valuable—some half million tons of coconut oil are used annually.

The coconut tree is a striking plant having a columnar trunk sixty to eighty feet high, bearing at its top a crown of bright green pinnate leaves, each from fifteen to twenty feet long. The fruit is a large nut composed of three united **carpels**. At the end of the nut are three germ pores; beneath one of these an **embryo** is located. The shell of the coconut has three distinct layers; the outer or epicarp is thin, smooth and brown; the middle, or mesocarp, is thick and fibrous, it is the source of the fiber, **coir**. Usually these two layers are removed before the coconuts are shipped, but not infrequently the entire fruit is exhibited as a curiosity by dealers in fruits. Within is the hard brown shell or **endocarp**. This contains the **endosperm**, which is of two parts, one the familiar white meat of the coconut, the other the milk which partially fills the cavity of the nut. It is within the meat that the embryo is embedded. The thin brown skin immediately investing the meat and sticking to it when it is removed from the shell is the inner seed-coat. The hard shell of the coconut is much used as a dipper or as a vessel for storage of various substances.

The leaves of the tree yield a fibrous material used by the native islanders, and are also used at times as a thatch for shelters. The trunk of the tree is sometimes used by cabinet makers for ornamental work.

Commercially the most valuable product of the coconut is copra, the dried meat of the nut. This is obtained by splitting the nut and drying the meat, preferably by the sun. Artificial drying is done in regions of great humidity. From the meat is obtained coconut oil, which forms about 63% of the meat. The natives obtain this oil by various means. The hot sun of the tropics may cause it to dry out of the pounded meat. Crude presses are often used to squeeze

the oil from the dried meats. Or again the crushed dried meats may be placed in hot water, the melted oil rising to the top and being skimmed off. Any one of these methods is sufficient to supply the moderate needs of the natives, but utterly inadequate to meet the requirements of the civilized nations.

For modern treatment, copra is shipped to large factories. Here it is cleaned and ground, then heated and pressed. The meal is then ground up once more, cooked in water and pressed by powerful hydraulic presses. By this method nearly all the oil contained in the copra is extracted.

The principal use of the oil is in the making of **soap**, especially in soaps which will produce a copious lather. Considerable quantities are also used in making butter and lard substitutes. Some oil finds use in salad oils and in confectionery.

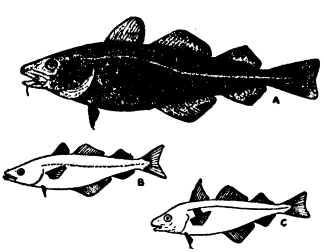
The copra cake remaining after the oil is expressed may be used as a stock feed.

Many coconuts are used to make shredded coconut, while some 20,000,000 are sold fresh each year in the United States. (R.M.W.)

COCOON. A case containing eggs or young, or a developing animal in an inert stage. In the **earthworms** a cocoon to contain the eggs is secreted by a special region of the body, the clitellum, as an external structure, but most cocoons are spun of silk, like those formed by the spiders to contain their eggs and those which some **larval** insects spin about themselves when they are ready for their final transformation. (A.W.L.)

CODEINE. An **alkaloid**, one of the most valuable and frequently used **drugs**. It is one of the components of **opium** (the dried opium contains 0.5 to 1 per cent of codeine). It is a much weaker narcotic than **morphine** and it has less power to produce sleep, or to allay pain. However, it does not readily cause habit formation. It is a component of nearly all good cough remedies because of its ability to diminish cough and allay discomfort. It is also very often used to control mild pain, and promote sleep, especially in combination with other sedatives. In these conditions codeine is much preferred to morphine, due to the ease of addiction with the latter. (R.S.M.)

CODFISH. Pisces, Teleostei. Fishes (**Pisces**) of a large number of species, chiefly marine. They occur



A, cod. (From U.S.B.F. Manual.) B, pollock. C, haddock. Nichols and Breder. (Courtesy of *N. Y. Zool. Soc.*)

in the northern hemisphere and are the most important of all food fishes.

In the cod family (Gadidae) are included the **hakes, haddocks, whiting, pollacks,** and coal fish, and in the fresh waters of northern North America a single species, the ling, **burbot**, or lawyer, is found.

The common cod, *Gadus morrhua*, has been ranked as the most important food fish. The annual catch amounts to more than one billion pounds. It is abundant in the North Atlantic. (A.W.L.)

CODLING MOTH. Insecta, Lepidoptera. The moth, *Cydia pomonella*, whose **larva** lives in apples. An important economic species.

This insect is so serious an enemy of the apple that the successful production of the fruit depends on a program of spraying which has been carefully worked out for all parts of the country. **Lead** arsenate is an effective poison but its application must be regulated according to the entrance of the caterpillars into the fruit. Once they have pentrated the surface they are beyond reach of sprays. The principle of spraying is to apply a first spray when the petals of the flowers fall, and a second when the eggs of the next generation of insects are hatching later in the summer. Economic entomologists of the various states are prepared to furnish the proper information for various localities according to the conditions of the year. (A.W.L.)

COEFFICIENT OF DISCHARGE. Water discharged from an **orifice, weir, pipe**, etc., theoretically has a velocity which is directly proportional to the square root of the head of water causing flow through the opening. Actually, however, contractions in the stream, surface roughness, and other causes, result in the actual velocity being smaller than the theoretical. The theoretical velocity is identical with that of the velocity attained by a freely falling body. It is $\sqrt{2gh}$, wherein g represents the acceleration of gravity, and h the height of fall corresponding to the pressure head creating the discharge. The ratio of the actual velocity to the theoretical is the coefficient of discharge. The coefficient of discharge from circular orifices is affected by the diameter of the orifice, the head, the sharpness of the edge, the velocity of approach to the orifice, and other minor factors. (F.T.M.)

COEFFICIENT OF EXPANSION. **Expansion.**

COEFFICIENT OF FRICTION. **Friction.**

COEFFICIENT OF HEAT TRANSFER. **Heat Transfer.**

COEFFICIENT OF PERFORMANCE. **Refrigeration.**

COELATA. A group of free-living flatworms which have an intestine. See **Turbellaria**. (A.W.L.)

COELENTERATA. The **hydroids, jellyfishes, sea anemones, corals,** and related animals. These forms make up a major division of the animal kingdom of simple structure. The body is developed from only two germ layers and is radially symmetrical. The alimentary track is saclike, with a single opening, but sometimes has complex tubular branches. The nervous system is a scattered network of cells connected by their slender processes. Coelenterates have peculiar stinging cells (**cnidoblasts**) which discharge irritating **nematocysts**. Most species are marine and all are aquatic.

Two forms of individuals occur in this phylum, the **polyp** or hydroid and the **medusa**.

The economic importance of the phylum is limited principally to the corals. Precious coral is sold in considerable quantities and the rock corals have built up many of the oceanic islands.

The principal subdivisions of the phylum are the following:

Class **Hydrozoa** (Hydromedusae). Both polyps and medusae occur in these species, usually alternating in a reproductive cycle. Species are often colonial. In colonies individual polyps or hydranths are borne on branches of a common stalk which also gives rise to reproductive individuals or **blastostyles** from which medusae arise. All individuals are joined by the continuous digestive tract. Most species are small but the **Portuguese man-of-war** and a few others are large.

Class **Scyphozoa** (Scyphomedusae) **The jellyfishes.** Usually free swimming species of moderate to large size All individuals are medusae Mostly marine
Class **Actinozoa** (Anthozoa) **Sea anemones, sea feathers, corals** and allied species Solitary or colonial marine species The individuals are polyps Colonies of some species build up massive hard deposits inside or outside of the body (A W L)

COELOM. The true body cavity, formed by the splitting of the middle **germ layer** of the body (mesoderm) and lined with a definite layer of cells

The coelom is well developed in **annelid** worms, where it appears as a series of **metameric** chambers It is of limited extent in other invertebrates but in the vertebrates gains great development Here it is divided into a thoracic and an abdominal cavity and in the terrestrial species the thoracic cavity is further divided into pleural cavities containing the lungs and a pericardial cavity containing the heart The abdominal or peritoneal cavity contains principally the greater part of the digestive tract

Excretory organs open from the coelom in the annelids and lower **vertebrates,** and the liquid which it contains is apparently supplementary to the blood In all cases the cavity furnishes a space into which developing organs may expand in complex animals (A W L)

COELOMATA. Animals which have a **coelom** The term embraces the phyla **Bryozoa, Brachiopoda, Phoronidea, Chaetognatha, Echinodermata, Mollusca, Annelida, Arthropoda,** and **Chordata** (A W L)

COELOMODUCT. A tubule opening at one end into the coelom and at the other on the surface of the body It occurs in a simple form in some **annelid** worms as an excretory organ and in other species is associated with the **nephridial** tubule to form a more complex excretory structure Coelomoducts are regarded as the evolutionary forerunners of the excretory tubules of **vertebrates** See **excretory system** (A W L)

COELOSTAT. In many types of astronomical research it is desirable to have the main instrument stand still To accomplish this purpose and also allow for the apparent motion of the **celestial sphere** it is necessary to reflect the light by a moving mirror from the object in question into the instrument Such a device which "makes the sky stand still" is known as a coelostat In the coelostat a mirror is mounted parallel to the polar axis of an **equatorial** mounting The axis is rotated by clock work from east to west at such a rate that it would complete one rotation in forty-eight hours of **sidereal time** Since the celestial sphere rotates from west to east once in twenty-four hours of sidereal time, and reflection doubles the angle, this rotation of the polar axis will compensate for the apparent rotation of the celestial sphere With one single mirror mounted in the manner described the direction in which the light will be reflected will depend entirely upon the declination of the object observed To obtain any desired direction of reflection a second mirror is employed to send the stationary beam from the first mirror in the desired direction

In case it is desired to hold an image of the sun apparently stationary the polar axis must be rotated once in forty-eight hours of solar time Such an instrument is known as a heliostat Other types of mounting, used for particular purposes, are known as siderostats. (W K G)

COENENCHYME The middle and outer tissues of certain coelenterates (**Alcyonaria**) (A W L)

COENOCYTIC CELLS. There are many plants which are composed of **cells** each containing many **nuclei** In some cases the entire plant is a single cell, no cross-walls being formed until **reproduction** takes place Multinucleate cells of this sort are called coenocytic cells The **Phycomycetes** contain many plants of this kind, as do also the green **algae.** (R M W)

COERCIVE FORCE. Magnetism.

CO-FACTOR OF A DETERMINANT. Determinants.

COFFEE. *Coffea arabica* Rubiaceae Probably the coffee plant is a native of Ethiopia In early historical times it was recognized as a valuable drink by the Arabs, who were responsible for its introduction into Europe The cultivation of coffee slowly spread throughout the Old World and later, beginning in 1720, in the New World The plant is a small tree with dark green leaves and fragrant white star-like flowers borne in axillary clusters The fruits are about half an inch long, have a deep crimson skin and a yellow pulp surrounding the two seeds within These seeds are the coffee beans

The trees grow best in well-drained soil in regions entirely free from frost In cultivation, the trees are grown from seed and begin bearing fruit in four or five years, continuing to bear up to 30 years Seed production, once started, is more or less continuous throughout the year The berries are gathered from the trees by threshing, or by hand, a costly operation in regions where labor is expensive The berries are separated from any dirt present by washing, the heavy berries sinking to the bottom and the trash washing away. After this the pulp surrounding the seeds is largely removed by machines, and the seeds allowed to ferment slightly They are then spread out to dry in the sun, or sometimes they are dried artificially This permits the removal of any remaining pulp and of the thin inner skin which surrounds the seeds The seeds are then ready to be bagged and shipped

Before they are ready for the consumer the coffee beans must be carefully roasted Roasted coffee contains from 1–2% of the alkaloid **caffeine,** which acts as a diuretic and as a cerebral stimulant The aroma of coffee is due to an oily substance, caffeol, which is quickly oxidized when exposed to the air By means of modern vacuum packing, this substance is preserved unchanged. Coffee also contains **glucose, dextrin,** and **protein**

Brazil is one of the greatest coffee-producing countries in the world The only important product of the coffee tree is the widely used beverage

In many Eastern countries other species of coffee, as *Coffea liberica* and *robusta,* are planted to some extent, because of their greater resistance to diseases which have seriously reduced the better *Coffea arabica* plantations. (R M W)

COFFERDAM. A cofferdam is a structure of a temporary nature, used to exclude water from an otherwise submerged area, for the purpose of preparing for **foundations** or for other subaqueous construction Cofferdams are frequently required both above and below the site of a permanent dam in order to by-pass the stream through a temporary channel during the construction period The simplest cofferdam is an earth dyke which should be used only in shallow water where there is little or no current Facing an earth cofferdam with sand bags or constructing it entirely of sand bags will make it serviceable when there is a current which would wash away loose materials

If the depth of the water to be held back by the cofferdam exceeds that for which the earth dam is practicable (approximately five feet) other types must be constructed Sheet piling (See **Piles**) can be used to form a cofferdam around a site by erecting it in double parallel walls, the space between being filled with sand or gravel and clay This mixture is thoroughly tamped in order to form a solid filling This materially adds to the stability of the structure Where a small area is to be unwatered, a single wall of sheet piling, internally braced, may be erected around the site

When cofferdams, constructed of sheet piling, are to rest on hard bottom, a timber framework is required to hold the sheeting in place These frames are generally built on shore, floated into position and sunk into place Sheet piling is then placed around the outside and banked with earth

After the cofferdam has been completed it must be unwatered by pumps As sheet piling is not entirely watertight, leakage must be pumped out in order to keep the interior as dry as possible (C W C, F T M)

COFFER FISH. Pisces, Teleostei Strangely shaped tropical marine fishes (**Pisces**) whose bodies are enclosed in bony plates (A W L)

COG. A cog is a tooth mounted on the periphery of a wheel, and intended to mate with a somewhat similar cog on another wheel On a cogwheel the entire circumference is occupied by spaced cogs In the strict sense a gear is a cogwheel, but mostly the word cog implies a comparatively rough type of tooth of fairly large dimensions, and the common machine cut gear (See **Gearing** and **Gear Teeth**) is not thought of as a cogwheel An example of the cogwheel is the heavy rough type used on a cog railway A cogwheel on a locomotive engages with a rail fixed to the roadbed The cog way (or cog railway) is used when the gradient of the roadbed is so steep that the conventional locomotive which receives its traction through friction, cannot be used The cogwheel and rail replace friction traction by a positive type (F T M)

COHERENCE Interference.

COHESION Adhesion.

COINCIDENCE METHOD. Physical Measurements

COIR. The outer husk of the **coconut** is composed of coarse rough brown fibers, and is known as coir These fibers are light, tough, and extremely resistant to heavy wear, as well as to wetting They are therefore much in demand for making doormats, cordage, coarse matting, and stuffing for upholstery Coarse brushes are made from shorter fibers India and Ceylon supply the greater part of the crop (R M W)

COITUS. Sexual intercourse, **copulation.** (R S M)

COKE Coke is a solid product obtained by heating **coal** (in practice, bituminous coal) in a furnace without access of air Coal is composed of moisture, ash, "fixed" carbon, and hydrocarbons which are volatile, in that they are distilled from the coal by the application of heat When coal is subjected to intentional and controlled distillation, the volatile matter and moisture are driven off and the residue, consisting of the fixed carbon and the ash-forming substances, is commercial coke The yield of coke from a coke oven may be only about three-quarters of that which might be expected upon the basis of the coal analysis The volatile products of the distillation are comprised of water, coal-tar, and gas The coal-tar is a complex mixture, containing many substances of value to industry, especially to the chemical industry The gas is widely used as an industrial fuel

Since the smoke-producing constituents are driven off during the "coking" of the coal, the coke forms a desirable fuel for stoves and furnaces in which conditions are not suitable for the complete combustion of the bituminous coal itself Coke may be burned with little or no smoke under combustion conditions which would result in a large amount of smoke were bituminous coal the fuel Coke is the standard fuel for metallurgical purposes, i e, cupola and blast furnace heating

The solid residue remaining from the refining of petroleum by the "cracking" process is a form of coke. Petroleum coke has many commercial uses besides being a fuel, and is employed in the manufacture of dry cells, electrodes, etc Gas works engaged in the manufacture of coal gas also have a coke end-product This is called gas house coke (F T M)

COKITE. The term applied by Lacroix in 1917 to natural **coke**, the result of the **contact metamorphism** of coal beds (R M F)

COL Cirque.

COLA. *Cola acuminata*, and other species Sterculiaceae Cola nuts are the **cotyledons** of trees growing native in the West African forests The natives chew the fresh nuts, finding therein stimulation to prevent fatigue From the dried nuts is made a beverage used in Africa

The nuts contain up to 3% **caffeine** and 2% **tannin**, as well as small amounts of **theobromine** They are used in the manufacture of beverages (R M W)

COLEMANITE. The mineral colemanite is a **borate** of **calcium** corresponding to a formula which is perhaps best represented as $Ca_2B_6O_{11}\ 5H_2O$ It occurs either as massive deposits or in **monoclinic** crystals It has a subconchoidal fracture, hardness, 4–4 5, specific gravity, 2 42, vitreous to adamantine lustre, may be colorless to milky white, grayish or yellowish, transparent to translucent Colemanite was found originally in Death Valley, Inyo County, California, and has since been found rather widely distributed in San Bernardino, Los Angeles, Kern and Ventura Counties, California, as well as in Clark, Esmeralda and Mineral Counties in Nevada

Colemanite was, until the discovery of **kernite**, the chief source of borax Kernite, $Na_2B_4O_7\ 4H_2O$, because of its easy solubility in water, has displaced very largely other boron bearing minerals as a source of borax Colemanite, kernite and **inyoite** (probably $2CaO \cdot 6B_2O_3\ 13H_2O$) are lake deposits associated with other and rarer boron minerals, laid down during periods of volcanic activity or resulting from the leaching of the adjacent Tertiary sedimentary formations Colemanite was named for Mr William T Coleman of San Francisco, Kernite and Inyoite were named from Kern and Inyo Counties, California (E S C S)

COLEOPTERA The beetles An order of insects usually recognizable by the thickened wing covers which meet in a straight line down the middle of the back These wing covers, or elytra, are modified fore wings In most species of beetles they are thickened or horny but in some they are soft In some species they are divergent and in some they are short, leaving much of the abdomen exposed The typical condition of the elytra is found outside of this order only in the earwigs Beetles have biting mouth parts and a complete metamorphosis in which the larval stage is often a grub

This order of insects is the largest group of its rank in the animal kingdom, with almost 200,000 described species It embraces almost the entire range of adaptation of the class, although very few beetles are parasitic Many species are of economic importance (A W L)

COLEOPTILE. In the **seeds** of grasses the primitive **bud** or **plumule** is enclosed in a protective sheath called the coleoptile During germination of the seed this coleoptile elongates, pushing its way out of the seed and up through the soil It is very sensitive to light, growing directly towards a beam of light (R M W)

COLIC. This is a general term denoting abdominal pain which comes on quickly and which is sharp and penetrating in character Biliary colic is a sharp severe pain that occurs with the passing of **gall stones** through the **bile** passages Lead or Painter's colic is abdominal pain due to **lead** poisoning Menstrual colic is a pain that occurs during the **menstrual** period Renal colic is a sharp severe pain that occurs with the passing of a **stone** through the **ureter**, etc (R S M)

COLITIS. Inflammation of the wall of the **colon** which may be due to a number of causes. Amebic colitis or amebic dysentery is colitis caused by the parasite *amebi coli.* Spastic colitis is inflammation of the colon accompanied by severe spasticity of its muscular walls. Mucus colitis is a chronic disorder of the colon chiefly seen in nervous or neurotic subjects. It is characterized by passage of mucus, constipation, or diarrhea and spasm of the walls of the colon. Non-specific ulcerative colitis is widespread infection of the colon with ulcer formation, diarrhea, and constitutional symptoms. It is a chronic disease having acute exacerbations the cause of which is unknown. It is difficult to treat. (R.S.M.)

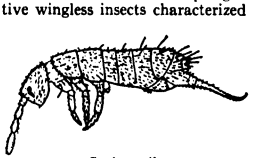
COLLAPSE. Extreme prostration with failure of the circulation occurring at times in severe illness. Collapse of the lung is a condition where a portion of the lung becomes airless. This is usually due to a plug of mucus obstructing the bronchial passages to the portion of the lung involved. (R.S.M.)

COLLAPSE THERAPY. A method of treatment in tuberculosis where the diseased lung is put at rest to promote healing. It may be done by injecting air into the chest cavity—(See **Pneumothorax**) or surgically, by removal of a portion of a number of ribs, thus allowing the soft parts to fall together—(See **Thoracoplasty**). (R.S.M.)

COLLAR. A fold or ridge of tissue more or less completely encircling the body behind its anterior end. In the snails, cuttle fishes, and related mollusks the ventral edge of the mantle is called the collar and in *Balanoglossus* (**Chordata**) the region of the body between the proboscis and the trunk is so named. (A.W.L.)

COLLAR CELL. A cell bearing a **flagellum** at one end, surrounded by a high membrane. Some of the one-celled animals and the choanocytes of sponges have this form. (A.W.L.)

COLLEMBOLA. The spring-tails. An order of primitive wingless insects characterized by a forked appendage at the tip of the body which is used in leaping. This appendage is bent forward beneath the body and when released snaps sharply down and back, projecting the animal into the air.

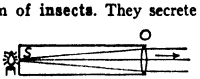


Spring-tail.

Spring-tails are small and delicate. They are found mostly in moist places on the ground or on bark, though a few species live in dry hot situations. The snow flea, which sometimes appears in large numbers on the surface of snow, is a spring-tail. Some species are found on the surface of water. (A.W.L.)

COLLES'S FRACTURE. A fracture of the arm near the wrist. Specifically, this type of fracture is one in which the radius is broken in its lower one-fourth. It is one of the most common of fractures, and occurs from a fall on the outspread hand, or a direct blow against the wrist. (R.S.M.)

COLLETERIAL GLANDS. Glands associated with the female reproductive system of **insects.** They secrete materials which cement the eggs together or form a protective covering over them. (A.W.L.)



Divergent rays from slit S rendered parallel by objective O.

COLLIMATOR. An optical arrangement for producing parallel rays of light. A common form consists of a converging **lens,** at one of whose focal points is placed a small source of light, usually a pinhole or narrow slit upon which light is focused from behind. Rays diverging from this focal point emerge from the objective **lens** in a parallel beam. The slit or other source is viewed through the collimator without parallax, since it appears at an infinite distance. The arrangement is very generally used on **spectroscopes** and spectrometers. (L.D.W.)

COLLISION. As used in physics, this term refers to any encounter between free bodies in which they come near enough to exert a mutual influence, generally with exchange of energy. It does not necessarily imply actual contact. The process is subject to conservation of momentum, and in an "elastic collision," also to conservation of energy. In the latter case, if the initial velocities are given, the velocities of the bodies after collision can be calculated by applying these two conservation principles. The subject is of special significance in the case of **atoms, molecules,** etc. Collisions of this type between two parties A and B are denoted as of the "first class" or the "second class" according as (1) particle A loses kinetic energy and thereby affects B in some way, or (2) particle A communicates to B energy which it has by virtue of excitation or ionization. In either case B may receive additional kinetic energy or may be excited or ionized by the energy given to it by A. (L.D.W.)

COLLOBLAST. An adhesive cell used by the comb jellies (**Ctenophora**) in catching prey. Lasso cell. (A.W.L.)

COLLOIDAL STATE. All living matter is built up of colloidal materials, and almost all of our food, clothing and shelter materials are colloidal. The colloidal state is determined by the size of the particles of the substance, being intermediate in size between visibly suspended particles and invisible molecules. Turbid suspensions, visible to the naked eye or by means of the ordinary microscope, consist of particles of 250 millimicrons (250×10^{-7} cm.) or larger diameter, and molecules invisible by the **ultramicroscope** are of 5 millimicrons (5×10^{-7} cm.) or smaller diameter. True suspensions, such as fine clay in water, settle on standing, but colloidal suspensions exhibit continuous random motion—so-called Brownian movement—of the suspended particles. **Diffusion** through animal membranes or parchment paper is negligible for substances in the colloidal state, whereas for true solutions diffusion is marked. Phenomena related to vapor pressure, freezing point, osmotic pressure of solvent or dispersion medium are marked in the case of true **solutions** but negligible for emulsions, like milk, emulsoids like gelatin, boiled starch, silicic acid, and suspensoids like **arsenious** sulfide sol, **sulfur** sol, **gold** sol, **ferric** hydroxide sol, clay (**ammonium** hydroxide) sol. In the case of emulsoid sols, the **surface tension** is lower than that of the dispersion medium, the **viscosity** is greater than that of the dispersion medium, and, in the case of organic emulsoid sols, the solid may be recovered from and redispersed in the medium at will, that is, they are reversible—for example, gelatin-water sol—and in the case of inorganic emulsions the system is non-reversible—for example, silicic acid-water sol. Particles of colloidal dimensions possess an **electric charge,** either positive or negative, and by treatment with certain **electrolytes** or colloids or by action of the electric current the electric charge is neutralized and the particles are coagulated.

The subdivided phase, corresponding to the solute in solutions, is called the dispersed phase, and the enveloping phase, corresponding to the solvent in solutions, the dispersing or continuous phase. Where both phases are continuous, the distinction between dispersed and dispersing phases merges into an interlacing system. Most of the stable colloidal systems are dependent for their stability on the presence of a protective colloid or sta-

bilizer. Thus gelatin is added to milk and to ice-cream to stabilize the colloidal system, and mustard flour (1 0%) and egg yolk (8 0%) serve as stabilizers in mayonnaise dressing where as much as 75% of oil is dispersed in 16% of water phase, which phase contains acetic acid and salt about 1 0 and 1 5 parts per 100 of the total mayonnaise mixture (Corran, 1935).

A jelly is a completely transparent elastic mass, a gel is a flocculent and gelatinous precipitate Jellies may be obtained without marked interference with the **equilibrium** in the solution, formation of gels disturbs radically the equilibrium in the solution Fruit jellies and soap jellies are familiar examples, silicic acid gel is produced by addition of hydrochloric acid to sodium silicate solution In using **pectin** for the production of jellies, the practical conditions are maximum concentration of pectin 0 97% of the weight of the finished jelly, pectin-sugar ratio definite for a given pH (See **Reactions Involving Recombination of Ions**), sugar 50% to 70%, maximum pH 2 9 to 3 1, with 50% dry material at least 1 2% pectin, with 70% dry material 0 6% pectin

Finely divided clay forms a colloidal suspension—is peptized—in water when treated with ammonium hydroxide or with tannin Acheson made use of this principle when he used tannin to peptize finely divided graphite for lubricants He relates that upon looking up the literature, he could find only one instance of the use of vegetable matter in clay working That was in the Bible where the Egyptians used straw in the making of bricks Since straw contains no tannin he wondered what the effect could be Upon boiling straw with water he found that about half of the straw dissolved in water, and that the solution produced the same results with clay that tannin produced He states that he found, in one case, that a sun-dried brick made of treated clay was of greater tensile strength than a burned one made of the untreated clay

Particles of a given substance may be brought into the colloidal state in one of two ways, namely, (1) by comminution or dispersion from macroscopic size—visible to the eye—to ultramicroscopic or colloidal size, (2) by precipitation or condensation from sub-ultramicroscopic, molecular or solution size to colloidal size, either without or with accompanying particles large enough to settle out of the medium

Dispersion Processes (1) The simplest method of accomplishing dispersion is by grinding the solid (or liquid) material with the liquid medium until particles of the required size are ultimately obtained The colloid mill (Plauson, 1921) is used for such purpose, as in mixing paints and pastes, regenerating milk from milk powder, dispersing cellulose in **sodium** hydroxide and **carbon disulfide** for the production of xanthates for viscose, and in emulsifying fats and waxes (2) **Zinc** sulfide, **cupric** ferrocyanide, **stannic** acid, **silver** chloride are examples of precipitates which, when washed on the filter paper until the accompanying soluble electrolyte has been removed, form colloidal solutions and pass through the pores of the paper Since this is usually to be avoided in practice, the washing is then done with an electrolyte which does not conflict with the treatment to follow Frequently **ammonium** nitrate solution is used (3) A peptizing agent is frequently employed **Tannin** is peptized by water, and by glacial **acetic acid** Soaps are peptized by water Gelatin swells in cold water but is not peptized, but is peptized in warm water Starch, although insoluble in cold water, behaves similarly to gelatin with warm water (63° to 74° C, depending upon the kind of starch). Cellulose nitrate swells in ethyl alcohol and not in ether, but is peptized in ethyl alcohol-ether mixture Clay is peptized by ammonium hydroxide, and it is held by some that the action of sodium hydroxide on **zinc, aluminum,** and **chromium** hydroxides is one of peptization (4) Water peptizable colloidal substances such as gelatin, dextrin, gum arabic, and soap peptize many precipitates, and are often called protective colloids Gelatin in the solution prevents the precipitation of silver dichromate upon mixing silver nitrate and potassium dichromate solutions (See Condensation Processes, below) (5) When dilute **silver** nitrate and dilute **potassium** bromide solutions are mixed so that there is a slight excess of either solution silver bromide is peptized Acheson's oil-dag and aquadag are suspensoids of graphite in oil or water containing a protective colloid, **tannin** Oil-dag contains about 15% of a "deflocculated graphite," and is used in dilute solution in lubricating oil (about 0 1% **graphite**) Bearings gradually become coated with a thin layer of graphite

Condensation Processes (1) When a solution of **ferric** chloride is poured into a relatively large volume of boiling water, colloidal ferric hydroxide is formed The ferric hydroxide sol does not react with hydrogen sulfide nor with **potassium** ferrocyanide, and like all colloidal substances does not pass readily through animal membranes or parchment (2) When **hydrogen sulfide** is passed into a solution of **arsenious** oxide, arsenious sulfide sol is formed which in the absence of an electrolyte may be made of the high concentration of 60 grams of arsenious sulfide per 100 grams of water Upon addition of **hydrochloric acid**, arsenious sulfide coagulates and is precipitated (3) When hydrochloric acid is added to **sodium** silicate solution either silicic acid sol or silicic acid gel is formed (4) When hydrogen sulfide solution is treated with an oxidizing agent, for example, the proper concentration of nitric acid, sulfur sol is formed (5) When **gold chloride** very dilute solution (0 01% to 0 001% of gold chloride) is made slightly alkaline (say by the addition of magnesium oxide) and then treated with a reducing agent, for example, formaldehyde or sodium hyposulfite ($Na_2S_2O_4$), red gold sol is formed (6) Use of a protective colloid in solution prevents the formation of the ordinary and expected precipitate in many cases and causes the formation of the expected substance as colloidal sol **Silver** nitrate (0 6 gram per liter) and **potassium** dichromate (0 5 gram per liter) to one of which is added 0 1 volume of hot gelatin solution (2 grams per 100 milliliters of water) are mixed with stirring silver dichromate is formed (7) When an electric arc is formed under water between two metallic rods, particles of the metal of colloidal size are formed along with more or less separation of free metal A protective colloid increases the stability If the metal vaporizes and then condenses to the colloidal state this is a condensation process, if otherwise, a dispersion process

The disappearance of the colloidal state of a substance may be accomplished in either of two directions, namely, by the colloid passing into solution or into suspension Practically, the latter is the more important method Coagulation, agglomeration or precipitation is readily brought about by discharge of the electric charge on the particles Ions carrying a charge of opposite sign to that carried by the colloidal particles are active precipitants, and the higher the valency of the ion the more effective (Linder-Picton-Hardy) When the colloidal particles are made neutral the conditions are least favorable to their stability For colloidal arsenious sulfide, which is negatively charged in water, the coagulating power of potassium iodide (K^+I), calcium chloride ($Ca^{2+}Cl_2$), aluminum chloride ($Al^{3+}Cl_3$) is in the ratio of 1 80 1500 (Svedberg), and for colloidal ferric hydroxide, which is positively charged in water, the coagulating power of potassium chloride (KCl^-), potassium sulfate ($K_2SO_4^{2-}$) is in the ratio of 1 45 The active ion is carried down with the precipitated particles Oppositely charged colloids, e g, arsenious sulfide and ferric hydroxide, when mixed, precipitate each other Other methods of coagulation are by migration of colloidal particles to and their discharge at electrodes, and by heating, as in the case of egg albumin Coagulation is usually irreversible, especially when caused by electrolytes

An interesting case, operating on a large scale in nature, of the precipitation of a colloidal system by an

electrolyte is that of the action of sea water on the mud and silt of river water entering the ocean. When river water flows into the ocean the former, on account of its lower specific gravity, tends to flow over the latter and spread out in widening range. As the current diminishes some of the suspended mud and silt settles out, but the finer colloidal particles are coagulated by the electrolyte of the sea water and form deltas at the mouths of rivers.

Scope and Importance of the Colloidal State. As was stated in the beginning all living matter, whether animal or plant, is made up of colloidal materials and is sustained by colloidal processes. Of similar importance is colloidal chemistry in everyday living, in almost all of our foods, such as proteins and starches, in our clothing, whether of natural or synthetic origin, and in our shelter materials, such as wood, bricks, concrete. When there is added to these other common things and operations of everyday life, such as pottery and porcelain, paper, rubber and leather, and cooking and washing, where colloidal matter and processes operate, it is evident how broad is the scope and how great is the importance of the field. To these there must also be added other applications in the realm of industry, such as dyeing, printing, photography, water purification, smoke prevention, ore flotation, sewage disposal and soil preparation, paints, varnishes and lacquers, plastics, adhesives, and innumerable other operations and materials. (R.K.S.)

COLLUM. 1. The dorsal plate of the first body segment in the millipedes (**Diplopoda**). 2. Any necklike part or structure. (A.W.L.)

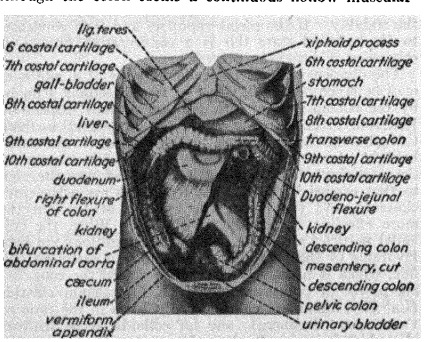
COLOB. Mammalia, Primates. *Colobus.* African thumbless **monkeys** of several species. (A.W.L.)

COLOCOLLO. Mammalia, Carnivora. A small **cat** of northern South America. It is light gray marked with black. (A.W.L.)

COLOCYNTH. *Citrullus colocynthus.* **Gourd Family.**

COLOGARITHMS. Logarithms.

COLON. The large intestine which extends from the cecum to the rectum. It is divided into several parts, although the colon forms a continuous hollow muscular



The abdominal viscera after the removal of the jejunum and ileum. (Cunningham, *Textbook of Anatomy*, Oxford Press.)

tube. The ascending colon extends from the lower right side of the abdomen at the termination of the small intestine, upward to the under surface of the liver, where it turns to the left and runs across the abdomen to the lower border of the spleen as the transverse colon. Beneath the spleen it bends downward, descending along the left side of the abdomen as the descending colon. As it enters the pelvis the colon makes a double curve, similar to the letter S. This portion is known as the sigmoid colon. The end of the sigmoid colon terminates in the rectum.

The functions of the colon are (1) final absorption of the products of digestion, (2) absorption of fluid from the feces so that this material becomes semi-solid, (3) removal of the fluid waste products into the rectum.

The principal diseases of the large intestine are **cancer, tuberculosis, diverticulitis, polyp** formation, and **colitis.** (R.S.M.)

COLONY. A group of individuals of the same species living together for mutual benefit. They may be structurally united or separate and may be alike in form or of different types suited for various functions. (A.W.L.)

COLOR. This vast subject is complicated by the distinction between the physical basis of colors and the sensations produced by them; and still further by a somewhat confused and unsettled vocabulary.

If one looks at two surfaces of the same size and shape, equally illuminated, and at the same distance, his only means of distinguishing them is by what is called their "color." To a physicist, the color means the **spectral energy distribution** of the light emitted or reflected by the surface. One may, however, specify it more simply, though less accurately, in terms of a limited number of variables employed in color measurement or colorimetry.

The practical standard "white" light is direct noon sunlight. A "perfectly white" surface would reflect white light completely without any alteration. No such surface exists. Even snow does not reflect white completely, though it does reflect all visible wave lengths in the same proportion. Its color is one of the "grays" or achromatic colors, of very high "brilliance"; while that of a lead-pencil mark is a much feebler achromatic color. A "black" surface would reflect no light at all (See **Black Body**). Most colors, however, are chromatic, that is, they exhibit "hue," because their spectral energy distribution differs so much from that of white or gray that they look "reddish," "bluish," etc. Some colors of the same hue are more "brilliant" than others. Just as snow is of a more brilliant gray than graphite, so bright red is more brilliant than dark red. Further, some colors have greater purity or "saturation" than others; that is, they have more pronounced hue, or are more chromatic, and therefore differ more from a gray of the same brilliance. Thus foliage looks "greener" when freshly washed than when dusty. A chromatic color having little hue but high brilliance is a "tint," e.g., pink; while one of little hue and low brilliance, like brown, is a "shade."

We must now recognize the fact that the same color sensation can be produced by entirely different physical stimuli. Tests of a large number of observers with the spectrometer indicate that, according to the average judgment, the common names of pure spectral hues should be applied to the several wave-length ranges approximately as follows:

	Angstroms		Angstroms
Violet.....	3900 to 4550	Yellow.....	5770 to 5970
Blue.....	4550 to 4920	Orange.....	5970 to 6220
Green.....	4920 to 5770	Red.....	6220 to 7700

But the sensations produced by any of these, or by any of their tints, shades, or mixtures, can also be produced in a variety of other ways. For example, red and green light may be mixed to produce a good imitation of yellow light, though no yellow wave lengths are present in the mixture.

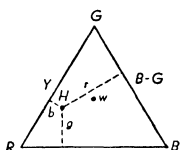
According to the Young-Helmholtz theory, the human vision has three separate color sensations, each capable of stimulation in various degrees. It is thought that, if stimulated separately, they would prove to be the sensations produced by red, blue, and green light, respectively. But they always act together, and every color sensation is the effect of their joint stimulation in some

definite proportion. A result of this is that any color can be successfully imitated by adding together red, blue, and green light with suitable relative intensities These are therefore called "additive primaries" If added in equal intensities, they produce a sensation of white This may, however, be produced also by adding in suitable proportions various pairs of pure spectral hues, which are "complementary" to each other, thus

Angstroms	Angstroms
6562 and 4921	5671 and 4645
6077 and 4807	5644 and 4618
5853 and 4854	5636 and 4330
5739 and 4821	

(The third pair, for example, is a certain yellow and a certain blue)

Color sensations are, however, commonly produced by removing certain components from white light, as by the use of filters Pigments such as paint and colored inks act in this way, being selectively reflective The complementary hues of the three additive primaries are the "subtractive primaries" blue-green (for red), yellow (for blue), and purple (for green)



Color triangle

Maxwell devised an ingenious graphical scheme, called the "color triangle," for representing mixtures of colored lights (not pigments) The three additive primaries *R, B, G,* are at the vertices of an equilateral triangle, with their complementary subtractives *B-G, Y, P* on the sides opposite Each altitude, as *PG,* is taken as 100% Any hue is represented by a point *H,* whose distances *r, b, g,* from the three sides represent the percentages of the three primaries *R, B, G* which must be added to imitate it $(r + b + g = 100)$ Thus for the point *H* in the figure, $r = 60$, $b = 10$, $g = 30$, giving a reddish yellow sensation The point *W,* at the center, corresponds to the sensation of white (L D W)

COLOR INDEX. The human eye is more sensitive to red light than is the photographic plate, while the latter is the more sensitive to the green and blue regions of the **spectrum** than is the eye Accordingly, if we have a blue and a red star of the same apparent brightness, or in other words, the same visual **magnitude,** the blue star will make a much stronger image on the photographic plate than will the red Hence, the scale of magnitudes determined from a sequence of stars of different colors, when determined photographically, will be different from that determined visually The difference between the photographic and visual magnitude of any given star is known as the color index of the star The algebraic sign of the color index is determined from the relation photographic magnitude — visual magnitude = color index

Since the **spectral type** of a star is also a function of the color of the star, we should expect to find a definite relationship between color index and spectral type The "zero point" of the scale of photographic magnitudes has been defined in such a manner that the color index is zero for an Ao type star between 5 5 and 6 5 magnitudes For the other spectral classes the values of the color index are approximately ·

B	A	F	G	K	M
−0 24	0 00	+0 28	+0 56	+1 00	+1 35

In accordance with the theory of **black body radiation,** the apparent color of a radiating gas should be a function of the temperature of the gas and color index may be used as an approximate method for the determination of the temperatures of the stars (W K G)

COLORADO POTATO BEETLE. Insecta, Coleoptera A leaf-eating **beetle,** *Leptinotarsa decemlineata,* native to the western United States Originally it fed on a native plant but about the middle of the nineteenth century it became troublesome in potato fields and rapidly spread across the country. Both larva and adult eat the leaves of potato plants They can be checked by the use of Paris green or lead arsenate used as a spray (A W L)

COLORATION. The coloration of animals embraces both the colors that appear in their bodies and the patterns in which they are arranged In many species color appears to be incidental but in others coloration has an important bearing on the life of the individual

Colors are due in some cases to the presence of compounds which are important for other reasons. The blood of insects, for example, may be green, that of certain mollusks blue, and that of the vertebrates and annelid worms red because of their chemical composition (See **Protein**), but these colors have no important bearing on individual life The black pigment found in eyes is a protection against random light rays but any impervious layer would be as effective, black color is unimportant in itself

In many animals colors of this kind are supplemented by special pigments located in the superficial layers of tissue and in the vestiture, such as hair, feathers, and scales The surface of the integument in insects is often formed so that it breaks up light rays and reflects only a portion of them The colors produced in this way are called physical colors and are usually metallic or glassy All of these colors, whether physical or pigmental, are often arranged in intricate patterns characteristic of the species In this arrangement details may be observed in some animals which seem to have definite value in relating the individual to its environment

The white tail patch found in some **deer** and **rabbits** has been interpreted as a signal mark It may serve for ready recognition in poor light and may catch the attention of other members of a group when danger is near

Warning colors are exemplified by the brilliant red and yellow of the **coral snakes** Poisonous or distasteful animals are usually avoided as food and conspicuous appearance makes it all the easier for other animals to see and avoid them

Concealing colors render the animal less conspicuous in its normal environment, and are essentially the same in the hunter and in the hunted The white winter coats of the **prairie hare** and of the **weasel** are equally inconspicuous against the snow, but the one animal is helped to escape its enemies and the other to catch its prey by this means Concealing colors may also be in patterns The black and tawny stripes of the **tiger,** for example, are said to conceal it admirably in tall grasses lighted by the sun, where vertical shadows are conspicuous This aspect of coloration, however, merges with protective **mimicry,** and in mimicry physical form is involved as well as coloration (A W L)

COLOSTRUM. The fluid secreted by the breast a few days before and after the birth of the child, before the start of the secretion of true milk It is a thin watery fluid containing considerable albumin (R S M)

COLUMBIFORMES. The order of birds (**Aves**) containing the **pigeons** and **doves** (A W L)

COLUMBIUM or **NIOBIUM.** Symbol Cb Atomic number 41 Atomic weight 92 91 Density. 8 4 Melting point 1950° C

Columbium is a slightly bluish metal, ductile, malleable, and when polished resembles platinum, burns upon being heated in air, insoluble in **hydrochloric** or **nitric acid,** but soluble in **hydrofluoric acid** or a mixture of hydrofluoric and nitric acids Discovered by Hatchett in 1801

Columbium occurs, usually with tantalum, in columbite ($Fe(CbO_3)_2$, 80% Cb_2O_5), pyrochlore (50% Cb_2O_5), samarskite (50% Cb_2O_5). chiefly found in western Aus-

tralia, and South Dakota Recovered along with **tantalum** by fusion with **potassium** bisulfate, and obtained in the residue after subsequent extraction with water Columbium and tantalum are separated by fractional crystallization of the potassium fluorides, columbium concentrating in the mother liquor and tantalum in the crystals Chemically related to **vanadium** and **tantalum.**

Chlorides Columbium trichloride ($CbCl_3$), columbium oxychloride ($CbOCl_3$), white solid, columbium pentachloride ($CbCl_5$), yellow crystals, melting point 194° C, boiling point 240° C.

Columbates (Columbium of valence plus 5)

Fluoride: Columbium potassium fluoride ($K_2CbF_5 \cdot H_2O$)

Oxides Columbium monoxide (CbO) (sometimes called dioxide, Cb_2O_3), columbium trioxide (Cb_2O_3), columbium dioxide (CbO_2) (sometimes called tetroxide, Cb_2O_4), columbium pentoxide (Cb_2O_5) (R K S)

COLUMELLA. 1 The axis of the spiral shell of a snail 2 A bone in the middle ear of amphibians, reptiles and birds (A W L)

COLUMN. A slender structural compression member, standing vertically, is a column The ratio of the length of the column to the least **radius of gyration** of its cross-section is called the slenderness ratio This ratio affords a means of classifying columns A short steel column is one whose slenderness ratio does not exceed 50, an intermediate length steel column has a slenderness ratio ranging from 50 to about 200, while a long steel column may be assumed as one having a slenderness ratio greater than 200 A short concrete column is one having a ratio of unsupported length to least dimension of the cross-section not greater than 11 If the ratio is greater than 11 it is a long column Timber columns may be classed as short columns if the ratio of the length to least dimension of the cross-section is equal to or less than 10 The dividing line between the intermediate and long timber columns cannot be readily evaluated One way of defining the lower limit of long timber columns would be to set it as the smallest value of the ratio of length to least cross-sectional dimension that would just exceed a certain constant K of the material Since K depends upon the **modulus of elasticity** and the allowable compressive **stress** parallel to the grain it can be seen that this arbitrary limit would vary with the species of timber The value K is given in most structural handbooks

If the load on a column is applied through the center of gravity of its cross-section it is called an axial **load** A load at any other point in the cross-section is known as an eccentric load A short column under the action of an axial load will fail by direct **compression** but a long column loaded in the same manner will fail by buckling (bending), the buckling effect being so large that the effect of the direct load may be neglected The intermediate length column will fail by a combination of direct stress and bending

In the middle of the eighteenth century a mathematician named Euler derived a formula which gives the maximum axial load that a long, slender ideal column can carry without buckling An ideal column is one which is perfectly straight, homogeneous and free from initial stress This maximum load, sometimes called the critical load, causes the column to be in a state of unstable equilibrium, that is, any increase in the loads or the introduction of the slightest lateral force will cause the column to fail by buckling The Euler formula for columns is given below

$$P = \frac{K\pi^2 EI}{l^2}$$

in which P = Maximum or critical load
E = Modulus of elasticity
I = Moment of inertia of cross-sectional area
l = Length of column
K = A constant whose value depends upon the conditions of end support of the column For both ends free to turn $K = 1$, for both ends fixed, $K = 4$, for one end free to turn and the other end fixed $K = 2$ approximately, and for one end fixed and the other end free to move laterally $K = \frac{1}{4}$.

Examination of this formula reveals the following interesting facts with regard to the bearing power of columns First, that elasticity and not compressive strength of the materials of the column determines the critical load Secondly, the critical load is directly proportional to the moment of inertia of the cross-section The strength of a column may therefore be increased by distributing the material so as to increase the moment of inertia This can be done without increasing the weight of the column by distributing the material as far from the principal axes of the transverse section as is possible consistent with keeping the material thick enough to prevent local buckling This bears out the well-known fact that a tubular section is much superior to a solid section for column service Another bit of information that may be gleaned from this equation is the effect of length upon critical load For a given size column doubling the unsupported length quarters the allowable load

Since the moment of inertia of a surface is its area multiplied by the square of a length called the **radius of gyration,** the above formula may be rearranged as follows Using the **Euler** formula for hinged ends, and substituting Ar^2 for I the following formula results

$$\frac{P}{A} = \frac{\pi^2 E}{\left(\frac{l}{r}\right)^2}$$

$\frac{P}{A}$ is the allowable unit stress of the column, and the quantity $\frac{l}{r}$ is known as the slenderness ratio This ratio is an important function of a column, since columns having a slenderness ratio below certain definite values (determined from the material of the column) cannot be considered to be in the Euler range, as the compressive stress may reach the yield point before failure by bending can occur

Since the structural column is generally an intermediate length column and it is impossible to obtain an ideal column, the Euler formula has little practical value for ordinary design

In architecture, the column is a round vertical structural member which may, however, sometimes be more ornamental than utilitarian As such columns are frequently made of inelastic material, the above analyses of critical loads would not necessarily apply to all architectural columns (C W C, F T M)

COLUMNAR STRUCTURE. Prismatic columns which develop in **basic** lavas, due to the stress-strain relationships set up by rapid chilling A relatively frequent phenomenon in **basalt** flows, such as those of the Giants' Causeway, Ireland (R M F)

COLY, COLIES. Aves, Cuculiformes *Colius* African birds (**Aves**) of several species, also known as mouse birds They have four toes, directed forward The beak is strong and slightly curved, the head crested, and the tail long (A W L)

COLYMBIFORMES. An order of swimming and diving birds (**Aves**) with lobed toes The **grebes.** (A W L)

COMA. A state of complete unconsciousness from which the individual cannot be aroused, even by powerful stimulants It is frequently seen in marked cases of alcoholism, in very advanced **diabetes, uremia** before death, and with overdosage of certain **drugs** (R S M)

COMANCHEAN. Cretaceous.

COMBINATION PRINCIPLE. The principle, first recognized by Ritz, that the many frequencies exhibited by the spectrum of a substance can be regarded as differences between a comparatively few terms characteristic of the substance, taken two at a time in their various possible combinations. Ritz's statement was quite empirical, but we now understand that these terms correspond to the different possible energy states of the atom or molecule, and that the much more numerous spectral frequencies correspond to "jumps" or transitions from one state to another with consequent release or absorption of radiation quanta For example, if an atom had twenty possible energy states or "levels," the number of possible transitions releasing energy would be theoretically $20 \times 19/2! = 190$

It does not follow, however, that all of the corresponding frequencies are actually found in the spectrum, some may be for some unknown reason apparently "forbidden," or of such rare occurrence as not to produce observable spectrum lines When the principle is applied to certain **molecular spectra,** slight discrepancies are found which may be explained by assuming that some of the energy levels are not single but are close doubles Such a discrepancy is known as a "combination defect" See **Quantum Theory.** (L D W)

COMBINATIONS Each of the groups or selections which can be made by taking some or all of a set of things, without regard to order of arrangement, is called a combination

The number of combinations of n things taken r at a time is denoted by ${}_nC_r$ or $C_{n,r}$ or $C(n, r)$

The number of combinations of n different things taken r at a time is

$${}_nC_r = \frac{n(n-1)(n-2)\cdots(n-r+1)}{r!} = \frac{n!}{r!(n-r)!}$$

Also

$${}_nC_r = {}_nC_{n-r}$$

The total number of combinations is

$${}_nC_1 + {}_nC_2 + {}_nC_3 + \cdots + {}_nC_n = 2^n - 1;$$

that is, the total number of combinations of n things taken 1, 2, 3, ..., n at a time is $2^n - 1$

Combinations are closely related to **permutations.** Each combination containing r elements can yield $r!$ permutations by rearranging its elements in different orders Hence, ${}_nP_r = r! \; {}_nC_r$ (L I S)

COMBINING WEIGHTS, LAWS OF. The laws of combining weights are

1 Fixed Proportions The elements in a chemical compound are combined together in a fixed and definite proportion by weight

2 Multiple Proportions When two chemical compounds contain the same elements, then the fixed proportions in each are related to each other by a simple ratio For example, in carbon dioxide 12 parts by weight of carbon element combined with 32 parts by weight of oxygen element, in carbon monoxide 12 parts by weight of carbon element combined with 16 parts by weight of oxygen element, therefore, in the two oxides the ratio of oxygen is 32 16 or 2 1 on the same carbon weight basis

3 Reciprocal Proportions The proportions in which two elements or radicals combine with a third element or radical are in a simple ratio to the proportions in which they combine with each other (if they combine) or with a fourth element or radical (Richter, 1792) Therefore, each element or radical has a characteristic equivalent weight (R K S)

COMB RIDGE. Cirque.

COMBUSTIBLE. Any substance which will enter rapidly into chemical union with **oxygen,** and produce light or heat in useful quantities, is combustible Practically all of the combustible fractions of useful commercial fuels, including solid, liquid, and gaseous fuels, are composed of carbon and hydrogen, either in the elementary or combined form (hydrocarbons) Even carbon monoxide (in water gas) and the alcohols are but oxygen compounds of carbon, and of carbon and hydrogen, respectively Nearly 100% of natural gas or **fuel** oil is combustible In **coal** there may sometimes be found a considerable amount of non-combustible matter, which is chiefly moisture and an aggregation of various mineral compounds known commonly as ash Ash-free and moisture-free coal is known as combustible (F T M)

COMBUSTION. Combustion is the rapid chemical union of a **fuel** with **oxygen,** accompanied by the liberation of useful heat energy See **Reactions Involving Oxidation-Reduction,** and **Thermochemistry** When a coal is subjected to combustion conditions it first absorbs the heat necessary to bring it to the volatilization temperature This will include both sensible heat and latent heat necessary to vaporize its moisture content Further heating evolves the volatile hydrocarbons, leaving behind the fixed carbon and ash It is the hydrocarbons that must be most carefully handled to insure freedom from smoke and attendant incomplete combustion A major function of any furnace and stoker, grate, or burner installation is the proper mixing of oxygen with this evolved volatile material, and the further subjecting of the mixture to the ignition temperature, with sufficient time being given for complete combustion The fixed carbon will then burn freely with an intense heat, and under correct conditions will be completely consumed to carbon dioxide Each small piece of incandescent carbon has its surface atoms burned to carbon dioxide upon contact with an oxygen atmosphere The piece will then be blanketed with carbon dioxide, an inert gas, unless additional air is applied in such a manner as to scrub the particles of carbon free of carbon dioxide and expose fresh surface to combustion Stokers and grates accomplish this by permitting the motion of air past a stationary fuel bed at high velocity induced by **draft** Pulverized coal **burners** are designed for the turbulent mixing of air and fuel, both of which are moving into the furnace about the same velocity

Combustion by different fuel burning methods and equipment proceeds as follows

Underfeed stoker Heat from an incandescent zone of burning carbon is radiated and conducted downwards into the green fuel which is being crowded up to the ignition line from below The volatile substances which are given off are mixed with air supplied from tuyeres, also below the ignition line The inflammable mixture then passes directly through the hottest zone of the furnace—the incandescent fuel bed—insuring all parts of it reaching the ignition point The ever-upward motion of the fuel keeps the bed well broken up, allowing free passage of gases and oxygen to all parts of it

Chain grate stoker Heat from the incandescent zone is radiated to the ignition arch and reflected back to the green fuel bed at its entry to the furnace Volatile substances that come off are mixed with air admitted through and over the green fuel bed and, being confined to the arch, they pass through the hottest zone of the furnace The carbon left behind then reaches the ignition point and burns, giving up heat, part of which is radiated back to the incoming green coal There is no means of breaking up a crust formed by a coal which will soften and fuse together, but the chain grate stoker will burn coals that would be too fine or easily packed for use in an underfeed, also coals that clinker badly

Pulverized coal First, the extremely small size of the coal particles must be realized A typical pulverized coal sample will have better than 90% through a 40-mesh screen, 90% through 100-mesh, and 65%

through 200-mesh Two hundred mesh U S Standard means 200 openings to the inch, each opening being 0 0029 inch. One hundred mesh openings are 0 0059 inch each Thus, it can be seen that the particles are extremely small, and an enormously larger combustion surface is presented than with lump coal Hence, combustion occurs rapidly—from ¼ to 4 seconds is required with different fuels and burners Yet small as the particles are, they are mountains compared to the combining carbon atoms, and the scrubbing action of air across their surfaces is indispensable. The average coal particle is 25,000 times larger than the oxygen molecule When enough turbulence is provided (and turbulence is all-important), and a furnace temperature above that of ignition for the inflammable mixture is maintained at the best ratio of air to coal, the flame will propagate itself back into the incoming stream at a rate varying from 15 to 40 feet per second, depending on the ratio of volatile to fixed carbon A coal high in volatile material will burn with a shorter flame than one high in fixed carbon because of the more rapid rate of combustion of volatile matter The velocity of the mixture must be in excess of the velocity of flame propagation to prevent flare-backs into the burner The use of preheated combustion air is widespread because of the excellent combustion conditions obtained with it The air is supplied both at the mill and at the secondary inlet in the burner Due to the rapid rate of combustion it is very important that the air be supplied immediately to each combining fuel atom, otherwise carbon monoxide and soot will pass up the stack The very finely divided state of the coal is an aid to thorough mixing of air and fuel, permitting complete combustion with but little excess air

Oil and gas burners The molecular structure of fuel gas enables it to unite with oxygen quickly, with little excess air (5 to 15%), using simple forms of burners But gaseous fuels for power boiler use are limited by cost to proximity to gas fields or to use of by-product gas, as from blast furnaces Liquid fuel will approach the efficiency of gas firing if it is sufficiently atomized to a spray which will present a large combustion surface Liquid fuel is easily controlled, and fired by burners of simple design However, like gas, its cost compared to coal often places it at a disadvantage In its combustion characteristics oil more nearly resembles coal than gas

The requirements for combustion are.

1. Thorough mixing of fuel and air in proportions which will insure complete combustion
2. Exposure of fuel particles to oxygen throughout a period of time sufficient for their combustion
3. Maintenance of the combustion zone at a temperature above that of ignition of the fuel

The air required for combustion may be considered as composed of two parts that which is used to supply oxygen for union with the fuel during the process of combustion, and that which is supplied in excess so that there will be a certainty of having an oxygen atom adjacent to a fuel atom when required Combustion equations of typical fuel elements or compounds are shown in the accompanying table The following equations illustrate how the information may be obtained Taking the combustion of carbon to carbon dioxide for example

Chemical reaction· $C + O_2 = CO_2$
Combining mols 1 mol + 1 mol = 1 mol
Combining weights 1×12 lbs + 1×32 lbs = 1×44 lbs

Thus, each 12 pounds of carbon require 32 pounds of oxygen for complete combustion Taking into consideration the fact that air has only 23 2% by weight of oxygen, a pound of oxygen is contained in $\frac{1}{232}$ pounds of air,

COMBUSTION PROPERTIES OF FUELS

Fuel	Molecular Weight	Molecular Equation	Approximate Ignition Temperature, Degrees Fahr	Gravimetric Basis						
				Pounds of Air Required per Pound of Fuel	Products of Combustion, Pounds			Combining Weights	Heating Value, B t u per Pound	
					CO_2	H_2O	N_2		Higher	Lower
C to CO_2	12 0	$C + O_2 = CO_2$	752	11 5	3 67		8 8	1 lb C + 2 67 lb O_2 = 3 67 lb CO_2	14,540	
C to CO	12 0	$2C + O_2 = 2CO$	752	5 7	2 33*		4 4	1 lb C + 1 33 lb O_2 = 2 33 lb CO	4,430	
CO to CO_2	28 0	$2CO + O_2 = 2CO_2$	1253	2 4	1 57		1 8	1 lb CO + 0 57 lb O_2 = 1 57 lb CO_2	4,380	
H_2	2 016	$2H_2 + O_2 = 2H_2O$	1090	34 5		9 0	26 5	1 lb H_2 + 8 lb O_2 = 9 lb H_2O	62,000	52,100
S	32 0	$S + O_2 = SO_2$	470	4 3		2 0†	3 3	1 lb S + 1 lb O_2 = 2 lb SO_2	4,000	
CH_4	16 03	$CH_4 + 2O_2 = CO_2 + 2H_2O$	1240	17 2	2 75	2 25	13 2	1 lb CH_4 + 4 lb O_2 = 2 75 lb CO_2 + 2 25 lb H_2O	23,850	21,373
C_2H_4	28 03	$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$	1124	14 8	3 14	1 29	11 4	1 lb C_2H_4 + 3 43 lb O_2 = 3 14 lb CO_2 + 1 29 lb H_2O	21,450	20,035

Fuel	Molecular Weight	Molecular Equation	Approximate Ignition Temperature, Degrees Fahr	Volumetric Basis (60° F, 14 7 Lb per Sq In)						
				Cubic Feet of Air Required per Cubic Foot or per Pound	Products of Combustion			Combining Volumes	Heating Value, B t u per Cubic Foot	
					CO_2, Cubic Feet	H_2O, Pounds,	N_2, Cubic Feet		Higher	Lower
C to CO_2	12 0	$C + O_2 = CO_2$	752	151 7	31 7		120 0	1 lb C + 31 7 C F O_2 = 31 7 C F CO_2		
C to CO	12 0	$2C + O_2 = 2CO$	752	75 5	31 7*		59 7	1 lb C + 15 8 C F O_2 = 31 7 C F CO		
CO to CO_2	28 0	$2CO + O_2 = 2CO_2$	1253	2 4	1 0		1 9	1 C F CO + 0 5 C F O_2 = 1 C F CO_2	323	
H_2	2 016	$2H_2 + O_2 = 2H_2O$	1090	2 4		0 048	1 9	1 C F H_2 + 5 C F O_2 = 048 lb H_2O	328	275
S	32 0	$S + O_2 = SO_2$	470	56 8		11 9‡	44 9	1 lb S + 11 9 C F O_2 = 11 9 C F SO_2		
CH_4	16 03	$CH_4 + 2O_2 = CO_2 + 2H_2O$	1240	9 6	1 0	0 095	7 6	1 C F CH_4 + 2 C F O_2 = 1 C F CO_2 + 095 lb H_2O	1004	900
C_2H_4	28 03	$C_2H_4 + 3O_2 = 2CO_2 + 2H_2O$	1124	14 4	2 0	0 095	11 4	1 C F C_2H_4 + 3 C F O_2 = 2 C F CO_2 + 095 lb H_2O	1581	1476

* Carbon monoxide † Sulfur dioxide. ‡ C F. Sulfur dioxide C. F = cubic feet.

consequently, in the combustion of carbon to carbon dioxide, 12 pounds of carbon require $\frac{32}{232}$ pounds of air, or 1 pound of carbon requires $\frac{32}{12 \times .232} = 11\ 5$ pounds of air, theoretically

Correspondingly, hydrogen needs 34 5 pounds of air per pound, and sulphur 4 3 pounds per pound The air theoretically required to burn a pound of coal is

$$\text{Air} = 11\ 5C + 34\ 5\left(H - \frac{O}{8}\right) + 4\ 35S \text{ pounds of air per pound of coal}$$

The symbols represent fractional proportions of the elements in the ultimate analysis The $\left(\frac{O}{8}\right)$ correction allows for the hydrogen which is already combined and for that which will be burned with free oxygen in the fuel.

An account of the dynamic conditions surrounding furnace combustion, more air than might be indicated by the above equation will be necessary for complete combustion The excess air is the ratio of the amount of air actually used over and above the theoretical amount to the theoretical amount It varies from about 10% in large furnaces fired by burners to 40% or 50% in well operated stokers, and 100% or more in hand-fired furnaces Otto cycle engines operate on an excess of practically zero percent, Diesel cycle engines use 100% or more of excess air

Since atmospheric air is composed of only 20 9% oxygen by volume, the remaining 79 1% (nitrogen chiefly, but with minute amounts of argon, carbon dioxide and other gases) is inert and merely absorbs heat, causing a loss of efficiency From these proportions, and the fact that a cubic foot of oxygen burns to a cubic foot of carbon dioxide, we see that the theoretical maximum of carbon dioxide in stack gas will be 21% with perfect combustion, no excess air and no hydrogen in fuel Actual coal burning conditions lower this to a point at which 14% is considered to represent very good combustion

If combustion is complete the percent excess air can be determined from the carbon dioxide content of the flue gas and the fuel ratio of the coal, $\frac{\text{Carbon}}{\text{Hydrogen}}$

$$\frac{\text{Percent excess air}}{100} = \frac{20\ 9R}{\text{CO}_2\,(R+3)} - \frac{R + 2\ 37}{R+3}$$

CO_2 = percent CO_2 by volume in the dry flue gas

R = fuel ratio $\frac{\text{C}}{\text{H}}$ R for Anthracite 50–25, Semi-anthracite 25–20, Semi-bituminous 20–16, Bituminous 16–12, Lignite 12–9 (F T M)

COMET. Comets are objects which are moving in space under the influence of the sun's gravitational field and which occasionally come close enough to the earth to be observed The name comes from the descriptive Latin phrase stellae comatae, (hairy stars), and aptly describes the appearance of this class of celestial objects Their appearance is so different from all other objects in the night sky that they have always attracted a great deal of attention They were formerly regarded with superstitious awe and supposed to portend all sorts of calamities to the earth and its inhabitants For these reasons the appearance of a comet was always recorded by the ancient scribes and we have records of comet observations running back over more than a thousand years prior to the Christian era

Only a very small proportion of the comets which are discovered ever become visible to the naked eye, and there must be many comets which are never discovered at all From a study of ancient records there has been, on the average, about one naked eye comet per year The year 1911, in which there were four such objects, apparently holds the record for maximum number, while there are many years in which no comet at all is visible to the unaided eye

In a comet which becomes visible to the naked eye there are three general parts the nucleus, the coma, and the tail The relative sizes and appearances of these parts change radically as the comet approaches **perihelion.** It is believed that the nucleus (or head) of a comet is a mass of more or less condensed material It appears much like an ordinary star when the comet is a long way from the sun As the comet approaches the sun the nucleus increases in brightness and apparently shrinks in size, although this latter characteristic may be an optical illusion since actual measures of the diameter of the head are practically impossible With the approach to the sun a hazy shell makes its appearance about the nucleus and this so-called coma increases in size When quite close to the sun the coma seems to stretch out in the direction away from the sun and the tail develops in this direction The real glory of a comet to the naked eye is this tail It should be carefully noted that the tail points in a direction directly away from the sun and does not, in general, trail out behind the comet in its motion The sizes and shapes of the tails of different comets vary in all characteristics Many comets apparently never develop a tail at all The tails which do develop have a variety of different shapes and curvature running from short, sharply curved tails, to long straight streamers pointing away from the sun

Comets are the largest members of the **solar system** The nucleus may have a diameter up to ten thousand miles, the coma diameters from ten to fifty thousand miles, and the tails have been observed with length as great as several hundred thousand miles Hence, the volume of a large comet may be greater than the volume of all other members of the solar system combined In contrast to the enormous bulk of these objects, their masses are so small that they have never been accurately measured The only available method for determining the mass of a comet is by means of the **perturbations** which they might produce in the **orbits** of the **planets** or **asteroids** Many cases of very close approach of comets to objects of known mass have been observed but, while the comet orbit itself may be enormously perturbed, no perturbations have ever been observed in orbits of other objects The best that can be said regarding cometary masses is that they must be less than one hundred-thousandth the mass of the earth

Orbits of comets differ from orbits of the other members of the solar system in that they are, in general, much more eccentric than the planetary orbits, and, while the planetary orbit planes are all nearly parallel to the plane of the **ecliptic**, comet orbits are found inclined through practically every angle The great majority of the orbits which have been determined are found to be parabolic in character which means that the objects will not return to visibility again, two or three objects apparently have hyperpolic orbits, and the remainder are moving about the sun in ellipses, returning to the vicinity of the sun and hence visibility, at periodic intervals Probably the most noted of all comets is **Halley's comet** This object was not discovered by Halley, but he was the first one to predict the period of return Halley's comet has a period of approximately seventy-five years and has been observed and recorded at practically every return for over a thousand years

Comparatively little is known regarding the composition and origin of comets The **spectra** have been carefully studied over a period of years From these observations we find that comets shine partly by reflected sunlight and partly by radiation from gases, largely hydrocarbon in character, which are excited to incandescence by radiant energy from the sun There is no valid explanation as to why the sun's radiation should stimulate this activity in comets and not in any

of the other members of the solar system. From a careful study of the orbits the preponderance of evidence points to the fact that comets are now and always have been members of the solar system and have evolved and developed with it

A definite connection has been established between comets and **meteors.** In one well authenticated case a comet was observed to be disintegrating at several successive returns and finally failed to reappear as a comet In its place there was a meteoric shower In several other cases we have meteoric **radiant points** following identical orbits with comets. These observations have lead to the hypothesis that the head of a comet may be nothing more or less than a densely packed mass of meteoric material Why this material should be stirred to activity by the sun's radiation so that it develops a coma or tail is not as yet explained

There is practically no danger to the earth from comets There used to be a belief that the tail of a comet contained poisonous gases which might cause wholesale death on the earth if the earth ever came close to the tail Such belief is entirely without foundation for the gas is in such a highly diffused condition that, even if it were poisonous, a lethal concentration would be highly improbable During the return of Halley's comet in 1910 the earth passed through the tail and not the slightest effects could be noted either in diminution of sunlight or change in the chemical constitution of the atmosphere A direct collision with the head of a comet would undoubtedly have a very destructive effect over the portion of the earth where the collision took place However, from the number of comets and the average orbital characteristics, such a collision is highly improbable (W K G)

COMMENSALISM An association between individuals of different species which is beneficial to both but not indispensable **Ants** and **plant lice** are sometimes associated in this way The plant lice are guarded by the ants and sometimes carried to a good food supply and the ants receive the sweet honey dew secreted by their charges (A W L)

COMMISSURE. A transverse nerve cord or fiber tract connecting paired components of the **nervous system.** (A W L)

COMMUTATION. A simple loop of wire rotating in a unidirectional magnetic field has induced in it a reversing or **alternating current.** When the conditions of usage make it desirable to have the current from the **generator** flow in one direction in the external circuit, commutation of some sort is required The function of a commutator is to effect a reversal of the current induced in the winding of the generator at the proper point to produce a direct current in the connected circuit

A single loop would generate a current which, when commutated, was pulsating in nature because of the varying rates at which the conductor, during rotation, cuts the lines of force of the **magnetic circuit.** The generator is composed of many such loops properly connected at their ends to the commutator The commutator for a single loop would be simply a split ring with the two halves insulated not only from each other, but from the frame and shaft of the machine as well In an actual practical generator having a multiplicity of windings, the commutator consists of a large number of segments of copper assembled around a hub which is attached to the shaft The segments are thoroughly insulated from each other, usually with mica, and to them the ends of the armature wires are soldered. **Brushes** bearing against the commutator conduct the current away from the generator (F T M)

COMMUTATIVE LAW OF ALGEBRA. Addition and **Multiplication.**

COMPANION CELL. This is a very small elongate cell always found in close association with a **sieve tube.** It contains a dense **protoplasm** with a prominent **nucleus** and very small **vacuoles.** It is assumed that in some way they function with the sieve tubes

For development, see **cambium.** (R M W)

COMPARATIVE Anatomy, Physiology etc The comparative treatment in any division of biological science focuses attention upon a limited subject, such as **anatomy,** but introduces into its treatment data drawn from many species This method of study has been applied widely to the vertebrates, hence comparative anatomy is likely to mean comparative anatomy of the vertebrates unless otherwise qualified

The comparative method is valuable in determining the evolutionary development of organs and the relationship of species (A W L)

COMPARATOR An instrument for the accurate measurement of moderately small lengths or distances The feature common to various forms is a reading microscope or telescope arranged to travel along a scale, its axis remaining parallel to a fixed line A typical form consists of a low-power microscope mounted on a carriage movable forward or backward by a **micrometer** screw The two points or lines whose distance apart is to be measured are brought into the focal plane of the microscope the cross-hairs of which are adjusted first upon one and then upon the other For example, the distance to be measured may be that between two star images on an astrographic plate, or the images of two spectrum lines taken by a spectograph, in either case the plate is simply mounted on the stage of the comparator microscope Another familiar type is the "cathetometer," consisting of a telescope sliding on a vertical scale and provided with a **vernier** This instrument is used to measure heights of liquid columns, or other differences of level (L D W)

COMPASS. With the exception of its use to designate that instrument employed to draw circles (pair of compasses), compass refers to an orientation or direction finding instrument There are three fundamental types as follows magnetic compass, **gyro-compass,** and **sun compass.** The present article will be confined to the magnetic compass

When a simple and delicately formed bar **magnet** is accurately pivoted, free to swing, it sets itself parallel to the earth's **magnetic field** A magnetic compass then, is such a bar magnet, suitably mounted and enclosed in a non-magnetic case having a circular circumference divided into equal parts in accordance with the ordinary angular divisions or any other accepted **compass card** Various accessories, such as damping devices, dip counterbalances, etc, may be part of a compass installation The surveyor's theodolite and the engineer's transit are usually provided with such a compass

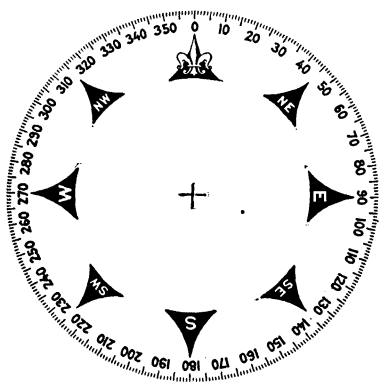
The magnetic compass, as used by navigators and aviators, consists essentially of a group of strongly magnetized needles which are attached to a compass card The needles are arranged beneath the card in a complicated manner to obtain the maximum directive force from the horizontal component of the earth's magnetic field The system is mounted about a pivot in such a manner that it will rotate freely about a vertical axis, and at the same time offer considerable resistance to rotation about a horizontal axis The needle and card system is mounted in a heavy copper bowl, which is completely filled with liquid and sealed with a heavy plate glass cover The liquid, usually a mixture of forty-five per cent pure alcohol with fifty-five per cent distilled water, remains liquid to —10° F and offers enough resistance to the swing of the compass card to damp out short, troublesome vibrations The bottom of the bowl is ballasted with lead and contains a device for taking up the expansion and contraction of the

compass liquid with changes in temperature, so that bubbles will not appear between the liquid and the glass cover. This heavy bowl is mounted in gimbals and placed within the ship's **binnacle** in such a manner that the card will remain horizontal even in a heavy seaway. In some instruments the card and the bottom of the bowl are made translucent so that the compass may be read by night by means of a light placed beneath it. On the inside of the bowl is painted a vertical black line called the lubber's line. The compass is so mounted in the binnacle that a line passing through the pivot about which the card swings and the lubber's line will be parallel to the keel of the ship. Frequently sights are placed on the mariner's compass for the purpose of taking bearings, but the **pelorous** is more commonly used for this purpose.

The short, quick motions of aircraft cause difficulties with the magnetic compass of the mariner's type and a so-called earth-inductor compasss has been designed primarily for use in airplanes. This compass is based upon the principle of **electro-magnetic induction.** The magnetic field used is that of the earth itself. A small coil of wire is caused to rotate in this field, being externally driven. The drive most frequently used is taken from a small propeller mounted in the wind stream of the airplane itself. Due to the weakness of the earth's magnetic field, a very small electric current will be generated, and a **galvanometer** is the instrument used to show the readings. The small current is taken from the coil through commutator and brushes, and the external circuit between brushes is completed through the galvanometer. The galvanometer reading is zero when the axis of the coil is parallel to the magnetic field, and maximum when perpendicular to the field. This principle is embodied in a useful instrument by making the position of the brushes adjustable. In actual practice, the pilot employing the earth-inductor compass sets the brushes in such a position that when the craft is headed in the desired direction, the galvanometer reading will be zero. Derivations from the desired **course** are shown immediately by deflection of the galvanometer needle right or left. The position of the brushes is conveniently indexed on a dial graduated in the same manner as a compass card.

Several **compass corrections** must be applied to any readings taken with a magnetic type compass in order that the true course or bearing relative to a meridian of the earth may be obtained. (W.K.G., F.T.M.)

COMPASS CARD. The compass card is a light cardboard or paper disk or annulus which is securely attached to the directing system of a mariner's **compass.** On this card are painted the "points" and other systems of markings for reading the compass.



Compass Card. U. S. Navy Standard.

During the sailing ship era, when it was difficult for a helmsman to hold the ship within two or three degrees of a given course, the point and quarter point system of marking was sufficiently accurate for graduating the compass card. With the increase in ease of steering the degree system, such as had long been in use on surveyor's compasses, made its appearance on the mariner's compass. Two such degree systems are in common use. One system has zero both at the north and south points of the card and reads in degrees both right and left from the zero's to the east and west points. In such a system the north-west point would be referred to as north 45° west and the north-east point as north 45° east. The present standard U. S. Naval system of marking has north marked zero and reads to the right through the east through 360°. The marking of the card for a naval ship's compass is shown in the accompanying figure. On such a system the north-west point is referred to as 315° and the north-east as 45°. (W.K.G.)

COMPASS CORRECTIONS. The directive force of the magnetic **compass** is the horizontal component of the **magnetic field** in which the instrument is placed. Usually the direction of this force is not parallel to a true **meridian** and certain corrections must be applied to any reading of the compass to obtain a true direction.

In the first place, the horizontal component of the earth's magnetic field may not be parallel to a true meridian. The angle between the magnetic and the true meridian is known as the variation, or magnetic declination. The variation is called East (+) or West (—) depending upon whether the north seeking end of the compass is drawn to the right or left of the true meridian as the observer looks from the center of the card towards the north seeking end. Variation differs from place to place over the surface of the earth and from day to day in any particular locality. As a result of long and painstaking research on the magnetism of the earth, it is now possible to plot on charts the variation for various places and also the rate of change of the variation. Lines, known as isogonic lines, are frequently drawn through places of equal variation.

It is important when using an old survey to ascertain whether the **azimuth** was magnetic or geographic north. If the survey was plotted without declination corrections, it is necessary to refer to declination tables to obtain the declination for that point in that year, to compare the same with the current declination, and to make appropriate corrections for the intervening swing of the magnetic north.

In addition to being directed by the earth's magnetic field, the compass is also affected by local fields. These are particularly strong and troublesome on board modern steel ships, in which there are large masses of machinery and many and varying electric currents. The effect of these local magnetic fields is known as deviation. Deviation is marked + or — in the same way as the variations: East (+) if the north seeking end of the compass is deflected to the right of the magnetic meridian as the observer looks from the center of the card toward the north seeking end.

Deviation varies with the heading of the ship and must be frequently determined by swinging the ship completely around a vertical axis and taking compass bearings of some distant object whose true azimuth is known. Furthermore, any disturbance of the ship, such as steaming through a heavy sea, may radically change the deviation and the navigating officer must frequently check the deviation by taking compass bearings of celestial objects of known azimuth. A ship's **binnacle** contains a number of movable magnets which may be adjusted to partially compensate for deviation, but they

cannot be expected to allow for all sudden changes in the magnetic field of the ship after they have been adjusted

In addition to the purely magnetic corrections to be applied in determining the true **course** of a ship relative to the surface of the water, the effect of leeway must be considered Leeway is defined as the angle between the keel of the ship and the actual direction of motion It is best determined by measuring the angle between the keel and the wake Leeway is marked as an East (+) compass correction when the ship is on the port tack, i e, the wind blowing on the left side of the ship, giving her a drift to the right

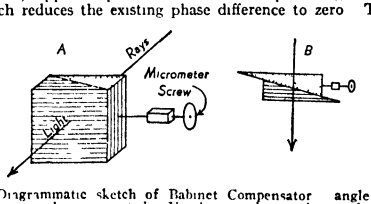
In case the compass is not mounted in gymbals (as is the case in an airplane) the tilting (or heeling) of the airplane will bring the vertical component of the earth's magnetic field into play and introduce a further correction On modern ocean vessels the heeling error is practically eliminated both by mounting in gymbals and also by using a heeling compensator in the binnacle (W K G)

COMPASS PLANTS Several plants are called compass plants It is characteristic of them that all their leaves extend in a north-south direction, regardless of the position in which the leaves are borne on the stem This arrangement of leaves is brought about by the bending of the **petioles** of the leaves *Silphium Scariola*, a relative of garden lettuce, exhibits this peculiar habit when grown in a dry open place This uncommon response of the leaves protects them from excessive sunlight at midday, but assures maximum exposure in early morning and late afternoon, when radiation is not so intense (R M W)

COMPENSATION SAC A reservoir opening to the exterior in certain **Bryozoa** which fills with water when the tentacles are extruded and empties when they are retracted. (A W L)

COMPENSATOR. While this term may serve to designate any device used for compensation, there are two specific applications of its use

In physics the term compensator is ordinarily restricted to an arrangement for measuring the phase difference between the two components of elliptically **polarized light** This is accomplished by introducing a known, opposite phase difference of equal magnitude, which reduces the existing phase difference to zero The



A Diagrammatic sketch of Babinet Compensator angle of wedges much exaggerated Hatching and stippling indicate direction of crystal axes B Shows wedges displaced

most familiar form, devised by Babinet, consists of two quartz wedges, with thin optic axes at right angles to each other When passed through this apparatus and a **Nicol prism** set to extinguish light plane-polarized at 45° to either axis, any given elliptically polarized light produces a system of parallel dark bands Plane-polarized light is first used (zero phase difference), then the elliptic light of unknown phase difference, and the relative displacement of the wedges necessary to restore the bands to their original position gives the phase difference required

Another use of the term compensator is in electrical engineering When a motor is to be started other than by direct connection to the supply line, some means must be incorporated in the circuit to limit the current taken during the starting period A method frequently used to start alternating current motors which are too large to be directly connected for starting, is to decrease the impressed voltage during the starting period The term compensator usually refers to the automatic transformers, switches, and wiring employed to limit the starting current for the squirrel cage type of alternating current motor This equipment is enclosed in a case through which projects an operating handle which has three positions, "off," "starting," and "running" This handle controls a double-throw switch When in starting position, the switch is thrown so as to connect the motor to the line through an auto-transformer, which reduces the voltage to an amount suitable for starting purposes When in the running position, the switch connects the motor directly to the line through fuses, and full line voltage is impressed upon the motor windings (L D W., F T M)

COMPLEMENTAL MALE. 1 In certain **barnacles** which are normally **hermaphrodite** a few individuals lack female organs and are called complemental males 2 In colonies of white ants, termite reproduction is carried on principally by a highly specialized king and queen Other sexually mature individuals resembling the immature insects are known as the second reproductive caste The males of this caste are complemental males (A W L)

COMPLEMENTARY COLORS Color.

COMPLEMENTARY FUNCTION OF A LINEAR DIFFERENTIAL EQUATION Linear Differential Equations

COMPLEX FRACTIONS. A complex **fraction** is one whose numerator or denominator or both are fractions or mixed expressions A complex fraction may be reduced to simpler form by multiplying every term of the numerator and denominator by the **least common multiple** of the denominators of the subsidiary fractions (L L S)

COMPLEX NUMBERS. An imaginary number is a square root of a negative real number Every imaginary number can be expressed as a product of a real number by the so-called imaginary unit $\sqrt{-1}$, thus, $\sqrt{-4} = 2\sqrt{-1}$

Sometimes the term imaginary number is used for what we call complex numbers, to emphasize the distinction, the term pure imaginary is sometimes used for the square roots of negative real numbers

The imaginary number $\sqrt{-1}$ is often called the imaginary unit, and it is generally denoted by the letter i for brevity, its fundamental property is expressed by $i^2 = -1$

The successive powers of the imaginary unit are i, $i^2 = -1$, $i^3 = -i$, $i^4 = +1$, $i^5 = +i$, $i^6 = -1$, $i^7 = -i$, $i^8 = +1$, and so forth in cycles of four

Complex numbers are numbers of the form $a + bi$, where a and b are real numbers and i is the imaginary unit, they consist therefore of a real part a and a pure imaginary part bi

The complex numbers $a + bi$ and $a - bi$ are said to be conjugate to each other

Two complex numbers are defined as equal when their real parts are equal and their imaginary parts are equal. When any two expressions involving real and imaginary parts are equal, we may equate their real and imaginary parts separately

The four fundamental operations with complex numbers are expressed by the formulas

$$(a + bi) \pm (c + di) = (a \pm c) + (b \pm d)i,$$
$$(a + bi)(c + di) = (ac - bd) + (ad + bc)i,$$
$$\frac{a + bi}{c + di} = \frac{ac + bd}{c^2 + d^2} + \frac{bc - ad}{c^2 + d^2}i;$$

That is, to add (or subtract) complex numbers, add (or subtract) the real and imaginary parts separately, to multiply two complex numbers, multiply them as though they were ordinary binomials and substitute $i^2 = -1$;

to divide two complex numbers, multiply numerator and denominator by the conjugate of the denominator.

Since a complex number $x + yi$ depends on two real numbers x and y, complex numbers require a two-dimensional field, such as the plane, for their graphic representation.

Argand's diagram represents a complex number as $x + yi$ graphically by the point whose **rectangular coordinates** are x and y, or by the corresponding vector from the origin to this point, as shown in Figure 1.

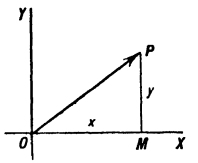


Figure 1.

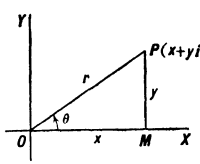


Figure 2.

Let the complex number $x + yi$ be represented graphically by the point $P(x,y)$ in rectangular coordinates, by Argand's diagram, and let the **polar coordinates** of P be (r,θ). (See Figure 2.) Then $r = OP = \sqrt{x^2 + y^2}$, and $\theta = \angle XOP = \text{arc tan } (y/x)$. Then the radius vector r is called the absolute value (or modulus) of the complex number and is denoted by the symbol $|x + yi|$, and the vectorial angle θ is called the amplitude (or argument) of the complex number and is occasionally denoted by $am(x + yi)$. The complex number $x + yi$ may then be represented in terms of r and θ by the expression

$$r(\cos\theta + i\sin\theta),$$

(sometimes abbreviated into $r\cos\theta$), which is called the polar (or trigonometric) form of the complex number.

The product and quotient of two complex numbers in polar form are expressed by the formulas:

$$r_1(\cos\theta_1 + i\sin\theta_1)\cdot r_2(\cos\theta_2 + i\sin\theta_2) = r_1r_2[\cos(\theta_1 + \theta_2) + i\sin(\theta_1 + \theta_2)],$$

$$\frac{r_1(\cos\theta_1 + i\sin\theta_1)}{r_2(\cos\theta_2 + i\sin\theta_2)} = \frac{r_1}{r_2}[\cos(\theta_1 - \theta_2) + i\sin(\theta_1 - \theta_2)]$$

(L.L.S.)

COMPOSITE COURSE. The shortest track for a vessel to follow between two points on the surface of the earth is a great circle if we neglect the slight oblateness. However, the following of such a track has two fundamental disadvantages: (1) such a course is a **rhumb line** only in the particular cases of two points both on the **equator**, or two points on the same **meridian** of longitude; (2) such a course will frequently lead the vessel into impossible positions (e.g., if the two points are in the same **latitude** but differ by 180° in longitude the great circle track between them would lead over the nearest pole).

A composite course is a combination of great circle and rhumb line courses designed to carry a ship from one point to another by the shortest practicable path. In case the great circle track does not lead the ship into impossible positions the composite course is usually a series of rhumb line courses to successive positions along the great circle track, the rhumb line distances so figured that the course of the ship will be altered at convenient times (e.g., the changing of the watch). In case the great circle course leads the ship into danger the problem of computing the composite course is one of a number of compromises which are different for every problem. A good example of such a composite course may be obtained by examining the steamer lanes across the Atlantic Ocean which will be found on many terrestrial globes. (W.K.G.)

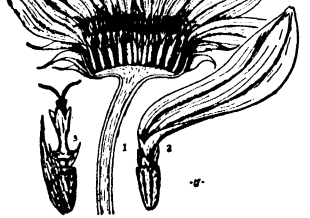
COMPOSITE FAMILY. Compositae. This is the largest family within the plant kingdom and contains over twelve thousand species in over eight hundred genera. Furthermore, it represents the highest evolutionary attainment among dicotyledonous plants. Composites are mostly herbaceous plants, distributed practically all over the earth. The few members which are shrubs or trees are largely limited to tropical regions, especially to island floras. The family is divided into two groups, distinguished by the nature of its flowers. The plants of one group have latex vessels usually containing a white latex, those of the other group lack latex, but in most cases contain oil-canals with acrid or bitter watery contents.

The leaves of most composites are alternate, often entirely radical, although in a few cases they are opposite, as in the sunflower, *Helianthus annuus*, or whorled, as in species of *Eupatorium*. Stipules are seldom found in this family. The root is most commonly a tap root, frequently much thickened, as in the dandelion. The inflorescence is of the type known as a head, or capitulum. Often the heads are aggregated in larger inflorescences of various types, as **panicles** or **cymes** or spikes. Commonly the single head is inaccurately regarded as a flower, rather than as an inflorescence. Surrounding the

Flower-head and flowers of the dandelion, *Taraxacum*. 1, the inflorescence or head, composed of many flowers upon a flattened stem. 2, a single flower more enlarged. 3, a single fruit.

head is a group of bracts, making up the involucre. These **bracts** are usually green and serve to protect the flowers before they are mature and also to protect the maturing fruit. The flowers of a head are arranged on the enlarged end of the stem or axis, called the receptacle. This receptacle may be flat and disc-shaped, as in the common sunflower, conical as in the yellow daisy, *Rudbeckia hirta*, or otherwise. It may be smooth or covered with hairs or scales.

The individual flowers show considerable difference in structure. In many species the flowers of a head are



Flowers and flower-heads of a sunflower, *Helianthus*. 1, the flowerhead, cut so as to show the relation of the ray and disc flowers to the end of the stem. 2, a single ray flower. 3, a single disc flower.

all alike and all perfect In other species they are of two kinds, one called ligulate and the other tubular Ligulate flowers, also called ray-flowers, are irregular, but bilaterally symmetrical, tubular flowers, also called disk flowers, are regular Both types occur in the head of the sunflower, where the tubular or disk flowers occupy the larger part of the receptacle, the ray-flowers being the conspicuous yellow flowers forming a ring around the periphery of the receptacle, just inside the involucral bracts Each disk flower is perfect and regular The **calyx** appears in different genera as bristles, barbs, scales, or teeth, and sometimes is completely lacking It is known as the pappus and occurs at the apex of the inferior **ovary** Often the pappus becomes a very important structure in the dissemination of the fruit The **corolla** is tubular and five-lobed, and inserted on the apex of the ovary The short filaments of the five **stamens** are inserted on the base of the corolla tube, while the **anthers** are attached to each other by their edges, forming a tube which surrounds the style The pollen is discharged into the anther tube The single **pistil** has an inferior ovary containing a single erect **ovule**, a simple style which splits into two parts, the inner surfaces of which are stigmatic The fruit is usually of the type called an **achene** Nectar is secreted in a ring-shaped **nectary** which surrounds the base of the style, located at the base of the tubular corolla This nectar attracts insects, but only those with mouth parts sufficiently long to reach to the bottom of the corolla tube can obtain it When the flower opens the **pollen** is shed into the anther tube At the base of this tube the style, as yet unforked, occurs This style elongates, pushing like a ramrod against the pollen above it, and causing an accumulation of pollen at the upper end of the anther tube Insects seeking the nectar necessarily come in contact with the pollen masses, which are thus likely to be transferred to another flower as the insect goes about collecting nectar However, should insect-pollination fail, self-pollination is assured in many species, by the behavior of the styles, which emerge from the anther tube, protrude considerably, and then split and coil backwards so that the inner stigmatic surface rolls down into contact with the pollen In some cases this self-pollination is almost the only method

The ligulate or ray flowers differ from the disk flowers in having the corolla of five united petals forming a tubular base which gradually emerges into a flat strap-shaped lateral structure with five teeth at its tip Growing from the tube of the corolla are the small **stigma** and the five coalesced stamens In many species where the ray flowers are marginal in the head they are entirely sterile or are pistillate

The Composites are divided into two groups If all the flowers of a head are ligulate the plant is a member of the Liguliflorae This group contains, among other common plants, chicory, dandelion, and lettuce It is in this group, also, that **latex** occurs The other group, the Tubuliflorae, comprises all Composites characterized by disk flowers These may occupy only the central portion of the head, or the latter may be entirely of disk flowers Examples of this group are sunflowers, daisies, asters and goldenrods

After **pollination** takes place the involucral bracts close over the head, pressing tightly against it and so protecting the developing **fruit** The **pappus** becomes a conspicuous part of the fruit in many cases and is a very important factor in insuring scattering of the fruit In some cases the pappus forms a parasol-like group of fine radiating hairs at the tip of a long beak of the achene These hairs make the achene buoyant, and hence capable of being carried long distances by air currents Often the base of the hair is **hygroscopic**, responding to changes in moisture, so that the parasol-like structure opens and closes with decrease or increase of humidity, which may help to loosen the achene from the receptacle, and also to shove it along over the surface of the ground, or to push it into a crack in the soil In *Bidens*, often called beggar-ticks or beggar-lice, the pappus is in the form of stiff usually downwardly barbed bristles which catch into the hair of passing animals or the clothing of man and so are carried about, finally breaking off and falling to the ground In the burdock, *Arctium*, the involucral bracts form recurved hooks which serve in the same way, the entire head often breaking off and being transported In thistles the pappus takes the form of a tuft of long silky hairs which enable the achene to float readily through the air In many cases members of the composite family have no special pappus development, seed dispersal being entirely accidental

The reasons which suggest that the Composite Family is highest in rank are found in the massing of the individual flowers into a compact head surrounded by protecting bracts, the structure of the individual flower with its inferior ovary, its united petals forming a corolla tube, the united anthers forming the anther tube, and the reduction of the number of carpels to two with but one ovule developing

For so large a family comparatively few of its species are used by man Several are extensively cultivated for ornament, the flowers often becoming very large and double and extremely showy, as in the case of the *Chrysanthemum* and *Dahlia* Less showy ornamentals are the *Aster*, *Bellis*, *Tagetes* and *Calendula*, among others Some composites yield oils or other substances useful to man, as *Arnica*, *Artemisia*, *Tanacetum*, *Calendula*, *Chrysanthemum* and *Helianthus* A few are used as food, such as Lettuce, Artichokes, Endive, Chicory, Salsify and Dandelion

Lettuce, *Lactuca sativa*, is an annual herb which is native to Europe, Asia and northern Africa The plant is very leafy and contains a milk-white **latex** In young plants the leaves are crowded on a short stem, forming a close rosette, in older plants the stem elongates greatly and bears a panicle of heads of yellowish flowers The achenes are flat, ribbed, and contracted into a slender beak bearing numerous soft white or brownish pappus hairs which radiate outward like a parasol Many varieties have been developed in cultivation Lettuce is used almost entirely as a salad plant

Endive, *Cichorium endiva*, is an annual or biennial herb having many basal leaves which in cultivated forms have become very much dissected and crisped Mature plants are tall-stemmed and have purple, rarely white, flowers, all ligulate The plant is used either as a salad plant or as a pot-herb It is a native of India, and has long been cultivated in European countries It is becoming more popular in the United States

Chicory, *Cichorium Intybus*, also called succory, is one of the many European plants which has become a persistent weed on introduction to North America It is a perennial plant having a deep tap-root, and a stiff tough stem two or three feet tall Root leaves are numerous, forming a dense basal rosette stem leaves are small, of various shapes, and clasping the stem The flowers are usually blue, sometimes pink, or white The plant is used as a salad plant or as a pot-herb, often being mistaken for dandelion Its roots have been dried, ground and roasted and used as a substitute for coffee There are several varieties in cultivation, one of which, Witloof chicory, finds considerable favor as a salad plant.

Salsify, *Tragopogon porrifolius*, or Oyster plant, is a plant indigenous to southern Europe It is a hardy biennial having a thick tap-root eight to twelve inches long and an inch or two in diameter This root is formed during the first year of growth when it bears a crowd of leaves During the second year's growth the rather succulent branching stems grow up two or three feet tall The stem leaves are alternate, entire and clasping, and have a smooth waxy surface The flower heads are borne on long hollow stalks, or peduncles, and have purple flowers, all ligulate The achenes are linear and have a long slender beak with radiating pappus hairs at its tip The roots of the plant have a flavor suggestive of that of oysters, and are used as a cooked

vegetable. A yellow-flowered species also occurs, and has been widely introduced into the United States

Scolymus hispanicus, another southern European member of the Composite Family, is also known as an Oyster plant, or salsify, usually being designated as Spanish salsify *Scorzonera hispanica*, Composite Family, is black salsify

Artichoke, or Jerusalem Artichoke, *Helianthus tuberosus*, is sometimes called by its Italian name, girosole, meaning sunflower, which corrupted into English becomes Jerusalem Artichoke It is a perennial herbaceous plant having thick fleshy rootstocks which bear somewhat irregular tubers with very evident "eyes" (actually dormant **buds**) The erect stems are six feet or more tall, stout and branching The leaves are simple, ovate, and long-petioled The heads are either solitary or in **corymbs**, and are composed of central disk flowers and marginal ray flowers, both yellow The achenes are thick and hairy, with two deciduous pappus scales The tubers are used largely as stock food, especially for hogs, but are also eaten by humans

Helianthus annuus, the common sunflower, is frequently grown, partly for ornament, partly for curiosity because of the tremendous flower heads which often contain an enormous number of flowers, and partly for the seeds These seeds are fed to poultry and larger caged birds From the seeds, sunflower seed oil is expressed

Globe artichoke, *Cynara scolymus*, is another Composite which is grown for food It is a herbaceous perennial native in northern Africa The flowers form large globular heads surrounded by several rows of fleshy **bracts** The basal portions of each bract and the thick fleshy receptacle are cooked and eaten The blanched leaves of a related species, *Cynara cardunculus*, or cardoon, are often eaten like celery

Dandelion, *Taraxacum officinale*, is a stemless perennial herb, having a thick tap-root and a rosette of basal leaves which grow close to the ground Contraction of the root each year keeps the leaves of that year's growth at the ground level The heads, composed of yellow ligulate flowers, are borne singly on hollow peduncles When the **achenes** are mature the **peduncle** elongates greatly, lifting the achenes well above the ground Each achene is beaked and has a crown of pappus hairs which aid it in floating through the air The dandelion is frequently used as a pot-herb, and is grown extensively Wild plants, often pestiferous weeds in lawns, are much gathered in the spring for greens The root contains a glucoside taraxirin, and is used medicinally as a tonic

Several other members of the Composite Family have medicinal value The young roots of the common burdock, *Arctium lappa*, are used in southern Europe and Asia as a drug plant The stem tips and young leaves of *Eupatorium perfoliatum*, a native North American plant, are used as a stimulant and tonic, and in the making of compounds to relieve colds and fevers Species of *Grindelia*, native in western United States, are used in preparations to relieve asthma *Matricaria Chamomilla*, a native of Europe, is a mild stimulant and tonic plant, as is also *Anthemis nobilis*

Certain species of **Artemisia** are used in several ways *Arnica montana*, of western United States, is another stimulant and tonic plant *Calendula officinalis*, a strong-smelling garden annual frequently grown for its brilliant yellow or orange flowers, contains a volatile oil, and serves a variety of uses in the East and in Europe Species of Chrysanthemum are grown extensively for their ornamental flower heads *Chrysanthemum Parthenium* is a febrifuge, popularly used to cure mild fevers The entire flower heads of *Chrysanthemum roseum*, *Chrysanthemum cinerariaefolium* and *C (Anacyclus) pyrethrum* are ground up and used as insect powders, under the name of pyrethrum

Several members of this family contain poisonous substances which cause serious consequences when eaten by stock *Helenium autumnale*, the sneeze-weed, is a perennial herb with smooth stem two to six feet tall, pointed lanceolate leaves, and bright yellow flowers in heads containing both ray and disk flowers It occurs widely scattered in North America Eaten in quantities it causes fatal results in cattle, horses and sheep White Snakeroot, *Eupatorium urticaefolium*, another perennial with stem one to five feet tall, with opposite ovate leaves and dense masses of small heads of white flowers, occurs widespread in northern North America It also produces fatal results if eaten by stock

Ragweed, *Ambrosia artemisiaefolia* and related species, is another widely known member of the family It is a native plant, widely distributed and usually very abundant It is a branching annual, growing two to four feet tall The leaves are finely divided and rather thin The flower heads are of two sorts, the staminate heads are borne in elongated racemes, while the pistillate are borne in clusters Flowers are produced in late summer and autumn and, unlike most composites, are wind-pollinated The pollen of these plants is one of the principal causes of hay fever (See **Allergy**) (R M W)

COMPOSITION, CHEMICAL. See **Chemical Composition.**

COMPOSITION OF VECTORS. **Vector Addition.**

COMPOUND, CHEMICAL. **Chemical Composition.**

COMPOUND CURVE. **Circular Curve.**

COMPOUND ENGINE. A **steam engine** in which the total pressure drop of the steam between throttle and exhaust conditions is divided into two or more stages is said to be compounded when the expansion in each stage is performed in a separate **cylinder** By common usage the engine in which steam is successively expanded in two cylinders is called a compound engine If three cylinders are used, the engine is triple expansion, if four cylinders, quadruple expansion, etc There are three very definite advantages attending compounding an engine. Any one cylinder does not have the big difference in temperature between incoming and outgoing steam that exists in a simple steam engine The amount of initial condensation of the steam consumed in warming the cylinder and ports at the beginning of each stroke is thereby lessened The confining of the highest pressure steam to the small high-pressure cylinder makes it possible to design the low-pressure cylinder, which is always the largest, against much lower loading forces than in the case of the simple engine, where one cylinder must not only meet the requirements of the highest pressure, but also contain the greatest volume of the steam Furthermore, the flow to the low-pressure cylinder may be split between two identical low-pressure cylinders, thus reducing the cylinder size

A compound engine may be tandem-compounded or cross-compounded Tandem compounding refers to the arrangement wherein the different cylinders are in line and their pistons are fastened to the same piston rod One crank and one connecting rod are required in a tandem compound engine The cross-compounded engine has cylinders set with axes parallel, each cylinder having its own piston rod and connecting rod, the latter bearing on separate cranks of the crankshaft There is more mechanical friction in the cross-compounded engine, but the cranks may be set at an angle to each other, and the rotative effort made more uniform Steam exhausted from the high or intermediate pressure cylinder in a tandem engine may be passed directly to the next lower pressure cylinder through short interconnecting piping since the pistons move in synchronism A steam receiver is necessary between the cylinders of a cross-compounded engine because of the angle between the cranks. The compound engine was at one time built in very large sizes, and a quadruple expansion engine was no uncommon thing, but while the engine was effi-

cient, it was bulky, slow speed, and extremely costly, and has been rendered obsolete by the steam turbine There are, however, many multiple expansion engines in service at present in excellent working condition, and they will probably continue to give good service for many years, but new installations at present are made with either the simple steam engine or the steam turbine (F T M)

COMPOUND FRACTURE. See **Fracture.**

COMPOUND GENERATOR A direct current **generator** which has incorporated a series field in addition to the normal shunt field is said to be compound-wound The line current flows through the series field, consequently, an increase of current drawn from the generator will increase the field strength so that the terminal voltage may be made to increase It is possible to adjust the series field so that the increase of the voltage at the generator will compensate for line loss and approximately constant voltage will be maintained at the load end of the transmission line (F T M)

COMPOUND PROBABILITY. **Probability.**

COMPOUND TURBINE. A compound **turbine** is one in which there are two casings - high and low pressure The steam is partially expanded in the high-pressure casing, then exhausted to the low-pressure casing The rotor arrangements may be either tandem- or cross-compound Two generators must be supplied to cross-compounded turbines The principal advantages of compounding a turbine are the reduction in physical size of any one casing, the confinement of the highest pressures to the smaller casing, which may be built of steel, and the possibility of divided flow in the low-pressure casing for the purpose of equalizing end thrusts (F T M)

COMPRESSION Compression is descriptive of the decrease of volume of a compressible substance due to the application of pressure The common example of compression is found in cylinders filled with gas being compressed by the motion of a piston moving in the cylinder The pressure increase required for any given reduction of volume of a gas depends upon the particular condition surrounding the act of compression, for example, if the cylinder is thoroughly insulated against heat transmission, the compression will be of a type known as **adiabatic**, and the temperature of the gas will rise during compression because the mechanical work expended on the piston in obtaining the compression is converted into heat energy in the gas On the other hand, if the cylinder is a good conductor of heat, and passes heat to the atmosphere as rapidly as it is received by the gas, the temperature at the end of compression may be the same as that at the beginning In this **isothermal** compression the pressure at the end of compression is less than that of an equivalent adiabatic compression In general, actual compressions are neither strictly adiabatic nor isothermal See **Air Compressor, compression ratio, polytropic**

In structural engineering compression is used to denote the type of stress which causes the fibers of a member to compress (F T M)

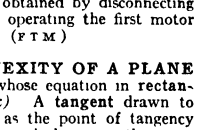
COMPRESSION RATIO **Ratio of Expansion.**

COMPTON EFFECT The well-known increase in wave length of **x-rays** scattered by the **electrons** of the lighter **atoms** Professor A H Compton found in 1923 that when a beam of homogeneous x-rays enters carbon, for example, and is scattered at various angles θ with the incident direction, the wave length of the scattered radiation, in angstroms, exceeds that of the incident by $0.0243(1-\cos\theta)$ This he explained as due to collisions of the x-ray quanta with free electrons in the carbon, assuming conservation of momentum and conservation of energy as in ordinary elastic collision The quantum is in general deflected obliquely (at angle θ), while the electron moves off in another direction, taking part of the energy $h\nu$ of the quantum This lowering of the quantum energy, when the proper relativistic formulae for momentum and kinetic energy are used, corresponds accurately with the reduction in frequency and increase in wave length actually observed

The recoiling electrons were later detected by Professor C T R Wilson by means of the cloud tracks which they produce in water vapor, and the speed of these electrons agrees exactly with Compton's analysis The whole phenomenon, as interpreted by Compton, is a most striking confirmation of the **quantum theory** of radiant energy. (L D W)

CONCATENATION. Variable speed control is more of a problem in alternating current **motors** than it is in motors operating on direct current The wound-rotor motors, the speed of which is controllable by insertion of resistance in the rotor circuit, nevertheless suffer from the disadvantage of losses occasioned by conversion of electrical energy into heat at the grids of the resistors A method of speed reduction without heating loss frequently used in railway service is known as concatenation This form of connection is also called cascade control Concatenation may be employed when there are two wound rotor induction motors mounted on the same shaft, i e , on the axle of a rail truck Full power output is obtained, of course, when both motors are drawing current directly from the supply, and all rotor resistance is cut out or short circuited Approximately half-speed operating conditions are obtainable if the rotor circuit of one motor is connected to the stator of the second motor The stator, or armature winding of the second motor, imposes a resistance in the rotor circuit of the first motor, which reduces the rotor current and the power delivered by the first motor This motor operates at half speed and supplies the second motor with current the frequency of which is one-half of the frequency of the main supply The rotor of the second motor will operate in the short-circuited state Now as the speed of the motors decreases somewhat below half normal synchronous speeds, the frequency of the current delivered by the rotor and the first motor rises somewhat over the half speed point, and increases the magnetic slipping of the second motor, which is then receiving current at a frequency higher than half that on the supply mains, and is operating at slightly less than one-half normal synchronous speeds The result is an increase of torque in the second machine, which will increase the speed until the decrease of frequency in the first machine's rotor circuit will cause the torque of the second motor to fall off to the value which will just maintain half speed in the face of load conditions A speed intermediate between the condition just described and full power speed may be obtained by disconnecting the second motor entirely and operating the first motor with its rotor short-circuited (F T M)

CONCAVITY AND CONVEXITY OF A PLANE CURVE Consider a curve whose equation in **rectangular coordinates** is $y=f(x)$ A **tangent** drawn to the curve will turn clockwise as the point of tangency moves from A to C, and counterclockwise as the point moves from C to E The curve from A to C is called concave downward and from C to E concave upward, the point C is called a point of inflection At a point of inflection the curve changes from concave upward to concave downward, or vice versa



A curve whose equation is $y=f(x)$ is concave downward at points where $f''(x)$ (i e , d^2y/dx^2) is negative, and is concave upward where $f''(x)$ is positive; if $f''(x)=0$ at $x=x_0$ and if $f''(x)$ changes sign as x increases through x_0, then the curve has a point of inflection at $x=x_0$. (L L S)

CONCENTRATION. Concentration is the amount of a given substance in a stated weight or volume of material The most commonly used method of expressing concentration is by stating the percentage, that is, parts by weight of the given substance in 100 parts by weight of the stated material There are settled exceptions to this method of expressing concentration, and the units used should be carefully recorded or observed according as the reader is operator or reader respectively Ethyl alcohol, in water mixtures, is commonly reported as a stated per cent by volume, where 50 0% by volume is equivalent to 42.47% by weight (See **Ethyl Alcohol.**) Gases in a mixture are commonly reported by volume per cent, thus nitrogen in air 78 0% by volume (equivalent to 75 5% by weight) (See **Air**)

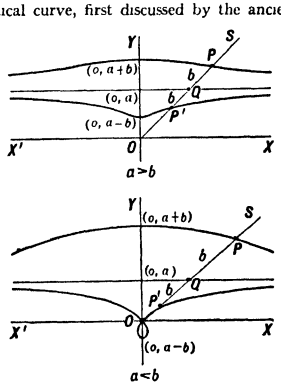
The concentrations of substances in solution are expressed variously, thus, per cent by weight of the actual material stated, per cent by weight of a material calculated chemically from the actual material, grams of the actual material (or a material calculated chemically from this) per 100 milliliters of solution, gram mols (the formula weight taken in grams) of the actual material per liter of solution (this is molar or formal concentration and the abbreviations, M or F, respectively, are used to express it), gram equivalents (the equivalent weight taken in grams—See **Chemical Composition**, IV Equivalents) of the actual material per liter of solution (this is normal concentration and the abbreviation, N, is used to express it)

Since the concentration is proportional in many individual cases to an easily determined physical constant, such as specific gravity (e g , of solutions), index of refraction, specific rotatory power (e g , sugar solutions, terpenes), such constants are frequently used to ascertain and express concentration data (R K S)

CONCH. Mollusca, Gasteropoda Any of numerous species of large marine mollusks (**Mollusca**) The spiral shells have a long aperture, in many species beautifully colored The shells are used for ornaments and as horns, and the animals are sometimes eaten (A W L)

CONCHIOLIN A horny material which forms the outer layer of the shell mollusks (**Mollusca**) (A W L)

CONCHOID OF NICOMEDES The conchoid is a mathematical curve, first discussed by the ancient Greek



Conchoid

mathematician Nicomedes The name given to it is due to its supposed shell-like shape

The conchoid may be defined geometrically as follows With a set of rectangular axes, draw a line AB parallel to the X-axis, above it and at a distance a from it Draw a secant line OS cutting AB at Q, and extend OQ in each direction a fixed distance b to points P and P' As the secant line rotates about O, the points P and P' describe the conchoid

In **polar coordinates**, the equation of the conchoid is $r = a \csc\theta \pm b$, in **rectangular coordinates**, the equation is $(x^2 + y^2)(y - a)^2 = b^2y^2$

The conchoid can be used for the "trisection of an angle," also to "duplicate a cube" (L L S)

CONCHOLOGY. The study of molluscan shells The word is sometimes applied to the study of mollusks generally but this field is more accurately called malacology (A W L)

CONCRETE. Concrete is a mixture of fine and coarse aggregates firmly bound into a monolithic mass by a cementing agent The cement ordinarily employed for concrete is the standard Portland cement The aggregates are sand and crushed stone or gravel Crushed slag or cinders are used in special kinds of concrete The formation of concrete can be thought of as a process in which the voids between the particles of coarse aggregate are filled by the fine aggregate, and the whole is cemented together by the binding action of the cement and water The nature of Portland cement in this respect is described under **cement.**

Due to its strength, permanency, and low cost, concrete is one of the most important building materials employed in modern construction It is widely used for **foundations** of all types, buildings, **bridges, dams, retaining walls, highways**, and other purposes too numerous to mention However, the success of concrete in meeting any particular set of conditions, depends upon the proper correlation of many factors bearing on the selection and mixing of the materials, the placing of the concrete, and the original design Concrete is strong in compression, but relatively weak in tension Therefore structures in which the concrete is likely to be in **tension** must be reinforced with steel rods, which carry the tension and relieve the concrete of tensile stress The design of plain and **reinforced concrete** structures has been placed upon a rational technical basis The uniformity of commercial cement enables the engineer to design an economical concrete structure—one having a minimum of unused excess strength For strong permanent concrete, the aggregates should be clean, coarse, and well graded River or coarse sand is better than pit sand, and should always be used where possible The accompanying table gives typical concrete mixes, with the characteristics of each

DATA ON CONCRETE MIXES TO YIELD 1 CU YD CONCRETE

Mixture	Cement, Sacks	Sand, Cubic Yard	Stone, Cubic Yard	Application	Weight, Tons per Cubic Yard	Safe Comp Stress, Tons per Square Foot
1 2 3	7	51	77	Roofs, sills, tanks, tunnels	2	35
1 2 4	6	44	88	R C floors, beams, and columns	2	30
1 2½ 4	5 6	52	83	Building walls	2	25
1 3 5	4 7	52	86	Foundations and footings	2	20
1 2 4	6 6	49	Cinders, Cubic Yard 98	R C floors	1 5	14
1 2 4	6 6	49	Slag, Cubic Yard 98	R C floors	1 6	14

This table is suitable for preliminary estimates or for small amounts of concrete, but it should be remembered that research and development in the science of concrete proportioning has advanced to the point where little short of a laboratory analysis can establish the best and most economical mix for a given condition. Type and gradation of aggregate, moisture content of the sand, and water-cement ratio are typical factors taken into account in a complete analysis for the specification of large amounts of concrete work.

Concrete should be transported rapidly from the mixer to the forms, so that no initial set will have occurred before the concrete is placed in its final position. It is necessary to place concrete in the forms with care to prevent segregation of the lighter and heavier parts. This precludes dropping the concrete into place from any height. After the "green" concrete has been poured, it should be cured, or hardened, slowly over a period of about a week, during which time it should be protected from vibration, freezing, and a too rapid rate of drying out. Concrete usually attains close to its maximum strength about twenty-eight days after pouring. (F.T.M.)

CONCRETION. An irregular but always rounded mass, which is usually built up in concentric layers around some sort of nucleus, found in **sedimentary** rocks and the manner of formation is not well understood but it seems to result from the concentration, through the agency of ground waters, of material originally disseminated through the rocks. Concretions may be made up of **clay, silica,** hydrate of **iron,** etc. Concretions with radial cracks which have subsequently been filled with some mineral substance are called septaria or turtle stones. (E.S.C.S.)

CONCURRENT FORCES. Statics.

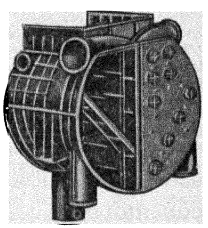
CONCUSSION. A condition resulting from a violent blow. Concussion of the brain is injury of the brain following a blow or fall, marked by swelling, **edema** and possibly **hemorrhage,** of a portion of the brain. A fractured skull does not have to be present. The symptoms associated with concussion of the brain may be, persistent headache, dizziness, double vision, vomiting, a low pulse and elevated blood-pressure. (R.S.M.)

CONDENSATE. A liquid in the vapor state may be reduced to the liquid by removal of such portion of the latent heat of evaporation as it may contain. The act is called condensation, and the liquid is condensate. It is the property of vapors that the condensate is dense as compared to the vapor, which, in condensing, formed it; that is, there is considerable shrinkage of volume upon a reversion to the liquid state. The thermal condition of the condensate immediately upon formation is that of saturated liquid at the temperature of vapor. In other words, it has the temperature of the heat of liquid corresponding to saturation conditions at the vapor pressure. (F.T.M.)

CONDENSATION PUMP. Air Pumps.

CONDENSER. An electrical condenser is an arrangement of conductors and **dielectrics** used to secure an appreciable capacitance, sometimes one of specified value. The essential feature of all condensers is a system of two or more conductors, separated by layers of dielectric. The potential difference between the conductors, when charged, is limited by the electric polarization in the dielectric. This makes it possible to accumulate large charges at comparatively small voltages. The oldest form of condenser is the **Leyden jar,** still often used where heavy electric discharges are desired. Many modern condensers consist of alternate metal and dielectric plates or sheets, sometimes of metal foil and paraffin paper strips rolled in a compact bundle. Condensers in which the dielectric is air, usually of adjustable capacitance, are much used in radio and other oscillatory circuits. Standard condensers, of accurately known capacitance, are employed in electrical measurements. The capacitance of a condenser depends upon the total area a and the thickness d of the dielectric and upon its dielectric constant k. If the dimensions are in centimeters, the capacitance for a condenser of flat plates is approximately given in electrostatic units by the formula $C = ka/4\pi d$ and in microfarads by $C = 8.84 \times 10^{-5} ka/d$. Thus if there are 21 metal plates 10 centimeters square, separated by 20 sheets of mica 0.01 centimeter thick and of dielectric constant 6, the capacitance is about 0.106 microfarads. The capacitance is often made adjustable by varying the distance d or by arranging the plates to move past one another so as to vary the area a of dielectric subject to the electric field between them. Recent special applications of the condenser principle are found in the condenser **microphone** and in the "ultramicrometer"; in the latter very small changes in the distance d are measured by the corresponding changes in capacitance.

A steam or vapor condenser is a device which performs the operation of reducing a vapor to a liquid through the extraction from it of the heat of evaporation it may contain. Industry and research use the condenser extensively to recover a liquid which has been separated from another liquid of higher boiling point or from impurities by the evaporation method. The condenser is an important part of the modern steam power cycle. The purpose of the steam condenser is to lower the back pressure on the prime mover, allowing the steam a larger pressure and temperature drop, thereby increasing both efficiency and capacity. A secondary purpose may be the supply of quantities of warm water or the collection of condensate for boiler feed water. Condensers are applicable to both engines and turbines, though especially to the latter because its thermodynamic advantages occur chiefly in the low pressure range. Engines are ordinarily operated condensing up to 26 inches vacuum and turbines up to 29.5 inches. Size of the equipment required to create the necessary piston displacement is the limiting factor in reduction of engine back-pressure. Furthermore, the larger the temperature difference between inlet and exhaust steam in the ordinary counter-flow engine, the larger the initial condensation loss. Economies effected by condensing operation may be from 10% to 30% higher than for non-condensing.



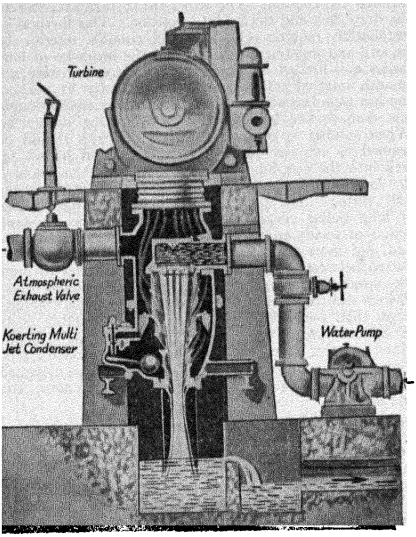
C. H. Wheeler Radial-Flow Condenser. End view with half of water box cover removed and cross-section at middle.

Condensers can be divided into *contact* and *surface* types. Steam and condensing water are intimately mixed in the contact type. Then the condensate and condensing water are withdrawn thoroughly mixed together. A dividing surface is interposed between steam and water in the surface condenser. Heat is transferred through this partition surface at rates varying from 300 to 800 B.T.U. per square foot per hour per degree Fahrenheit. The steam and condensing water never come into direct contact and are withdrawn from the condenser separately. The dividing surface is ordinarily a tube with condensing water circulating inside and steam outside.

The contact condensers (jet condensers) may be further subdivided into those from which the water is extracted directly by pumps, those from which it is forced by the ejector action of a high-velocity water jet, and those from which it flows by virtue of a head of water maintained in a long tail pipe. Elements of the jet condenser are: (1) nozzles or distributors for the condensing water, (2) steam inlet, (3) mixing chamber, (4)

hotwell, (5) in some cases, a diffusing chamber or a tail pipe.

Surface condensers are classified as horizontal or vertical by the position of their tubes. They are single-pass or double-pass according to whether the water



Typical arrangement of multi-jet condenser under turbine.

passes the length of the condenser once or twice. Three-pass condensers are infrequently used at present. They are also classified upon a basis of the shape of the shell, as, for instance, cylindrical, heart-shaped, U-shaped, oval; and upon the location of the air-cooling surface—internal or external. The elements of the surface condenser are (1) cooling surface for both air and steam, usually ¾, ⅞, or 1-inch copper alloy tubes from 10 to 25 feet long, (2) tube sheets into which the tubes are expanded or packed, (3) intermediate tube supports (sheets bored similar to the tube sheets but in which the tubes fit loosely), (4) water boxes provided with circulating water connections and enclosing the space furnished for water flow to and from the tubes, (5) steam inlet, air and condensate outlet, (6) hotwell in which the condensate collects (in some plants deaeration of the condensate is done in a deaerating hotwell, while in a few cases reheating hotwells are installed to offset undercooling of the condensate), (7) condenser shell enclosing and supporting the other elements.

Dimensions of a condenser should be based on an economic study balancing the capitalized condenser cost against net operating savings; that is, the saving effected by increased vacuum less the cost of operation including cost of cleaning and cost of auxiliary energy.

The jet condenser is incapable of maintaining economically the high vacua possible in the surface condenser on account of the large power requirements of the air pump at high vacua. But the jet condenser is relatively simple and inexpensive, and may be installed without excavating a condenser pit. The jet condenser will be classed as low-vacuum or high-vacuum, depending upon whether a dry vacuum pump handles the air separately from the hotwell pump.

Heat transfer action in a surface condenser is hindered by the presence of non-condensable gases which mix with the film of condensate on the tube surface. The sources of air and other non-condensable gas leakage are numerous. Some may come over with the boiler steam, or leak in through turbine packing gland or exhaust nozzle connection. Air leakage will seriously affect the heat transfer and every effort is made to minimize it. For maximum heat transfer and minimum wasted cooling surface (1) the steam should enter the condenser with minimum resistance, (2) tubes should be arranged for rapid penetration of the steam to all parts of the cooling surface by providing lanes or by staging the tubes (good longitudinal distribution of the steam is of equal importance), (3) condensate should be removed rapidly and efficiently so that it will not be undercooled too much, (4) the tube surfaces should be cleared of air by maintaining positive flow of the non-condensable gases through the shell to an air cooler section. These so-called "non-condensable" gases are chiefly oxygen and nitrogen. While they may, of course, be liquefied under suitable conditions of pressure and temperature, they are non-condensable from the standpoint of steam condenser operation.

Fouled tubes, air leakage, or insufficient circulating water are all causes of low vacuum. The fouling of tubes may arise from numerous sources, such as silt or sand in the water, organic waste from sewage, organic and inorganic slimes or scale of calcium carbonate and sulfate. When fouled, the tubes are cleaned according to the characteristics of the deposit or scale. The principal methods are: (1) bake by draining the water side (certain scales will crack loose and can be washed out after baking), (2) wash out slimes by increasing the water velocity through the tubes to 15 feet per second or more, (3) force rubber or metal plugs through the tubes under water or air pressure, thus scraping out the scale, (4) wire brushes, (5) sandblast (very effective), (6) circulate very weak solution of hydrochloric acid to dissolve the scale. A common treatment for fouled steam side surface is to boil a sal soda solution in the steam space. Organic slimes have been prevented by systematic chlorination of the circulating water.

The auxiliaries required for condensers can be arranged under two heads: first, those connected with the flow of water; second, those connected with the vacuum. The condensate pump serving a large condenser is always of the centrifugal type but reciprocating pumps may be used for small surface condensers and jet condensers. The head on it is the vacuum plus friction of the piping to the surge tank plus the velocity head plus the difference in elevation between the discharge to the surge tank and the condenser hotwell.

A high vacuum surface condenser requires around a hundred pounds of water per pound of steam condensed. Supply of circulating water is often a deciding factor in station location and a limiting factor in extension of existing plants. These large amounts of circulating water make the circulating water system of considerable importance. In case of limited supply of circulating water it may be necessary to resort to cooling towers and ponds to cool the water for recirculation.

The auxiliary equipment having to do with vacuum includes the vacuum pump, atmospheric relief, vacuum breaker, and manometer. Vacuum pumps may be classified as reciprocating, rotary, or ejector types. The reciprocating type, similar in principle to the air compressor, becomes inconveniently large for other than small or low vacuum condensers. The steam jet ejector is a widely used air pump, especially on large condensers. It can be used with both the jet and surface types. When the heat liberated by condensing the ejector exhaust is recovered in the feed water the ejector becomes a compact, efficient, and simple machine for exhausting the non-condensable gases. Having no moving parts and requiring little attention, the ejector can be located in inaccessible positions. Its first cost compares favorably with other types of exhausters. (L.D.W., F.T.M.)

CONDOR. Aves, Falconiformes. A large vulture of the Andes of Peru and Chile. This bird reaches a

length of more than four feet and a wing expanse of ten feet, and is among the largest birds now existing A smaller condor has been reported from Ecuador and the California vulture, *Gymnogyps californianus*, is also called a condor The last species occurs in Lower California, southern California, and east to Arizona, living in the mountains It is sometimes larger than the condor of South America All of the condors eat carrion (A W L)

CONDUCTION. Electric Conduction; Thermal Conduction.

CONDUCTIVITY. For conductivity of electricity, see **resistance,** for conductivity of heat, see **thermal conductivity**

In biology, conductivity is a fundamental property of living matter through which impulses generated by some form of stimulus are transmitted from one part to another of the individual body It attains its highest expression in the nervous tissue of animals Here impulses set up by the reception of stimuli by sense organs travel through the nerve fibers and arouse other impulses in associated nervous structures or activate muscle fibers or other organs capable of appropriate action A stimulus may also arise in the nervous system itself, conditioned by memory, to bring about some action

The nature of conduction in living substance is not completely understood In nerve fibers the simultaneous occurrence of electrical and chemical changes during the passage of impulses has been demonstrated (F T M, A W L)

CONDUCTOR. A material which, when placed between terminals having a difference of electrical potential, will readily permit the passage of an electric current, is an electrical conductor Different materials have different degrees of conductivity, and their effectiveness in this respect is computed as the **conductivity.** The best conductors are the metals, such as silver, copper, aluminum, platinum, mercury, etc, but non-metallic substances such as carbon, saline solutions, moist earth, also are sufficiently conductive so that this property becomes of significance under certain circumstances By virtue of their cost-conductivity characteristic, copper and aluminum are the most widely used conductors They will usually be found as wires or buses Copper is used more commonly than aluminum, the use of which is still largely confined to high voltage transmission lines, where its lighter weight is of definite advantage Steel as a conductor is inferior to the other two materials mentioned, but its greater strength and resistance to wear have led to its adoption as a conductor of special purposes, such as that of third rail service on electrified railways The resistance of a linen conductor wire is its resistivity multiplied by its length and divided by its cross-sectional area When the length is expressed in feet, and the area in **circular mils,** the resistivity of aluminum is 17 48, of copper, 10 35, and of iron, 58 This property varies with the temperature of the conductor, and the constants quoted apply only at 20° Centigrade (F T M)

CONDUIT. In engineering, a conduit is ordinarily taken to be a means for holding and enclosing electrical wires in locations where exposed wires are impracticable The most widely used electrical conduit is the rigid iron conduit Iron conduit is simply wrought steel pipe well enameled on the inside for the protection of the wires, which are drawn into the conduit Fiber and brass conduits are used when all wires of an alternating current circuit cannot be run in one conduit, for the installation of one conductor in an iron conduit would make of the body of the conduit a magnetic circuit in which would circulate currents similar to the core loss of a transformer The reason for the popularity of rigid iron conduit is that it is fire- and moisture-proof, reliable, and mechanically strong It can be laid rapidly by methods similar to those employed in plumbing

Wires are installed in a conduit as follows A fish tape or wire, a tempered steel wire of rectangular cross-section, is pushed through the conduit until it appears at the farther end A draw line is then attached to it and by withdrawing the fish tape, the line is drawn through the conduit The wires are in turn attached to the draw line and drawn into position This method of installation requires (1) that the conduit interior be smooth and uninterrupted, (2) that the bends be of long radius and limited in number If the conduit were not smooth internally there might be difficulty in pushing the fish tape through it, also the roughness would doubtless damage the insulation on wires being drawn in When conduit is cut and threaded the ends should be reamed to remove burrs The ends should be set up well into the coupling and should be leaded unless in a dry location Ordinary pipe elbows are not used in conduit wiring The pipe itself is bent to a long radius or long radius elbows are used Due to the snubbing action of bends on wire being drawn through the conduit, not more than four equivalent 90° bends are permitted between pulling points, and many prefer to limit the number to three In size, conduits smaller than ½-inch iron pipe size are not to be used, while conduits larger than 4-inch size are seldom required Fiber ducts or tunnels are favored over the large iron conduit Manufacturers have developed, in place of ordinary pipe elbows, tees, etc, lines of special conduit fittings designed to satisfy all requirements for outlets, junctions, etc (F T M)

CONDYLARTHS. Paleocene.

CONDYLE. A rounded prominence on a bone, associated with a joint (A W I)

CONE. A cone is one of the simple and basic type forms of geometric solid

The surface generated by a straight line turning around one of its points and intersecting a given curve is called a conical surface, and the solid bounded by such a surface and a plane cutting it is called a cone

The volume of a cone is equal to one-third the product of the area of the base by the altitude For a right circular cone of altitude h, radius of base r and slant height s, the volume is given by $V = 1/3\pi r^2 h$, and the lateral area by $A = \pi rs$

A frustum of a cone is the portion of a cone between two parallel planes The volume of a frustum of a cone is given by the formula

$$V = \tfrac{1}{3}h(A_1 + A_2 + \sqrt{A_1 A_2}),$$

where h is the altitude of the frustum (perpendicular distance between cutting planes or bases), and A_1 and A_2 are the areas of the bases

The **locus of an equation** which is **homogeneous** in the **rectangular coordinates** x, y, z is a conical surface whose vertex is at the origin

The **locus** of a second-degree equation in x, y, z which is **homogeneous** in these variables is a conical surface with vertex at the origin

The standard equation of a cone is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 0 \qquad \text{(L L S)}$$

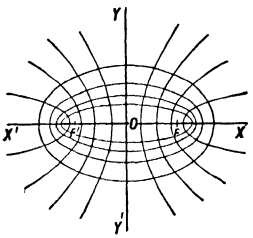
CONE-IN-CONE STRUCTURE. Probably a **concretionary** structure frequently observed in **limestones, dolomites** and other **sedimentary** rocks which originated as fine-grained sediments As the term suggests the structure is formed by a series of concentric cones, the result of radial **crystallization** around a common axis, probably due to differential pressures (R M F)

CONFOCAL CONICS. If two **central conics** have the same foci, they are said to be confocal.

The equation

$$\frac{x^2}{a^2 + k} + \frac{y^2}{b^2 + k} = 1 \quad (a > b),$$

where k is an arbitrary constant, represents the system of confocal conics consisting of the **ellipses** and **hyperbolas** whose common foci are at the points $(\pm\sqrt{a^2-b^2}, 0)$ When $k > -b^2$, the conic is an ellipse, when k is between $-a^2$ and $-b^2$, the conic is a hyperbola.



Confocal conics

Through any given point there pass just one ellipse and just one hyperbola of the confocal system The two conics of the system which pass through a given point intersect at right angles (I L S)

CONFOCAL QUADRICS. Confocal quadrics are geometric surfaces having a common focus

The system of surfaces represented by the equation

$$\frac{x^2}{a^2+k}+\frac{y^2}{b^2+k}+\frac{z^2}{c^2+k}=1,$$

in which k is an arbitrary constant, is called a system of confocal quadrics The principal sections of the system (sections by the coordinate planes) are **confocal conics**

Through every point there pass three quadrics of the system, namely, an **ellipsoid**, an **hyperboloid of one sheet** and an **hyperboloid of two sheets.** These three surfaces are orthogonal, that is, their **tangent planes** are mutually perpendicular (L L S)

CONGENITAL A condition or deformity that exists at, or before birth (R S M)

CONGER Pisces, Teleostei Large marine **eels,** *Leptocephalus,* with sharp cutting teeth They are widely distributed Also applied to the **Congo snake** (A W L)

CONGLOMERATE. Conglomerate, called in older writings "pudding-stone," consists of aggregates of gravel or pebbles with a matrix of sand and cement The proportion of pebbles and matrix may vary considerably both as to amount and actual or relative size of the component material The common cementing materials are silica, **calcite,** and iron oxide

Consolidated glacial debris called **tillite,** may consist of boulders of considerable size in an heterogeneous mixture of pebbles, clay and sand (R M F)

CONGO SNAKE. Amphibia, Urodela A slender aquatic **salamander,** *Amphiuma means,* of the southeastern states The legs are very small, hence the animal is much like a snake in appearance Also called the blind eel, Congo eel, and conger (A W L)

CONGO RED. Dyes.

CONIC SECTIONS. The curve of intersection of a right circular **cone** by any plane is called a conic section or simply a conic If the cutting plane does not pass through the vortex of the cone, the conic section belongs to one of the following three types

(a) If the cutting plane cuts all the elements of one nappe of the cone, the section is an **ellipse,** including the **circle** as a special case

(b) If the cutting plane is parallel to an element of the cone, the section is called a **parabola.**

(c) If the cutting plane cuts both nappes of the cone, the section is called a **hyperbola.**

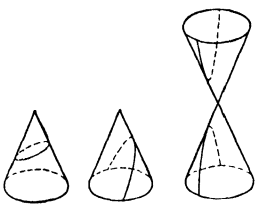


Fig 1 Ellipse Fig 2 Parabola Fig 3 Hyperbola
Sections of a cone

The conic sections were discussed by the ancient Greek mathematicians

When a variable point moves so that its distance from a given fixed point to its distance from a given fixed line has a constant **ratio,** the **locus** is a conic The given fixed point is called the focus, the given fixed line the directrix, and the ratio of distances the eccentricity e of the conic

If $e = 1$, the conic is a parabola, if $e < 1$, the conic is an ellipse, if $e > 1$, the conic is a hyperbola

The ellipse and hyperbola are called central conics, since they each have a center of symmetry

The general equation of the second degree, in **rectangular coordinates,**

$$ax^2+2hxy+by^2+2gx+2fy+c=0,$$

represents

(1) a hyperbola if $h^2-ab>0$,
(2) a parabola if $h^2-ab=0$,
(3) an ellipse if $h^2-ab<0$,

it represents a proper conic (non-degenerate) if

$$\Delta=\begin{vmatrix} a & h & g \\ h & b & f \\ g & f & c \end{vmatrix} \neq 0$$

If $\Delta=0$, the equation is represented by a pair of straight lines An equation of the form $ax^2+by^2+2gx+2fy+c=0$ will represent an ellipse if a and b are of the same sign, and a hyperbola if a and b are of opposite signs

The equation of a conic in **polar coordinates** is

$$r=\frac{ep}{1-e\cos\theta},$$

where e is the eccentricity and p is the distance from the focus to the directrix, if the pole is at the focus and the polar axis is perpendicular to the directrix

The equation of the **tangent** to the conic

$$ax^2+2hxy+by^2+2gx+2fy+c=0$$

at the point (x_1, y_1) is

$$ax_1x+h(x_1y+xy_1)+by_1y+g(x+x_1)+f(y+y_1)+c=0$$

The tangents and **normals** to conics have many interesting properties A few of them will be mentioned

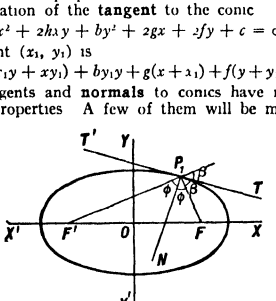


Figure 4 Reflecting property of ellipse

The tangent and normal to an ellipse bisect, respectively, the external and internal angles formed by the focal radii of the point of contact (See Figure 4) There is a similar theorem for the hyperbola

This theorem has an interesting application to drawing a tangent and normal to an ellipse at a given point on the curve.

The phenomenon observed in "whispering galleries" depends on this property. Thus, in Figure 5, let the elliptic arc $A'PA$ be a vertical section of such a gallery. The waves of sound from a voice at focus F will, after meeting the ceiling of the gallery at P, be reflected in the direction PF'. The law of reflection of sound waves is that the angles of incidence and reflection are equal. Hence sound waves emanating from F in all directions will converge at F'. A whisper at F, which would not carry over the distance FF', might consequently, through reflection, be audible at F'.

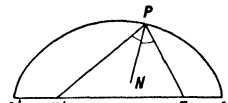


Figure 5.

The tangent and normal to a parabola bisect respectively the internal and external angles formed by the focal radius of the point and the line through that point parallel to the axis. (See Figure 6.)

This can be applied to the construction with ruler and compass of the tangent and normal to a parabola.

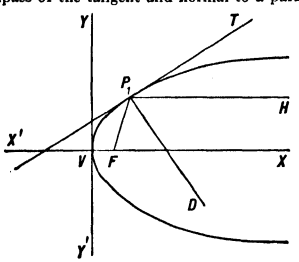


Figure 6.

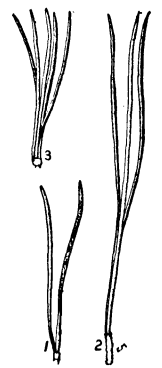
The principle of parabolic reflectors depends upon this property. The reflecting surface of such a reflector is obtained by revolving a parabolic arc about its axis. If now a light be placed at the focus, the rays of light which meet the surface at P_1 in the figure will be reflected in a direction making with the normal P_1D an angle equal to the angle FP_1D. But this direction is, by the above property, parallel to the X-axis (axis of parabola). Reflecting telescopes operate on this principle. (L.L.S.)

CONIDIA. A conidium is an asexual spore, characteristic of many **fungi**. Commonly it is formed at the tip of a hyphal branch, which is called a conidiophore. Conidia may be one- to many-celled. (R.M.W.)

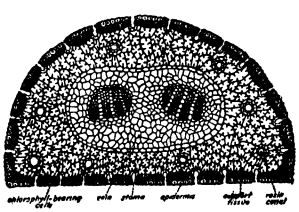
CONIFERS, OR CONIFERALES. This group contains some 400 of the 500 species of **gymnosperms**. It includes the dominant evergreen trees of the north temperate zone, as well as many tropical species. Conifers are at their best in regions where severe winters occur. Nearly all conifers are trees, often of great size, and may attain great age, as for example the redwoods of California and the Douglas firs of Washington and Oregon.

While they are dominant plants in the northern forests of today, in Mesozoic times they were much more numerous and often of much greater size. The petrified forest of Arizona contains a fossil Gymnosperm, *Araucarioxylon arizonicum*, from the **Triassic** period. As recently as the **Miocene** age, coniferales were much more widely scattered than at present, species of Redwood and Cypress growing in regions as far north as Greenland; today they are found only in warmer climates and often in a very restricted range there. Though naturally restricted in habitat, many of them are easily introduced into new, often distant regions, where they thrive.

The plant body of the conifers varies from low straggling shrubs to large trees. The several parts of the plant also show great diversity. Nearly all of them have tall straight stems extending to the very top of the tree, and numerous lateral branches which are progressively shorter from bottom to top of the trees, which therefore have an attractive conical shape. In many species there is a central tap root extending deep into the ground, from which smaller lateral roots arise. In other species extensive lateral roots spread out near the surface of the ground. The leaves of conifers of the northern hemisphere are either slender and needle-shaped or short and scale-like. Those of the pines are formed in fascicles or bunches of two to five which grow from a very short lateral branch. In spruces and firs the leaves are borne singly around the stem. In white cedar and certain other conifers the leaves are reduced to short pointed scales which are formed in pairs of opposite sides of the stem, and are pressed tightly to it. In the southern hemisphere there are several conifers with broad leaves very similar in outward appearance to those of many angiosperms. The leaves of conifers have an epidermis of thick-walled cells which give stiffness to the leaves. The stomata are sunk deep in grooves. The assimilating tissue of the leaves, the cells containing the **chloroplastids**, is formed of cells the walls of which are curiously infolded. These cells surround the central vein, in which are found the **vascular** bundles. Some species have one, others two bundles in a leaf. In the assimilating region numerous resin canals are found. These are also present in the bark and in the wood of many gymnosperms. The leaves of most gymnosperms remain on the tree from two to five or more years, and even, in some species, persist for as long as twenty years. Those of the larches



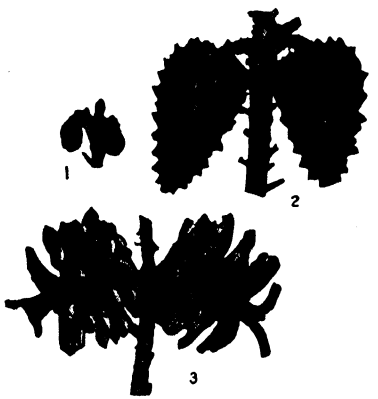
Leaf clusters from different species of pine.
1, *Pinus Murrayana;*
2, *Pinus ponderosa;*
3, *Pinus flexilis.*


Cross-section of a pine leaf.

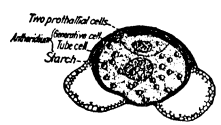
are deciduous, falling in the autumn, and leaving the branches bare through the winter.

The reproductive structures of the conifers are the cones or strobili, which are of two kinds, staminate and ovulate cones. Usually these are found on the same tree, which is therefore **monoecious**. The **staminate** cones, too, often called the male cones, are small and short-lived. They are generally found near the tips of the branches. A staminate cone consists of a central axis and a series of spirally arranged **sporophylls**. Each sporophyll bears two pollen-sacs or microsporangia on its lower surface. Each microsporangium contains numerous cells called microspore mother cells which divide by reduction divisions to form microspores, or

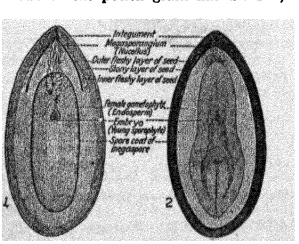
pollen grains, four from each microspore mother cell. The number of pollen grains produced is tremendous; often they are liberated from the sporangia in such quantities as to produce what are known as "sulfur showers," which cover the ground with a layer of yellow pollen, or cause the water of ponds to become turbid with the pollen grains. The pollen is carried about by the wind, often to distances of many miles. The wall of a pollen grain is composed of two layers, an inner, called intine, and an outer, exine layer. In some conifers the outer layer is separate from the inner in two places, forming conspicuous balloon-like structures which presumably are an aid in keeping the pollen grain floating in the air. Even before shedding, the **nucleus** of the pollen grain has divided, so that the grain at the time of shedding contains three or more cells. All but one of these are very small and last but a short time before they disintegrate, leaving thin disk-like cells pressed against one side of the pollen grain. These small cells are usually called prothallial cells, and are thought to be vestiges of extensive vegetative tissue or earlier forms. The large cell of the pollen grain divides to form two, known as the generative and tube cells.



Lodgepole pine, *Pinus Murrayana*, showing development of ovulate strobili. 1, Pair of strombili shortly after pollination; 2, pair of strobili one year old; 3, pair of strobili two years old after the seeds have been shed.



Austrian pine, *pinus laricio*. Microspore developing into pollen grain. (From Chamberlain's *Elements of Plant Science*, McGraw-Hill Book Company, Inc.)

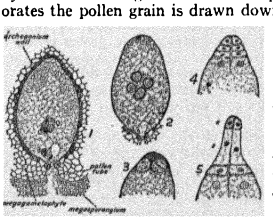


Development of pine seed. 1, two embryos have started and the suspensors have pressed one of them deep into the endosperm; 2, single mature embryo, its mate having failed to develop to maturity. (From Chamberlain's *Elements of Plant Science*, McGraw-Hill Book Company, Inc.)

The ovulate cones require a much longer time than the staminate to reach maturity. Often they remain on the tree for many years. The structure of the ovulate cone varies in the different genera, and is the cause of much discussion in many cases. In the pines, the genus in which the development of the ovulate structure is best known, the cone is made up of numerous scales. On the upper surface of each scale there are two ovules. The greater part of each ovule is a mass of cells called the nucellus or megasporangium. This is surrounded by an integument, a tissue which does not completely enclose the nucellus, a small opening known as the micropyle being left. It is through this opening that the pollen grains reach the surface of the megasporangium. As the ovule develops, one or sometimes more of the cells in the nucellus becomes distinct from the other cells because of its larger size and denser protoplasm. This is the megaspore mother cell. It divides by reduction division to form a row of three or four cells, one of which becomes the megaspore, the others degenerating. The single megaspore divides into many cells which form the female gametophyte or megagametophyte. At the end of the megagametophyte nearest the micropyle several **archegonia** develop. Each archegonium contains a single very large egg cell.

1, megasporophyll and two **seeds**; 2, a single seed with wing. (From Curtis, *Nature and Development of Plants*, Henry Holt & Co.)

The pollen grain, carried by the wind, comes in contact with a small drop of fluid which has been secreted by cells in the region of the micropyle. As this evaporates the pollen grain is drawn down into the micropyle to the surface of the nucellus. There the pollen grain puts out a pollen tube which grows through the nucellus tissue until it reaches the tip of the megagametophyte. During this development a final division of the generative nucleus has occurred, and two male gametes or sperm nuclei are formed. When the tip of the tube reaches an archegonium these nuclei are discharged into the egg. One of the nuclei passes to the egg nucleus and fuses with it; the other disintegrates. The time required for the pollen tube to reach the egg varies greatly in different genera; in some, like the spruce and the hemlock, it is a matter of a few weeks; in others, like the pine, it is nearly a year.



Stages in the early development of a pine sporophyte. 1, fertilization; 2, zygote nucleus has divided into four nuclei which pass to the end of the sac farthest from the micropyle and divide again; 3 and 4, walls have formed between the nuclei; 5, suspensor cells (s) elongate, pushing proembryo cells (e) into the megagametophyte. (From Curtis, *Nature and Development of Plants*, Henry Holt & Co.; after Ferguson and Coulter and Chamberlain.)

The nucleus of the fertilized egg passes to the basal end, dividing twice, and forms a rosette of four nuclei. Each of these divides again, forming two tiers of four nuclei. Walls then begin to form separating the apical tier from the other. Subsequent nuclear divisions increase the number of tiers to four, each composed of four cells.

The apical tier presently divides and forms the **embryo;** the second tier, called the suspensor, elongates greatly, shoving the embryo down into the gametophyte tissue. There the embryo absorbs food substances from the tissues around it and matures.

The mature seed of a gymnosperm consists of a hard **seed** coat, developed from the integuments, the nucellar tissue, and the embryo. The latter consists of a straight slender **hypocotyl** and two or more **cotyledons,** and a very small **epicotyl** or plumule. During its development this embryo has been surrounded by a mass of tissue called the **endosperm,** which is megagametophyte tissue.

The seeds of different conifers vary greatly in size. In some species of pine, they are large enough to be used as food for human beings. In the southwestern United States there are several species of pine which bear edible seeds. These are called piñon nuts, and are used in the same way as peanuts are. In southern Europe other species of pine yield edible seeds. One of these, called pignolea nuts, is frequently used in confectionery.

The conifers yield many other valuable products. The **wood** of many of them is extremely valuable, forming the principal timber used in construction work. Its use in this work is largely due to its composition. Each annual ring is composed of two distinct layers, an inner soft layer and an outer hard layer often much darker colored than the other; these give to the wood great strength and also flexibility, and allow easy driving of nails into the wood without splitting it. **Turpentine** and **resin** are obtained from many of the conifers. **Amber** is a fossil resin coming from an extinct conifer. Many conifers are grown as ornamental trees, often in regions far from their natural habitat.

Several genera of conifers are well known for various reasons. Perhaps the best known are the Redwoods, two species of the genus *Sequoia,* which is found in California. *Sequoia gigantea,* the giant redwood, grows in scattered groves on the slopes of the coastal mountains south of San Francisco. The trees may reach a height of 300 feet and have massive trunks 12–36 feet in diameter. Many of them are 3000 years old or more. Fortunately the wood of this species is a poor timber, so that they are reasonably safe from cutting for lumber. The other species, *Sequoia sempervirens,* grows north of San Francisco near the coast. It also is a tall tree, but more slender than the "big trees," averaging 15 feet in diameter. It grows more rapidly, reaching maturity in 1000 years or less. Its soft red wood is an excellent timber and much used.

Another conifer native in the western United States is the Douglas Fir, *Pseudotsuga Douglasii.* This tree, like the redwood, attains great size, growing 200 feet or more in height, and 6–10 feet in diameter. It is a valuable timber tree.

A third conifer, the cedar of Lebanon, *Cedrus libani,* is an attractive tree with numerous spreading branches which grows 70–100 feet tall and 5–7 feet in diameter.

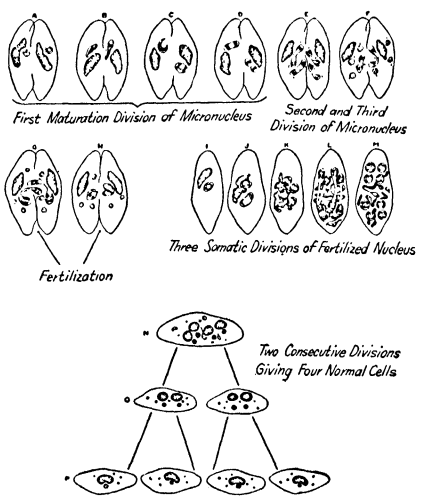
The Cypress, *Taxodium distichum,* is a tree of the wet lowlands of southern United States and Mexico. It is a large tree, often more than 100 feet high and 4–6 feet in diameter. When growing in wet swamps, erect woody protuberances known as cypress "knees" grow out from the roots. These have a long conical shape and may be several feet high. The wood of the cypress is soft, straight-grained, and has a peculiar somewhat unpleasant odor. The heartwood varies from red to very dark brown; the sapwood is light. The wood is very resistant to exposure to water, and also not liable to damage by insects. It is used in greenhouse construction, in making vats, and other containers for liquids, in furniture-making and for many other purposes requiring a soft durable non-shrinking wood. One of these trees, growing in southern Mexico, is very large and, while undoubtedly very old, is still sound. This is the "Big tree of Tule," which has a trunk diameter of 50 feet.

Many species of Firs (*Abies*) and Pine (*Pinus*) also reach great size. But others are remarkable for their ability to endure adverse conditions and thrive. Under these conditions they may remain very small. Specimens of *Pinus Thunbergia,* for example, are much grown in cultivation by the Japanese, who give to them a bizarre yet very attractive shape, while keeping them very small. Some of these dwarf trees may be many years old and yet only a foot or less in height. Grown normally, it is an irregularly branched tree 100 feet or more high and 6–7 feet in diameter. Other conifers are also used by the Japanese in pot cultures and dwarf gardens (See **Paleobotany**). (R.M.W.)

Isolated tree of the Western Yellow Pine, *Pinus ponderosa.*

CONIINE. Alkaloids.

CONJUGATION. A process of interchange of nuclear material between two individual one-celled animals. The **cells** come together in a close association and undergo nuclear divisions. One nuclear component of each passes over into the other conjugant and unites with a nuclear derivative of that individual to form a new nucleus. The completion of the process takes place after the separation of the two cells. It is equivalent to **fertilization.** (A.W.L.)



Conjugation in *Paramecium caudatum.* (After Calkins.)

CONNATE WATER. A term proposed by A. C. Lane in 1908 for underground water which is preserved as the water, fresh or saline, in which the **sediments** were originally deposited. (R.M.F.)

CONNECTING ROD. The common connecting rod is one of the four elements of the mechanism known as the slider crank chain. This mechanism consists of a base which carries two members, one of which rotates while the other reciprocates. The connecting rod connects the reciprocating and rotating elements by means of pinned or hinged joints at its ends, the same constituting the connecting rod bearings. The importance of

this mechanism, and of its elements, including the connecting rod, is that it is the basis for a large number of machines of great importance to modern civilization. This is probably due to the fact that in so many cases a reciprocating motion is produced where rotary is desired, and vice versa. Among the more common illustrations of the machines of which the connecting rod is a vital and important part, are **engines, pumps, compressors, punches,** etc. A familiar example is the connecting rod of the gasoline engine. This engine derives its power from the push of the exploding gas against the reciprocating piston. One end of the connecting rod is joined to the piston by the wrist pin on which it has bearing. The other end of the connecting rod has a bearing on the rotating crank pin. Thus the connecting rod has a composite motion: one end of it reciprocates, while the other rotates. It is subject not only to tension and compressive stress, but also, by virtue of its inertia, to transverse bending. Due to this latter factor, high-speed connecting rods are carefully designed so that their mass will not only be as small as possible, but so placed as to cause the least shaking forces. Commonly used sections are the solid rectangular, the I-beam, and the tubular. Almost all materials, including cast iron, brass, wood, steel, aluminum alloy, have at one time or another been used for connecting rods. (F.T.M.)

CONNECTIVE TISSUE. The connective **tissues,** as the name suggests, are primarily those which bind together other structures. They are derived from the loosely arranged **mesenchyme** of the embryo and are characterized in the adult by the presence of various kinds of cells and of much intercellular substance, also in various forms.

In addition to **bone** and **cartilage** the connective tissues of the adult **vertebrate** include the loose irregularly arranged tissue which underlies the skin and occupies spaces between other organs. In this tissue lie cells which produce its own structures, blood cells, fat cells, and cells which become active in the repair of wounds. Between the cells is a soft matrix containing two kinds of fibers: white and elastic. The white fibers give tensile strength to the tissue and the elastic fibers give elasticity.

The other connective tissues are made up of certain of these structures. Thus **tendons** and **ligaments** are composed principally of parallel white fibers. Fibrous membranes may be either elastic or tough according to the fibers composing them.

Some of the connective tissues have other functions which are not associative. Adipose tissue, for example, is composed largely of cells in which fat is stored.

Some minute parts of many organs are held together by a network of reticular tissue whose fibers run in all directions among the cells of the organ.

The development of these tissues is so extensive that if all other components of the body could be removed, its gross form would still be evident. (A.W.L.)

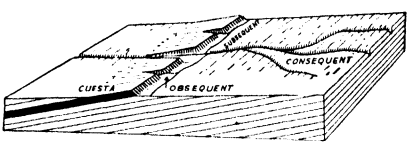
CONODONTS. Invertebrate Paleontology.

CONRADSON CARBON TEST. This test is an indication of the percentage of carbon residue in an oil, either fuel or lubricating. Where lubricating oil is exposed to high temperatures during use, a certain amount of carbon remains after the volatile parts of it have been volatilized. This is true of the lubrication of the cylinders of the internal combustion engine, one of the objectionable features of which is the deposit of carbon in the cylinder head after continued use. Likewise with fuel oils, especially the Diesel fuel oil, carbon residue is an important characteristic. Although not very well understood at present, even by many of those associated with Diesel power development, recent research indicates that the carbon residue as indicated by tests such as the Conradson, may be expected to be an important factor in the selection of a fuel oil.

The Conradson test consists of heating, under special conditions, a weighed sample of the oil at a sufficiently high temperature to volatilize all of the volatile matter of the oil. Once the distillation is completed, there remains the carbon residue, which is determined by weighing. Although it is objected that this test fails in many important respects to duplicate the conditions under which a carbon residue is formed in internal combustion engines, it is a reasonably successful indicator of the value of an oil with respect to its carbonizing qualities. (F.T.M.)

CONSANGUINITY. As used by geologists this term implied the "blood relationship" of **igneous** rocks. Proposed by Iddings in 1892 to designate a related group of igneous rocks which have been derived from a common **magma** and thus form a distinct **petrographic province.** (R.M.F.)

CONSEQUENT STREAMS. The type of **drainage** pattern which develops on the dip slopes of tilted forma-



Block diagram to illustrate the meaning and relations of consequent and obsequent streams, in a youthful stage of the normal cycle of erosion, in a region of tilted strata. The more resistant rock layer (in black) stands out in the form of a cuesta, against the erosion.

tions. If one of the parallel series of tilted formations is more resistant to **erosion** than the others, a cliff or cuesta will be developed. Stream valleys which develop parallel to the cuesta are called subsequent, and their tributaries which cut back into the cuesta are called obsequent. (R.M.F.)

CONSERVATION OF ENERGY. Energy.

CONSTANT OF INTEGRATION. Indefinite Integral.

CONSTANTS. A constant is a symbol for a single number.

An absolute constant is one which has always the same value. The symbol for such a constant may be a particular number-symbol, as 5 or $1/3$ or $\sqrt{2}$, or it may be a special symbol always representing the same number, as $\pi \approx 3.1416$.

An arbitrary constant is one which has only one particular value in a given case, but may have another value in another case.

Arbitrary constants are often represented by letters, as *a, b, c,* etc., from the first part of the alphabet. (L.L.S.)

CONSTELLATIONS. In astronomy this term is used to designate certain groupings of the **stars.** From earliest recorded history we find that the larger star groups (constellations), the smaller groups (asterisms such as the **Pleiades**), and the individual stars have received names symbolizing meteorological, religious, or mythological beliefs. The idea that the constellation names and myths are of Greek origin has been quite completely disproved. It seems highly probable that they are of Semetic or Pre-Semetic origin and that they found their way into Greece through contact with the Phoenicians (sailors who used the stars constantly in their profession).

The oldest record of actual constellation listing is found in the Creation Legend in about 650 B.C. This Legend was recorded on Cuneiform from even earlier records. From this time onwards frequent references to the constellation legends are to be found both in poetical and historical writings. The basis for the modern con-

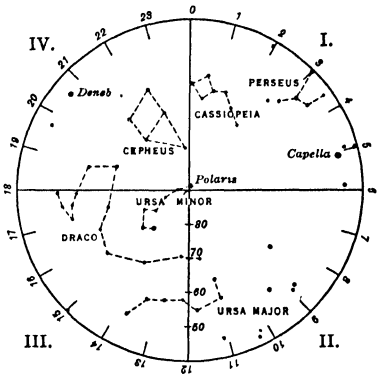


Figure 1. Circumpolar stars

stellation division is to be found in the list of 48 constellations published by Ptolemy in about 150 AD This list of Ptolemy is based upon the writings of his predecessors, notably Hipparchus

The boundaries of Ptolemy's constellations were very indefinite and many visible stars were left out entirely. Furthermore, his list only covered that portion of the heavens visible from the southern Mediterranean regions In the 1800 years since Ptolemy's time the list has been added to and the boundaries defined until at present all stars are included in some one of the constellations The International Astronomical Union placed the matter of defining the constellation boundaries in the hands of a special committee and in 1930 the final list was published.

Several attempts have been made to supplant the ancient mythological names with more modern ones (e g , the Coelum Stellatum Christianum of Julius Schiller in 1627 in which we find the ancient names replaced by names of various Church dignitaries) but none of the attempts have been successful

The following list contains the names of all of the constellations now used, those in bold face type are treated elsewhere in this volume in special articles, and

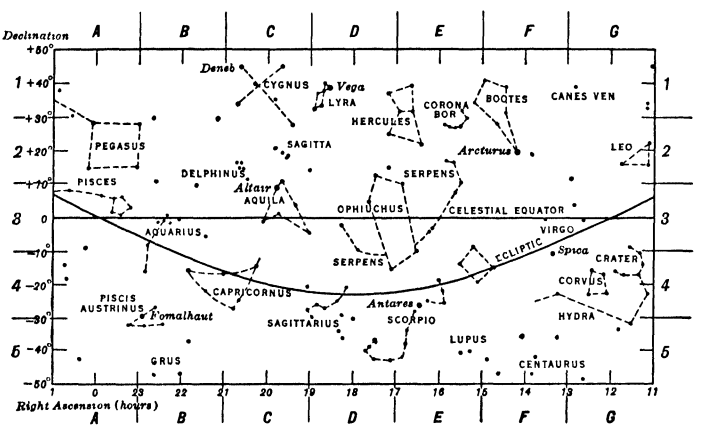


Figure 2 Equatorial stars

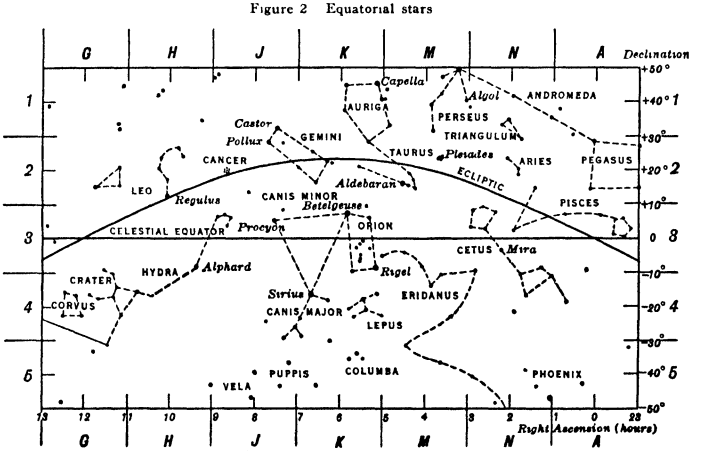


Figure 3 Equatorial stars

those marked with an asterisk are the original constellations of Ptolemy. The most important and easily recognized constellations will be found on the star maps, on opposite page, and the numbers (e g , Aries—Fig III, 2,N) refer to the particular map and location on that map where the constellation will be found

LIST OF CONSTELLATIONS

North of the Ecliptic

* **Andromeda**—Fig III, 1, N
* **Aquila**—Fig II, 3, C
* **Auriga**
* **Bootes**—Fig II, 1, F
Camelopardalis
Canes Venatici
* **Cassiopeia**—Fig I, I
* **Cepheus**—Fig I, IV
Coma Berenices
* Corona Borealis
* **Cygnus**—Fig II, 1, C
* Delphinus
* Draco
* Equuleus
* **Hercules**—Fig II, 2, E
Lacerta
Leo Minor
Lynx
* **Lyra**—Fig II, 1, D
* Ophiuchus
* Pegasus
* **Perseus**—Fig III, 1, M
* Sagitta
* Serpens
* Triangulum
* **Ursa Major**—Fig I, II
* **Ursa Minor**—Fig I, III
Vulpecula

Zodiacal

* **Aquarius**—Fig II, 3, B
* **Aries**—Fig III, 2, N
* **Cancer**—Fig III, 2, J
* **Capricornus**—Fig II, 4, B
* **Gemini**—Fig III, 2, K
* **Leo**—Fig III, 2, H
* **Libra**—Fig II, 4, E
* **Pisces**—Fig III, 3, A
* **Sagittarius**—Fig II, 4, D
* **Scorpius**—Fig II, 5, E
* **Taurus**—Fig III, 2, M
* **Virgo**—Fig II, 3, F

South of Ecliptic

Antlia
Apus
* Ara
Caelum
* **Canis Major**—Fig III, 4, K
* Canis Minor
Carina
* **Centaurus**—Fig II, 5, F
* Cetus
Chamaeleon
Circinus
Columba
* Corona Australis
* **Corvus**—Fig II, 4, G
* Crater
* Crux
Dorado
* Eridanus
Fornax
Grus
Horologium
* Hydra
Hydrus
Indus
* Lepus
* Lupus
Mensa
Microscopium
Monoceros
Musca
Norma
Octans
* **Orion**—Fig III, 3, K
Pavo
Phoenix
Pictor
* Piscis Austrinus
Puppis
Pyxis
Reticulum
Sculptor
Scutum
Sextans
Telescopium
Triangulum Australe
Tucana
Vela
Volans

(W K G)

CONSTIPATION. Infrequent or delayed passage of the intestinal contents There are many causes of this condition One of the most common causes in a normal person is neglect of the impulse to move the bowels The stimulus gradually lessens or is lost entirely. Two factors are involved which prevent formation of a habit cycle of a daily bowel movement at a certain regular time They are laziness or inability to adjust the time of impulse to the time of evacuation

Constipation is common in those who take no exercise, and consequently suffer from an impairment of muscular tone. In other cases diet is at fault It may be too concentrated, so that it leaves too little residue or bulk to enable the intestinal muscles to function properly. On the other hand, the diet may contain too much roughage, producing an irritated spasm of the colon Certain individuals suffer from a spastic colon due to reflex nervous causes—as chronic illness, neurasthenic constitution, worry, strain and emotional worries—and normal intestinal function is prevented Instead the large intestine is usually in a state of spasm or contraction preventing normal passage of intestinal contents through it Laxatives only increase the spasm, many constitutional symptoms accompany this condition with symptoms of indigestion, abdominal pain and headache predominating

The question of habit is an important one in the subject of constipation Frequently the cause is a continued lack of habit hygiene beginning in infancy Again, there are many individuals who believe, in some cases due to the influence of cathartic advertising, that they must help Nature along Gradually the artificial stimulus has to be increased and the dose must be increased or a stronger cathartic taken. Eventually the various drugs have little or no effect The same applies to the enema habit

Some individuals suffer from a relaxed dilated colon when there is insufficient tone to the intestinal muscles so that there is always a stasis with delay in passage of the intestinal contents

There are many local causes of constipation These include weakness of the abdominal muscles, hemorrhoids or other painful disorders causing spasm of the sphincter muscles at the lower rectum, tumors within the intestine or causing pressure from without, adhesions, bands or any structural defect or abnormality causing a partial obstruction of the intestines

The symptoms of constipation depend largely on the cause of the condition Many mistaken ideas about constipation have gained wide popular acceptance Intestinal "auto-intoxication" is largely a myth Symptoms from constipation occur largely in those whose nervous systems, especially the sympathetic system, are easily disturbed—this is true particularly in those who suffer from a spastic colon It must be remembered that certain individuals may normally have one, two, or three bowel movements a day, others may normally have a movement every other day In other words, the frequency of bowel movements largely depends on habit Certain individuals may have a daily bowel movement and still be constipated—producing a hard irritating movement instead of a normal formed one

Treatment of constipation involves correction of the cause and considerable habit training coupled with a satisfactory diet and gradual avoidance of all laxative preparations and drugs This is best established in infancy (R S M)

CONSTRAINED MOTION. Kinetics.

CONSTRAINT. Constraint is that property which distinguishes a mechanism from other mechanical linkages A mechanism has constrained motion in that a motion of one part is followed by a predetermined motion of the remainder of the mechanism To determine whether a mechanical linkage is a mechanism or not, Klein advocates applying the criterion of constraint, which he writes as follows:

$$J = \frac{3N - 4 + \gamma - P}{2}$$

in which J is the number of joints in the mechanism, N is the number of links in the mechanism, γ is the number of independent prismatic chains, that is, those whose joints are of the sliding type, $P =$ the number of point or line type of contact joints in the mechanism When this equation yields an identity, the mechanism is said to be constrained for all dimensions (F T M)

CONSUMPTION. Tuberculosis; and Pulmonary Diseases.

CONTACT METAMORPHISM. Metamorphism.

CONTACT POTENTIAL DIFFERENCE. In his experiments with electroscopes, Volta found that when pieces of two different metals, otherwise insulated, are brought into contact, they acquire opposite charges and maintain a difference of electrical potential even while still touching This potential difference he found to be characteristic of the given pair of metals Thus when the metals are iron and copper, the iron has a potential about 0 15 volt higher than the copper, while for tin and iron the difference is 0 31 volt, tin being the higher Volta listed a series of several metals, viz , zinc, lead, tin, iron, copper, silver, gold, such that when any two are put in contact, the one first named is at the higher potential "Volta's law," which he was not in position to demonstrate but which was established much later, states that the potential difference between any two metals in direct contact is the sum of the potential differences between intervening metals of the series Thus for tin and copper (above) it is 0 31 volt + 0 15 volt = 0 46 volt, and it makes no difference whether the tin and copper are in direct contact or have other metals intervening between them

A distinction must be made between the contact potentials in air and the so-called "intrinsic" contact potentials in a vacuum with all adsorbed gases removed According to Millikan, the intrinsic potential difference between two metals A and B is expressed by $V_{AB} = h(\nu_A - \nu_B)/e$, in which h is **Planck's constant**, ν_A and ν_B are the critical frequencies of photoelectric emission for the two metals (see **Photoelectric phenomena**), and e is the electronic charge In any case, if the electronic **work functions** of the metals are p_A and p_B, the contact potential difference is $V_{AB} = p_A - p_B)/e$ The work functions, and hence V_{AB}, are in general dependent upon the medium surrounding the metals Accurate measurements of these potentials are, unfortunately, very difficult (I D W)

CONTAGION The communication of disease by (1) immediate contact, (2) contact with excretions or secretions of a sick person, i e , saliva by coughing, sneezing or talking, etc (R S M)

CONTINUOUS BEAM. A continuous beam is one which has more than two supports A beam which is continuous over several supports offers more difficulty in analysis than would a series of freely supported beams covering the same overall span Because of the restraint at the intermediate supports, the continuous beam can carry a greater load than a simple beam of the same size and span It is quite important to provide a firm **foundation** for the intermediate supports, as small **deflections** due to sinking of an intermediate support may introduce **stresses** of an entirely different nature than those used in designing the beam (F T M)

CONTINUOUS FUNCTION. A function of one variable $f(x)$ is said to be continuous at a value $x = c$ when $f(c)$ has a definite finite value which is equal to the limit of $f(x)$ when $x \to c$

$$\lim_{x \to c} f(x) = f(c)$$

This may also be expressed as follows $f(x)$ is continuous at $x = c$ if $f(c)$ exists, and if for any arbitrary number $\epsilon > o$ there exists another number δ such that $|f(c) - f(x)| < \epsilon$ for all values of x such that $|x - c| < \delta$

A function $f(x)$ is said to be continuous in an interval (a, b) when it is continuous at every point of the interval, it being sufficient at the end points that

$$\lim_{x \to a^+} f(x) = f(a),$$

and

$$\lim_{x \to b^-} f(x) = f(b)$$

A function is said to have a discontinuity at a point where it is not continuous The usual type of discontinuity is a point at which the function becomes infinite, or where it has a finite jump

Important properties of a continuous function are the following

If $f(x)$ is continuous in a closed interval (a, b) then among the different values of $f(x)$ in (a, b), there is a greatest value M and a least value m

If $f(x)$ is continuous in an interval (a, b), then between every two values x_1 and x_2 of x in (a, b), $f(x)$ takes at least once every value between $f(x_1)$ and $f(x_2)$

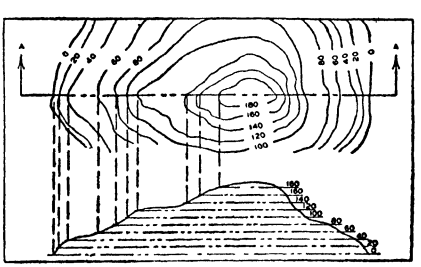
A function of two variables, $f(x,y)$, is said to be continuous at a point (a, b) if

$$\lim_{\substack{x \to a \\ y \to b}} f(x, y) = f(a, b) \qquad \text{(L L S)}$$

CONTINUOUS SPECTRUM. Light or other radiation may have such composition that, when analyzed with a **spectroscope** it reveals an unbroken continuity of wave length over a wide range Such, for example, is the light from an ordinary lamp filament Any incandescent solid, liquid, or gas under high pressure will radiate with a continuous **spectrum.** In contrast to this, the spectrum of a glowing gas, as in a **neon** tube, is made up mainly of sharply defined maxima ("lines") or of more diffuse bands with dark spaces between them Sunlight appears to have a continuous spectrum until analyzed carefully, when the continuous spectrum is found to be crossed by a multitude of dark **Fraunhofer lines**

A continuous spectrum may extend without interruption from the extreme **infrared** to the extreme **ultraviolet.** Study with a **spectrophotometer** will indicate that the relative intensity of the radiation differs in different wave lengths, having a well marked maximum at some particular wave length The position of this maximum intensity is a function of the temperature of the source, and the study of **spectral energy distribution** in stellar spectra provides a method for the determination of the temperatures of the stars (L D W)

CONTOUR. A contour is an outline or a boundary line, or it is a line passing through a series of points, all of which have some one characteristic in common The contour is a useful means of displaying on one plane described by x and y coordinates, the interrelation of three variables, x, y, and z Each contour line drawn



Contours.

upon the xy plane represents a single value of the variable z

In surveying terms, a contour is a means by which the three dimensions necessary to represent a point in space can be shown on a map These three variables are, length measured north and south, length measured east and west, and height, above some arbitrary reference plane On a **topographical map** height is shown by contours All points on a given contour line will be at the same elevation The accompanying figure shows the relation between height of a small irregular hill, and

the corresponding contour lines as drawn upon a map Occasionally special maps, instead of showing elevation as the third variable, give line of constant magnetic **declination.** These lines are called isogonic lines and the map is known as an isogonic chart

While the contour line has its greatest use in land surveying and mapping, there are other technical uses For example, the efficiency of a centrifugal pump varies both with the pumping head and with the discharge Accordingly, centrifugal pump characteristics are often given with the efficiency displayed as contour lines upon a head discharge plane (F T M)

CONTRACTILITY. The fundamental property of living matter on which its power of movement depends In the simplest forms of living things it is evident in a flowing movement of the material of the **cell.** In more complex forms the property is centralized in muscle tissue Muscle cells are elongate and are so arranged that necessary movements result from their shortening when stimulated Chemical explanations of contractility have been formulated but they are theoretical (A W L)

CONTROL. An experiment or test done to confirm or to rule out error in clinical or experimental observations (R S M)

CONURE. Aves, Psittaciformes Small **parrots** of numerous species found from Mexico into South America Their prevailing colors are green and yellow The Carolina paraquet of North America is a member of this group (A W L)

CONUS ARTERIOSUS. The division of the primitive vertebrate **heart** which receives blood from the ventricle and passes it on to the ventral aorta It is characterized by the presence of cardiac muscle and of valves In the evolution of the mammalian heart the conus arteriosus is included in the ventricles Also called bulbous cordis (A W L)

CONVECTION. Thermal Convection

CONVERGENCY OF SERIES. Infinite Series.

CONVERTER. In certain fields of engineering the nature of the desired electrical power may be different from that available For example, an electric railway having direct current motors propelling its rolling stock may obtain its electrical energy in the form of **alternating current.** This situation calls for the conversion of alternating to **direct current** with the minimum amount of loss The converter accomplishes this If a conversion is made from direct to alternating current, we have an inverted converter The most common type of converter at present is the rotary converter, which is essentially an alternator and direct current generator combined in one machine having a single **armature** This is not to be confused with a motor generator set which, although it may be classed as a converter, is basically two machines having separate armatures, and shafts connected by a **coupling** The rotary converter receives alternating current at one set of terminals, and delivers direct current at another The energy delivered is less than that received by the amount of the converter losses, consisting of friction, resistance heat, and core losses For the use of the term converter in metallurgy, see **Bessemer Process.** (F T M)

CONVEYOR. Strictly speaking, a conveyor is any device which is capable of moving material from one point to another The material may be moved intermittently, that is to say, in a succession of separate loads on the conveyor system, or continuously The term furthermore embraces the conveying both in horizontal or vertical directions, or a combination of the two This general definition of a conveyor would include a vast number of cases which it is not proposed to treat here Ordinarily, a conveyor is thought of as a mechanical conveyor constituting a definite installation fixed in position except for its belts, buckets, sprockets, and other moving parts Equipment for vertical conveying would come more properly under the designation of **hoist.** In many instances materials are conveyed at an angle to the horizontal, in which case the conveyor system partakes of the nature of a hoist A conveyor may be designed either for handling loose bulk material such as coal, sand, ore, etc, or for handling individual parts during or after production

One of the simplest and most used conveyors consists of a **belt,** usually horizontal (although it is possible to use a belt conveyor at small angles), continuous over two end **pulleys,** one of which drives it The belt is supported at intermediate points on rollers For transporting material in bulk, the rollers are arranged so that the belt forms a trough, but for handling packages, as on a factory conveying system, the belt would be flat Another simple form of conveyor is the drag conveyor, which, in its primitive form, consists of a flat, heavy chain which is caused to move along the bottom of a trough, and which drags with it the material being conveyed The friction losses are comparatively heavy in this type The flight conveyor is an improvement, since vertical wood or steel plates are attached to the chain and nearly fill the trough from side to side These effect a much more thorough movement of material, and a reduction of friction and wear The flight conveyor may be used at fairly steep angles

Mass production methods depend largely upon the successful application of conveyor systems to the enterprise The mass production of automobiles is one of the best examples Economies effected by maintaining the workman at a station and moving the material past him on conveyors have made possible the production of higher quality vehicles at moderate prices The trolley conveyor is frequently used where parts are being fabricated on an assembly line It is an overhead steel monorail which has suspended on it a number of two-wheel trolleys the carriages of which are connected by a chain which serves to motivate, as well as space them The parts being conveyed are suspended from the carriages by appropriate attachments of the required design

Movement of raw materials and finished articles is often accomplished in factories on roller conveyors The roller conveyor is a line of parallel rollers The load travels along the conveyor from roller to roller under the influence of a gravity force component derived from a slight slope of the conveyor Articles having flat surfaces, such as boxes, may be loaded directly on such a conveyor

An apron conveyor consists of two chains upon which are mounted a number of flat metal plates or boards which are small enough to allow the chains to pass over sprockets at the ends of the conveyor, but which, between sprockets form a continuous flat moving apron upon which are placed the articles to be conveyed

Bucket conveyors consist of a number of V-buckets which are fastened between two moving chains In the plain bucket conveyor, the buckets are fixed to the chains Therefore, on horizontal runs, they must be carried through troughs and act much like flight conveyors If the buckets are pivoted so that they always maintain a level position, they will carry the material on horizontal runs rather than scrape it A long spiral worm revolving in a closely fitting trough forms a type known as the screw conveyor Bucket elevators may accomplish vertical turns, trolley and roller conveyors may accomplish horizontal turns, but the others are essentially straight run conveyors On them, turns must be made by dumping from one conveyor on to another running in the new direction Some use has been made of pneumatic conveyors, in which loose material may be drawn along with the stream of air, or in which articles may be sent in special containers which, fitting the walls of the conveyor conduit rather closely, are moved along somewhat as air pressure would move a piston in a cyl-

inder Modern conveyors are usually driven by electric motors operating through reduction gearing in order to operate the conveyor at an appropriate speed If inclined, the conveyor will be equipped with a device to prevent it from starting backwards when stopped Various automatic or semi-automatic conveyor discharging devices are employed Power requirements are minimized by the use of anti-friction bearings on rollers, sprockets, or pulleys Wear is minimized by the use of hardened wearing parts, or allowed for by the use of renewable wearing parts (F T M)

CONVULSION. A violent spasm or involuntary contraction (generally a series of them) of a group or all of the body muscles Convulsions may be associated with extreme toxicity and high fever in certain diseases, especially those involving the brain or nerve centers They are most commonly and regularly seen in **epilepsy, eclampsia, tetanus, strychnine** poisoning, **meningitis, uremia** and brain injuries Convulsive seizures are also commonly seen in **hysteria.** (R S M)

CONY, CONEY. Mammalia 1 Rodentia The pika, *Ochotona,* a small stoutly built animal found at high altitudes in the northern hemisphere Numerous species 2 Hyracoidea The hyraces, small rodent like animals, form an order of their own They occur in Syria, Arabia, and Africa Most of the toes are armed with broad nails and the superficial resemblance to rodents is due to the long cutting teeth and the compact tailless body (A W L)

COOLIDGE TUBE. X-Rays.

COOLING TOWER. The cooling tower is a means for cooling water through the medium of partial evaporation The action that takes place is one whereby the stream to be cooled is broken up into a fine mist or rain, thus exposing a very large surface area In this condition the water is mixed with air which is brought into the cooling tower by natural convection currents, or which is forced in by fans If that air is not already saturated with water vapor, it will become so by coming in contact with the large area of moisture exposed in the cooling tower The water is taken up by the air in the form of vapor at the partial pressure as determined by atmospheric temperature It will, however, be vaporized to steam before it can become part of the humidified air The heat necessary to effect this evaporation comes from the water itself Since to vaporize a pound of water requires in the neighborhood of 1,000 B T U, while to cool it 1° F requires only 1 B T U, it follows that an evaporation loss of 5% of the water passing through a cooling tower is capable of reducing the temperature of the remaining 95% some 50° F

Cooling towers are usually constructed of wood having wooden, sheet iron, or terra cotta interior baffles so arranged as to convert the stream of water delivered to the tower at its top into a large surface of exposure The cooled water is retained in a catch basin at the bottom of the tower Such cooling towers are frequently employed to cool the jacket water of internal combustion engines, and the circulating water of condensers of various types, i e, in connection with refrigerating plants Long, narrow cooling towers are more effective than squarely built ones Higher cooling towers are more efficient than low ones. The efficiency of a cooling tower is stated as follows·

$$\text{Efficiency} = \frac{\text{Hot water temperature} - \text{cold water temperature}}{\text{Hot water temperature} - \text{wet bulb temperature}}$$

A cooling tower in good condition should have an efficiency of at least 60% (F T M)

COOPERAGE. Wood.

COORDINATE PAPER. Rectangular Coordinates in a Plane, and **Polar Coordinates in a Plane.**

COORDINATES OF A POINT. Coordinates of a point are **numbers** which determine the position of the point

In a plane, the position of a point is usually determined by either **rectangular coordinates** or **polar coordinates.**

In space, the position of a point is usually determined by either **rectangular coordinates, polar coordinates, spherical coordinates** or **cylindrical coordinates.** (L L S)

COORDINATION. The regulation of an organism so that its various parts act cooperatively for the benefit of the whole

Coordination depends upon the reaction of living structures to surrounding conditions, both inside and outside the body Reaction to substances present in the body is classed as chemical coordination and reaction to stimuli which cause the transmission of impulses through the living substance is nervous coordination The separation between the two is not sharp. In general the maintenance of a normal state in the body is due to the transformation and distribution of substances within it, or to chemical coordination These processes are, however, subject to nervous regulation. The rapid transmission of nerve impulses likewise is conditioned by substances within the body The two kinds of coordination are conspicuously illustrated by the action of **hormones** and of the **nervous system.** (A W L)

COOT. Aves, Gruiformes Birds (**Aves**) of several species occurring in Europe and Asia, North America, and Africa They are waders and swimmers, with lobed toes The plumage is dull in the adult, in contrast with the beak and part of the head In the American species, *Fulica americana* the beak is ivory-white Although sometimes eaten the coots do not rank with the ducks as food and game birds (A W L)

COOTER. Reptilia, Testudinata A **turtle** of the genus *Pseudemys* The several species are found chiefly in the eastern and southern United States Also called sliders (A W L)

COPAL. Copal is the hardened **resin** derived from several tropical trees One of these, *Trachylobium Hornemannianum,* is a large white-flowered tree of tropical east Africa Another *Hymenaea Courbaril,* a tree with large white or purplish flowers, is a native of tropical South America

The resin may be obtained from living trees, in which case it is a soft substance naturally slow to harden In Zanzibar, copal resin occurs in fossil form, masses of resin closely resembling amber being dug from the ground This is the best grade of copal, known as Zanzibar copal Similarly in South America the resin may be dug from the ground at the base of the tree, where it slowly accumulates Copal is used in the making of high grade varnishes Of late it is being supplanted with synthetic cellulose lacquers Several other trees also yield copal resin (R M W)

COPALITE or **COPALINE.** The mineral copalite or "Highgate resin" is a fossil **resin** found in irregular fragments in the **blue clay** of London, England It resembles copal, the resin of certain modern tropical trees Copalite is pale yellow to greenish or brownish, and emits an aromatic odor when broken It has a hardness of 1 5 and a specific gravity of 1 046, burns with a very smoky yellow flame (E S C S)

COPEPODA. A subclass of small **crustaceans.** Some species are free-swimming and others live as parasites on fishes The latter are called fish-lice. (A W L)

COPERNICUS (1473–1543) Nicolas Copernik, who is commonly known by the Latinized form Copernicus, was born at Thorn, in Polish Prussia, in 1473.

He graduated from Cracow as a doctor in arts and medicine and was destined for an ecclesiastical career He received training both in mathematics and astronomy and went to Rome as a professor of mathematics Shortly after this, he took the Church Orders and was returned to the principal church in his native place where he eventually became a canon He lived the remainder of his life at Frauenburg, near the mouth of the Vistula, and apparently entered but little into the political or social life of his community All accounts of him which remain indicated that he was a quiet monk of studious habits who drew about himself a group of earnest students

He compiled a table of **planetary motions** which were more accurate than any known previous to his time and which were used for many years after his death He endeavored to improve and simplify the **Ptolemaic** system of the universe by transferring the center from the earth to the sun He worked over this hypothesis for many years and eventually published his results in his one publication "De Revolutionibus Orbium Caelestium" The volume appeared in 1543, and tradition relates that the first copy was placed in his hands on his death bed

The two fundamental doctrines first advanced by Copernicus were (1) that the apparent rotation of the celestial sphere from east to west is, in reality, produced by the rotation of the earth about an axis from west to east, and (2) that the earth is one of a family of planets each moving about the sun in a circular **orbit.** Copernicus recognized that as a consequence of his hypothesis the planets **Mercury** and **Venus** should both show **phases** similar to those of the **moon,** and that the apparent positions of the stars should shift during the year Since neither of these effects could be observed he showed considerable hesitancy in advancing the hypothesis and, as a matter of fact, held up the publication for many years Neither did his theory completely remove the epicycles of the Ptolemaic theory because of the fact that Copernicus clung to the old doctrine that celestial objects can only move in the circle, "the perfect curve"

The influence of the Church, which considered the Copernican hypothesis contrary to its interpretation of the Bible, coupled with man's conservatism, prevented the immediate acceptance of the new ideas by all except a very few

While the transfer of the center of the universe from the earth to the sun was undoubtedly the most influential of all of the contributions of Copernicus, it must not be forgotten that he also offered the first explanation for the **precession** of the equinoxes which had been discovered centuries before by Hipparchus He explained the effect on the basis of a conical motion of the axis of rotation of the earth, but was unable to account for cause of this motion (W K G)

COPPER. Insecta, Lepidoptera In zoology, coppers are small **butterflies** whose prevailing colors are coppery shades, often with metallic luster With the **blues** and the **hairstreaks** they make up the family Lycaenidae

Copper is the metallic element—Symbol Cu (cuprum) Atomic number 29 Atomic weight 63 57 Density 8 92 Hardness 2 5–3 0 Melting point 1083° C Boiling point 2310° C (**Isotopes.** page 23)

Copper is a yellowish-red metal, very malleable and ductile, soft, good **conductor** of electricity, but traces of certain impurities markedly decrease the **conductivity;** unattacked by dry air, but in moist air containing **carbon dioxide** a protective greenish film of basic carbonate is formed, dissolved best by **nitric acid,** not **attacked** by cold dilute **hydrochloric** or **sulfuric acid,** but in hot hydrochloric acid dissolves to yield cuprous chloride, in hot concentrated sulfuric acid to yield copper sulfate; attacked by **chlorine,** especially when heated, to form cuprous and cupric chlorides, only slight action by **hydrogen sulfide** or **sulfur dioxide** at ordinary temperatures in the absence of air Very thin sheet copper is translucent and transmits greenish-blue light Discovery prehistoric Probably the first metal to be used by mankind. Copper is the second most largely used metal, being exceeded only by iron, and considerable scrap metal is recovered

Copper is largely used (1) in construction and apparatus where workability is demanded of and definite resistances to corrosion supplied by the metal, (2) as an electrical conductor (99 95% Cu) commonly in the form of wire, (3) as a constituent of various **alloys,** especially brass and bronze, coins Aluminum bronze (90% copper, 10% aluminum) is light, strong, and elastic, (4) as a catalyzer when finely divided, for certain chemical reactions

Copper occurs as native copper particularly in the region south of Lake Superior (often 99 9% Cu), as sulfides (**chalcocite,** copper glance, cuprous sulfide, Cu_2S, **chalcopyrite,** CuFeS), as oxide (**cuprite,** cuprous oxide, Cu_2O, red), as basic carbonates (**malachite,** $CuCO_3 Cu(OH)_2$, green, **azurite,** $2CuCO_3 Cu(OH)_2$, blue) The copper content of its ores varies from 0 3% to 8% Cu and the average is of the order of 2 5% The value depends largely upon the content of silver and gold The area of production is widely distributed, in the United States, Montana, Utah, New Mexico, Arizona, Michigan, Tennessee, in Canada, Mexico, Chile, Peru, Africa, Spain, Portugal, Japan (1) Native copper ore is crushed, concentrated by washing with water, smelted, and cast into bars (2) Oxide and carbonate ores are treated with **carbon** in a smelter (3) Sulfide ore treatment is complex, but in brief, consists of smelting to a matte of cuprous sulfide, ferrous sulfide, and silica, which molten matte is treated in a converter by the addition of lime and air is forced under pressure through the mass The products are blister copper, ferrous calcium silicate slag, and sulfur dioxide gas Refining is conducted by electrolysis, and the anode mud is treated to obtain the gold and silver

Acetates copper acetate, cupric acetate ($Cu(C_2H_3O_2)_2 H_2O$), greenish-blue solid, soluble, formed by reaction of cupric oxide (or copper plus oxygen of the air) and **acetic acid,** and then crystallizing Used as an insecticide, fungicide, basic copper acetate, copper subacetate, "verdigris," green and blue solids, insoluble, color depending upon the ratio of copper oxide to copper acetate present, used (1) as paint pigment (2) as insecticide and fungicide, (3) in dyeing and printing fabrics See **Acetoarsenite**

Acetylide cuprous acetylide ($Cu_2C_2 H_2O$), red precipitate (explosive when dry), formed by passing **acetylene** into cuprous chloride solution in ammonium hyroxide.

Arsenite copper arsenite, cupric arsenite, "Scheele's green" ($CuHAsO_3$), light green solid, insoluble, poisonous, formed by reaction of soluble copper salt solution and **sodium** arsenite solution, used as paint pigment and insecticide, copper acetoarsenite, cupric acetoarsenites, "Paris green" ($Cu(AsO_2)_2 Cu(C_2H_3O_2)_2$), green powder, insoluble, used as (1) paint pigment, (2) insecticide, (3) in wood preservatives

Bromide cuprous bromide ($CuBr$), white solid, insoluble, formed by reaction of cupric bromide solution and copper metal, or of excess copper metal with **bromine;** copper bromide, cupric bromide ($CuBr_2$), brownish-black solid, soluble, formed by reaction of cupric oxide and **hydrobromic acid,** and then crystallizing Color of solution depends markedly upon the concentration, e g, concentrated is dark brown, dilute is blue, intermediate is green

Carbonates basic copper carbonates, green precipitate by reaction of soluble copper salt solution and sodium carbonate solution, or superficially by oxidation of copper metal in moist air containing **carbon dioxide. Malachite** (green) and **azurite** (blue) occur in nature

Chlorides cuprous chloride ($CuCl$), white solid, insoluble, formed by reaction of cupric chloride solution

and copper metal, or of excess copper metal with **chlorine**; copper chloride, cupric chloride ($CuCl_2 \cdot 2H_2O$) green crystals, soluble, formed by reaction of cupric oxide (or copper plus oxygen **of** the air) and **hydrochloric acid** and then crystallizing Crystals become anhydrous and brownish-yellow at 110° C, and the chloride melts at 500° C

Cyanides cuprous cyanide (CuCN), white solid, insoluble, formed by decomposition of cupric cyanide, upon heating with water, very poisonous **cyanogen** gas being evolved at the same time Used in certain organic reactions, i e, **Sandmeyer's** for benzenoid cyanides, cupric cyanide ($Cu(CN)_2$), brownish-yellow precipitate by reaction of soluble cupric salt solution and **sodium** cyanide solution Upon heating with water, very poisonous cyanogen gas is evolved, and cuprous cyanide

Ferrocyanide cupric ferrocyanide ($Cu_2Fe(CN)_6$), reddish-brown precipitate, formed by reaction of soluble cupric salt solution and **potassium** ferrocyanide solution This is a very delicate test for copper, and enables the detection of as little as one part of copper in a million parts of solution

Hydroxides cuprous hydroxide (CuOH, formula doubtful), yellow precipitate, by reaction of cuprous salt solution and **sodium** hydroxide solution, soluble to colorless solution by hydrochloric acid or ammonium hydroxide, cupric hydroxide ($Cu(OH)_2$), blue gelatinous precipitate, by reaction of cupric salt solution and sodium hydroxide solution, soluble to deep blue solution by ammonium hydroxide, cupric hydroxide is changed to black cupric oxide upon boiling with water

Iodide cuprous iodide (CuI), white solid, insoluble, formed by reaction of soluble cupric salt solution and **potassium** iodide solution with separation of **iodine** at the same time Used in certain organic reactions, i e, Sandmeyer's for benzenoid chlorides

Nitrate copper nitrate, cupric nitrate ($Cu(NO_3)_2 \cdot 6H_2O$), blue crystals, soluble, formed by reaction of cupric oxide (or copper) and **nitric acid**, and then crystallizing Copper nitrate is decomposed, upon being heated, leaving cupric oxide residue

Oxides cuprous oxide, red copper oxide, (Cu_2O), red solid, insoluble, formed (1) by reaction of cupric salt solution in alkaline medium with a reducing solution such as glucose or arsenite The cupric salt solution in sodium hydroxide is maintained by the addition of sodium tartrate or citrate Fehling's test is the application of this reaction, (2) by superficial oxidation of copper upon heating to moderate temperature, cupric oxide (CuO), black solid, insoluble, formed (1) by the oxidation of copper upon heating in air, (2) by heating cupric hydroxide, carbonate or nitrate to red heat

Sulfate copper sulfate, cupric sulfate, "blue vitriol," "blue-stone" ($CuSO_4 \cdot 5H_2O$), blue crystals, soluble, formed by reaction of cupric oxide (or copper plus oxygen of the air) and **sulfuric acid**, and then crystallizing Crystals lose water upon being heated and the white residue of anhydrous copper sulfate is used to detect the presence or absence of water in certain organic liquids (water causes blue coloration)

Sulfide cuprous sulfide (Cu_2S), black solid, insoluble, formed by reaction of cuprous salts, e g, cuprous chloride, with **hydrogen sulfide** or **sulfur** upon boiling, cupric sulfide, copper sulfide (CuS), black precipitate, formed by reaction of cupric salt solution and **hydrogen** or **sodium** or **ammonium** sulfide, soluble in dilute nitric acid

Cupric salts (the common copper salts) dissolve in water to give a beautiful blue color, the crystalline salts are blue solids (e g, sulfate, nitrate), green solid (e g, chloride), brownish-black solid (e g, bromide) and the oxide is black The salt solutions yield, with excess ammonium hydroxide, a dark blue solution Various forms of this solution are applied in special reagents, e g, Fehling's, where reducing agents form cuprous oxide, and Schweitzer's, where cellulose is dissolved, and upon making the solution acid, cellulose is precipitated, as in the earliest artificial fiber process

Cuprous salts are insoluble in water, the salts are white (e g, chloride, bromide, iodide) and soluble in concentrated hydrochloric acid to brownish solution, and in ammonium hydroxide to colorless solution (the blue coloration usually encountered is due to the presence of cupric) These solutions readily absorb **oxygen** or **carbon monoxide**, and are so utilized in the analysis of gases Cuprous oxide or hydroxide is formed of various colors ranging from yellow to red (R K S)

COPPERHEAD. Reptilia, Sauria A poisonous **snake**, *Agkistrodon mokasen*, of the eastern United States, extending locally into the central states It is a pit viper, related to the rattlers and water moccasin The species frequents rocky uplands more than wet ground and is nocturnal and retiring in habits

The reddish head of this snake has led to confusion with certain harmless species, including the hog-nosed snake The copperhead can be distinguished with certainty by the pit between the eye and the nostril It is not a large snake, usually reaching a length of less than four feet, and is not as dangerous as supposed because of its shy nature Its bite is treated like those of the other **pit vipers** (A W L)

COPPERSMITH Aves, Piciformes A small Indian bird, *Xantholaema haematocephala*, one of the **barbets.** It is green above and yellow with green markings below (A W L)

COPRA. Coconut

COPRELITES. Paleontology.

COPULATION The act of sexual union by which the seminal fluid, containing the reproductive cells of the male, is transferred to the genital passages of the female

The germ cells are adapted for locomotion through liquids, hence many aquatic species need only discharge them into the surrounding water simultaneously to enable them to come together for **fertilization** If the egg is to develop in the body of the mother, however, or if the animal is entirely terrestrial, the liquid medium in which fertilization occurs is secreted by the body and a direct transfer from male to female is necessary

In some animals copulation is accomplished merely by the apposition of the orifices of the genital ducts, but in most cases the terminal portion of the female organs becomes a vagina for the reception of a male intromittent organ This organ varies greatly In some of the **rotifers** the pointed end of the body serves for the introduction of the germinal material, although some have a special projecting organ called the penis Some of the roundworms have a pair of copulatory **setae**, which project from the alimentary tract In the **crustaceans** certain paired appendages are modified for introduction into the female and in the **spiders** the male discharges the seminal fluid onto a web and takes it up into his **palpi**, which are modified for the transmission of the material to the female ducts

Among the vertebrates most intromittent organs are in the form of a penis developed either as a projecting fold in the wall of the **cloaca** or as a protrusible organ associated with the urogenital passages at their caudal extremity In the **shark** the pelvic fins sometimes bear lobes which are thrust into the cloaca of the female during copulation Copulation is associated with the involved process of **mating.** (A W I)

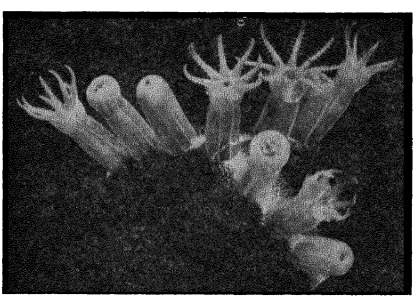
COQUETTE Aves, Micropodiformes A **hummingbird** of a small group of species found from southern Mexico to southern Brazil They are distinguished by the crested head and conspicuous frills at the sides of the neck. (A W L.)

COQUINA. This is a Spanish word meaning little shells. It is a coarse and highly porous **limestone** made up of shells and shell fragments loosely cemented. It is being formed at present along the coasts of Florida, where it is frequently referred to as "beach rock." Only a few of the limestone formations of former geological periods are true coquina. In Bermuda coquina, largely of **Aeolian** origin, is sawed into blocks and used as a building material. (R.M.F.)

CORACIIFORMES. An order of birds including the **hornbills, kingfishers** and **rollers.** (A.W.L.)

CORAL. Coelenterata, Actinozoa. The hard deposit built up by minute colonial animals called coral polyps which occur in the warmer oceans. The deposit consists principally of **calcium** carbonate.

The term coral is applied to the deposits of animals of two orders, **Alcyonaria** and **Zoantharia,** of different form and habits. Those of the alcyonarians are made up of minute spicules formed within the tissues, occasionally compacted in a hard central rod running through the entire colony and somtimes supplemented by an external covering. Red or precious coral is the



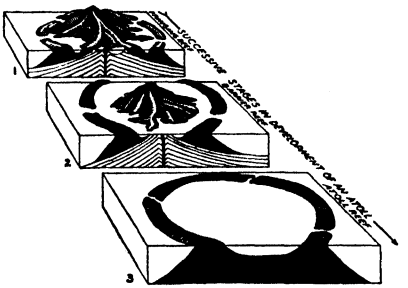
Coral. (Courtesy of *American Museum of Natural History.*)

hard axis of such a form and organ-pipe coral is made up of the connected tubes which once surrounded the living animals. Zoantharian corals build up hard deposits externally beneath the basal disk which attaches them to the ocean floor. As new individuals arise from the edge of the living tissue their deposits become continuous with those already laid down and so large colonies produce extensive masses of coral rock. The form of these deposits varies. Some are slender and branching and others rounded and massive. They have received common names such as staghorn coral and brain coral.

Precious coral is secured principally in the Mediterranean and is the foundation of a considerable industry in Italy. Several thousands of persons in that country work coral into beads and other ornaments and make it into jewelry.

The formation of coral islands in the warmer oceans has resulted in many habitable land masses, and in the same waters submerged reefs of this material are serious obstacles to navigation. (A.W.L.)

CORAL REEF. A complex, **ecological** association of benthonic (bottom-living) and attached, calcareous, shelly marine **invertebrates,** forming either fringing reefs, barrier reefs, or atolls. The lagoons of barrier reefs and atolls are important loci for the deposition of fine-grained calcium carbonate mud called drewite. Fossil reefs include all types of organic reefs which show a distinct ecological and structural evolution from the earliest known fossiliferous limestones to the typical atolls of the South Pacific Oceanic Islands. (R.M.F.)



Block diagrams illustrating the successive stages in the development of an atoll during the subsidence of a volcanic cone. *Field, Laboratory Manual, Princeton University Press.*

CORBINO EFFECT. Hall Effect.

CORDAITALES. Paleobotany.

CORDIERITE (IOLITE) (DICHLORITE). The mineral cordierite, composition $Mg_2Al_4Si_5O_{18}$, is an **orthorhombic** mineral frequently seen, however, in pseudo-**hexagonal** forms, as well as massive. It is brittle, with a subconchoidal fracture; hardness, 7–7.5; specific gravity, 2.60–2.66; luster, vitreous; color, blue of varying shades; translucent to transparent. Cordierite exhibits pleochroism (or dichroism) being dark blue, light blue and light yellow when examined by transmitted light in different directions. Hence it is frequently called dichroite. It is occasionally used as a gem. Cordierite is found as a primary mineral in the igneous rocks. It is, however, found ordinarily in **gneisses, schists** and in areas of contact metamorphism. Localities for good specimens are numerous in Europe including Bavaria, Finland, Norway. It is found in Greenland, Madagascar and Ceylon from which latter place come the rolled pebbles of a rich blue color known as saphir d'eau and prized as a gem. In the United States it is found principally in Connecticut. Named for the French geologist, Pierre Louis Antoine Cordier, this mineral has also been called iolite from the Greek word meaning violet, and stone, as well as dichroite from the Greek meaning *two colored.* (E.S.C.S.)

CORE. A magnetic core is an important element in many applications in electrical design. Electro-magnetic equipment, as exemplified by the transformer, the motor, and the generator, have electrical circuits, usually of copper conductors, and **magnetic circuits.** The magnetic circuit follows a path largely contained in a core composed of iron or iron alloys. The property of the core metal is to offer the best path for the magnetic lines of flux, and its success in this respect is measured by its permeability. Cores are usually composed of a large number of thin metal laminations which are fabricated by punching from thin sheets of metal, and after being enamelled are assembled to form a core. The enamel forms an insulation between laminations which reduces the eddy currents induced in the metal of the core by transformer action.

A drilled core of suitable size is frequently removed from a material to be used as a sample for inspection or test. Thus, subterranean exploration with a diamond core drill brings up a core which gives a vertical section through the ground being investigated. If enough of these drillings are made in various positions, a fairly accurate picture may be formed as to the nature of underlying strata. However, not all core drillings are subterranean. It is a common practice for engineers to take cores from a newly constructed concrete road in order to determine the character of the contractor's

work. The core will show thickness of the road slab, character of the concrete, and may be used to test for strength (F T M)

CORK. Cork cells are found in the **bark** of most woody-stemmed plants, but in amounts too small and with too brittle walls to be of any use to man But in *Quercus suber,* the Cork Oak, the cork cells become a very large part of the tissue of the bark, and have been used for centuries by man The cork oak tree is a medium-sized tree, seldom much over fifty feet in height, growing in nearly all countries bordering the Mediterranean Sea The evergreen leaves are small, an inch and a half to three inches long, and about an inch wide, with slightly toothed margins The bark of the tree soon becomes rough and deeply furrowed, but is of little value except as ground cork or as a source of **tannin.** When the tree is about twenty years old this first formed bark is removed, care being taken not to injure the **cambium** layer Within ten years a new cork layer has formed This layer is the first of many layers which are removed once every ten years or so throughout the life of the tree Removal is generally done in the early summer at a time when hot dry winds will not cause injury to the unprotected cambium

After removal, the cork is air-dried for a time, then boiled to soften it and to remove some of the tannin The outer part of the bark is scraped off, and the rest pressed out flat and dried It is then ready to ship

The physical properties of cork account for its many uses It is very light and buoyant, more than 50% of its volume being air, and hence is used in the manufacture of floats, life-preservers, and so forth Since the living **protoplasm** of the cork cells dries up early in their development, leaving hollow cells, each containing a small mass of air which expands after compression, cork is very resilient, and is frequently used as a core on which to wind yarn or string in the manufacture of baseballs In the early stages of their formation, the walls of cork cells are **cellulose,** but this is soon replaced by a waterproof and non-absorbent substance, **suberin** Therefore cork is used in making handles for fishing rods, shoe-soles, and cork stoppers Since the hollow cork cells are poor conductors both of heat and sound, cork is much used as insulating material For this use cork is ground up and then pressed into sheets with various binding materials, giving much larger sheets than can be obtained from the tree Ground cork is also an important constituent of linoleum

Cork is transversed by lenticels, loose masses of porous tissue, which appear as dark spots or holes in stoppers Usually in making stoppers the bark is cut so that these will be transverse in the stopper In making stoppers, the forms are first punched out as cylinders, and then trimmed down by machine to the required tapering shape (R M W)

CORLISS. Engine.

CORM. In botany a corm is a very short, thick **rhizome,** usually growing erect instead of horizontal Its surface shows more or less distinct **nodes.** From the nodes of the upper portion **buds** develop Generally roots are formed in the lower part of the corm In many plants the corm is surrounded by scaly leaves or leaf bases The crocus and the gladiolus produce corms

In zoology the corm is the median branch or endopodite of the appendage of certain **crustacea** together with the common basal portion When the exopodite is reduced these parts sometimes appear as the principal axis of the appendage (R M W, A W L)

CORMIDIUM. A group of individuals of various forms budded from the parent stalk of certain floating marine coelenterates. (**Siphonophora**). (A W L)

CORMORANT. Aves, Pelecaniformes A large bird (**Aves**) of slender build with a moderately long neck and slender beak, slightly hooked at the tip The feet are webbed and the birds are strong swimmers and divers They live entirely on fish The numerous species are widely distributed, the common cormorant, *Phalacrocorax,* occurring in eastern North America, Europe, Asia, and northern Africa

In Japan and China cormorants are kept in captivity to be used for fishing A ring or strap around the bird's neck keeps it from swallowing the fish that it catches, although some are said to be so well trained that they bring fish to their owners without this check.

Cormorants are eaten in some parts of the world. (A W L)

CORN. This term is used in physiology and in botany

In physiology, a corn is a hard callus or horny thickening of the skin on or between the toes, caused by constant pressure or friction Beneath the hardened callus there is often a small sac or bursa filled with fluid A soft corn is one found usually between the fourth and fifth toes, and is formed of thickened moist skin and fibrous tissue

In botany, corn is a well known plant, (*Zea mays* Gramineae) There has been considerable speculation as to the origin of this plant Everything indicates that it is native to America, probably originating in Mexico The claim has been made, however, that the Chinese knew the plant before America was discovered, and that the grain was carried from Asia to America during the periods of migration of man from one continent to the other The evidence supporting this claim is not very strong The plant is not known to occur in the wild state, but a native Mexican grass, teosite, *Euchlaena mexicana,* is a closely related grass with which corn **hybridizes** freely Some botanists hold that teosite is the ancestral grass from which corn originated

There are many kinds of corn in cultivation, ranging from dwarf forms less than three feet high to giant plants fifteen feet or more in height All kinds have an extensive fibrous root system, the individual roots not only occupying the surface portion of the soil but also extending downward to depths of three feet or more In addition to these normal roots, which all arise from the basal portions of the very young stem, there develop from the lower **nodes** of the older stem prop roots These prop roots are coarse outgrowths which radiate outward and downward until they reach the surface of the ground During their growth in the air, their tips are protected from drying by an abundant slime coating, once they have entered the ground they branch abundantly and become like normal roots They serve to support the plant The stem of the corn plant is coarse and, unlike other grasses, solid throughout its length The leaves, borne alternately on the stem, have large broad blades at the base of which is a conspicuous ligule, a membranous outgrowth which tightly invests the stem and so may serve to prevent water entering between the stem and the leaf-sheath The corn plant is **monoecious,** that is, both staminate (**stamen**) and pistillate (**pistil**) flowers are borne on the same plant However, they are usually not borne in the same inflorescence The staminate inflorescence or tassel, appears at the top of the plant, and matures some time before the pistillate flowers do The male flowers produce immense quantities of pollen which when ripe is shed in the air, to be carried by wind currents or gravity to the pistillate flowers Corn pollen is a cause of hay fever (See **Allergy**) to many people The pistillate inflorescence, or ear, is a modified branch developing in the axis of a leaf This branch has a fleshy axis or cob on which are borne rows of pistillate flowers These occur in two flowered **spikelets,** the lower flower usually being abortive,

but its **bracts**, the lemma and palea persisting, as do the two short **glumes** which subtend the entire spikelet The ovary bears a long style, commonly known as the silk of the corn When first developed the silk is green and has a sticky surface, after pollination has occurred, the silk turns brown and dries up The entire pistillate inflorescence is enclosed in many overlapping modified leaves known as husks, from the tip of which the silk protrudes The mature corn grain is variously shaped according to the kind of corn In most species it is a flattened object with a shallow groove on one side, indicating the location of the **embryo.** This embryo is on one side of the grain, the rest of which is filled with a starchy substance, the **endosperm.** This endosperm is usually separable into two parts, one hard and horny, called the horny endosperm, the other less firm and of lighter color, known as the starchy endosperm The horny portion contains more protein than does the starchy and has its starch grains more densely packed together The corn grain will not germinate unless the temperature is above 40° F, and sprouts best when the temperature is about 90° F

Corn is grown most successfully in regions having a deep warm well-drained loam soil, an abundance of rainfall and a growing season of ninety days or more, depending on the kind of corn Improved varieties have been developed which grow satisfactorily in regions having a shorter growing season Corn is principally grown in the Americas, especially in the United States and Argentina It has been introduced in European countries and into Africa, but is not grown there to any great extent In the United States the so-called corn belt grows more than half the entire world crop This corn belt comprises the states from Ohio west to South Dakota and south to Kansas, a region having climatic conditions most favorable for this crop

The uses of the corn crop are many and varied The green plants are fed to stock directly or are stored in silos For storage in silos the entire plant is cut down and chopped into small pieces These are compactly stored in large tight structures of wood, concrete or other material, in which partial fermentation occurs, forming a product called ensilage This is an important part of the ration of dairy cows

Corn grains form a most important food product for man and his domesticated animals The ripe ears are picked from the plants and allowed to dry The grain is then removed from the cob and used directly as stock and poultry food or ground into coarse particles known as cracked corn, much used in feeding poultry Ground somewhat finer, but still consisting of coarse particles, white corn becomes grits, much used in southern states More finely ground, corn becomes corn meal, used in making corn bread and various kinds of puddings Rarely corn is finely ground to flour Another corn preparation is hulled corn In making this the grain is soaked in lye which loosens the **pericarp** or outer portion of the grain This is then removed and the remaining grain cooked soft As a breakfast food corn appears principally in the form of corn flakes In making these, clean corn grains are steamed and the hulls and embryo removed, leaving the endosperm This is sweetened and flavored, and then cooked by steam under pressure Following this cooking, the grains are partially dried and then passed between heavy rollers, which make them flakes These flakes are carried to huge ovens where they are quickly toasted Cooling follows, after which the product is packed in waterproof cases and is ready for the consumer

In addition to use as food for man and beast, corn yields many important secondary products, such as corn starch, glucose (See **Carbohydrates**) and corn oil Starch is prepared from corn by soaking the grains in slightly acidulated water for several days, after which they are broken up, the embryos removed and the grain ground Following the grinding, the whole is passed through sieves which remove the pericarp The resulting paste is allowed to flow slowly over tilted tables, which allows the starch to settle This starch is washed, and dried, then pulverized for use

From corn starch is prepared glucose, or corn syrup a thick substance which results from the partial hydrolysis of starch with acid The acid is neutralized with **sodium** carbonate, and the liquor resulting from neutralization is filtered This liquor is evaporated, and again filtered, emerging as a clear thick syrup, which is boiled down even further It now becomes commercial glucose, a thick syrupy substance about half as sweet as cane sugar, and with little flavor It is used in making jellies and preserves, and in blending with other sweets such as cane syrup and maple syrup

From the embryos of corn, corn oil is prepared Corn oil is used as a cooking oil and also in making soaps and paints The cake remaining after the oil is pressed from the embryos becomes a stock food

Corn stalks have been used experimentally in manufacturing paper However, the abundance of objectionable non-fibrous material will probably prevent any extensive use of the stalks in this industry The cobs left after shelling the grain are used as a fuel to a slight extent and also in making cob-pipes The dried husks form a stuffing for a particularly disturbing kind of mattress, and are also used to some extent as a stuffing in upholstery

The principal varieties of corn include pod corn, a rarely grown form in which the glumes, lemma and palea of each floret are particularly well-developed, surrounding the kernel, pop corn, in which the sudden explosion of the moisture within the grain turns the latter more or less inside out, sweet corn, characterized by the high sugar content of the grains, and largely grown in home gardens, flint corn, with very hard grains containing a large amount of horny endosperm; and dent corn, so-called because the floury endosperm extends to the end of the kernel and is surrounded laterally by horny endosperm On maturing the floury endosperm shrinks, causing an obvious dent to appear at the apex of the kernel (R S M, R M W)

CORNCRAKE Aves, Gruiformes A small shore bird (**Aves**) with long legs and short beak, found in Europe and Asia and occasionally in North America It is also called the land rail and is related to the Carolina rail of North America (A W L)

CORN ROOTWORM Insecta, Coleoptera Larvae of two species of **beetles** The adult of one is yellowish green with six black spots on each wing cover The **larva** of this species, the southern corn rootworm, damages the roots and lower stems of various grains and grasses and sometimes kills the plants The other species is the western corn rootworm The adult is entirely yellowish green and the larva burrows inside the roots of corn and stunts or kills the plant Both beetles are about three-eighths of an inch long

The most effective protection against these pests is proper crop rotation Since the southern rootworm lives on other plants than corn this treatment is supplemented by planting early or late to avoid the most serious attack of the larvae (A W L)

CORNEA. The transparent outer layer of the front of the **eye**-ball It is a complicated structure composed of five layers The cornea may be the site of inflammation or **ulcer** formation (R S M)

CORNEAGEN CELL. A kind of cell found in the eyes of some insects It produces the transparent lenticular cornea at the outer surface of the **eye.** (A W L)

CORNER. A corner is the point of intersection of adjacent property lines Landed property is ordinarily bounded by broken lines meeting at the "corners" of the property A land survey is generally a **traverse**

with the transit stations at the corners and with the traverse lines coinciding with the property lines The corners are indicated on a survey plat They are frequently marked by monuments, either artificial or natural When subdividing land in accordance with the scheme of the United States **land subdivision,** the corners are designated by standard monuments whose character and markings are governed by certain specific regulations

If it is impossible to set a monument at a corner, permanent markers called "witness corners" are placed on all lines intersecting at the corner When a property line intersects a body of water the intersection is marked by a permanent monument known as a "meander corner" (C W C, F T M)

COROLLA. Flower.

CORONA. In zoology, corona is the shell of the sea urchin, formed of hard plates developed in the wall of the body and firmly united together

In physics, this term is used variously to designate a radial stream of light surrounding an object Specifically, in electrical engineering the corona is a luminous **brush** discharge which occurs between two **conductors** carrying extremely high voltage The luminosity sometimes observed along a high tension transmission line at night is the result of this corona discharge When the intensity of an electric field around a conductor reaches a value of about 55,000 volts per inch, there begins a certain amount of **ionization** of the air, accompanied by a luminous glow about the body Corona discharge is a loss, and must definitely be taken into account in the design of a transmission line The high voltages which are adopted in order to reduce heating loss tend to increase the corona loss The use of larger diameter wire, such as the aluminum wire, reduces the surface curvature which is one of the important factors determining corona loss Weather conditions and character of the conductor surface are also contributing factors Various physical aspects of the term corona are treated in the articles on **Halo** and **Ionized Gases.**

In astronomy, the outermost layer of the solar **atmosphere** is known as the corona Its name is obtained from the fact that at the time of a total **eclipse** the corona appears as a crown or halo about the eclipsed sun Thus far no apparatus has been devised for observing the corona except at the time of a total solar eclipse, although many attempts have been made to devise such equipment

The light from the corona is relatively very feeble, totalling approximately half that received from the full moon In color it varies from yellowish at the lower layers to a pearly white as it fades away with increasing distance from the sun **Spectographic** observations indicate that a considerable portion of the light is scattered light from the **photosphere,** but there are certain bright lines appearing in the spectrum which indicate that the corona is partly self luminous Many of the lines have not been reproduced in the laboratory, but it is believed that they are due to well-known elements which are radiating in a peculiar fashion due to the conditions of extremely low pressure in these outer regions of the sun

The form of the corona is different at different eclipses and there is a well-known correlation between the form of the corona and the **sun spot** number At the time of maximum number of spots the corona appears approximately circular, with petal like streamers extending out in various directions At the time of sun spot minimum the corona is considerably flattened out in the regions of the sun's poles of rotation, with short curved streamers extending out from this flattened region At the equatorial regions long thin streamers are frequently observed extending out for great distances

There is no adequate explanation for the solar corona available at the present time It is difficult to state the distance to which it extends out beyond the photosphere It is always observed at least 300,000 miles out from the sun and some of the streamers have been traced on long exposures out to distances as great as 5,000,000 miles There is one theory that the corona represents material moving out from the sun with a velocity greater than the velocity of escape and hence is actually leaving the vicinity of the sun completely. (F T M, W K G)

CORONARY THROMBOSIS (Coronary Occlusion). Obstruction of a branch of coronary **arteries** which furnish the blood supply to the **heart** muscle (myocardium) Such obstruction results in death of heart muscle supplied by the branch involved

This vascular accident occurs quite commonly and is more frequently a cause of death between the ages of 45 and 75 years than is generally indicated by mortality statistics There is no single cause, but in general the picture of increased blood pressure (hypertension) and hardening of the arteries (**arteriosclerosis**) precedes the coronary disease in most cases A definite familial tendency is present Most of the victims give a history of **angina pectoris**

The obstruction that blocks the vessel is usually a **thrombus,** although in rarer instances progressive narrowing of the vessel produces the same end result If sufficient circulation is cut off instant or very quick death results

The characteristic symptom is severe pain over the region of the heart not related to exertion or any related activity which may last for hours or days The symptoms of shock or collapse are often present

Electro-cardiagraph examination confirms the usual history and physical findings Many of the cases of sudden death from this disorder are called "acute indigestion" because vomiting is often present and in some instances pain in the upper abdomen, instead of over the heart, is present

In those cases which do not die at once, or after a few hours or days, sufficient recovery will take place to allow the patient to lead a greatly restricted life In other cases healing of the heart muscle may be so complete that a fairly active life may be led There is a tendency towards future attacks The immediate mortality rate is between 50% and 60% (R S M)

CORONATAE An order of jellyfishes (**Scyphozoa**) with a lobed margin Found in the open ocean (A W L)

CORPUS CALLOSUM. A broad band of nerve fibers within the **brain,** connecting the two cerebral hemispheres (A W L)

CORPUSCLE A term applied to many minute bodies 1 The cells of the **blood** 2 The excretory unit of **vertebrates,** consisting of a small knot of blood vessels enveloped by a capsule **Renal corpuscle** 3 Bone cells are called corpuscles of Purkinje 4 Many nerve endings including Pacinian or lamellar corpuscles, Grandry's corpuscles, tactile corpuscles These and all other sensory corpuscles consist of nerve endings enveloped by accessory cells of various forms They are sensory organs (A W L)

CORPUS LUTEUM. Sex Hormones; Menstruation.

CORRASION. This term is applied to the mechanical wearing away of rocks through the agency of running water and the rock fragments which it carries in suspension (R M F)

CORRODENTIA. An order of minute **insects** containing the **book lice** and psocids They have biting mouths and some species bear four wings Some are found among plants and on bark and other frequent books and papers, especially in damp buildings (A W L)

CORROSION. The term applied by mineralogists and petrologists to the resolution and modification of the crystal form of **phenocrysts** during their growth in the parent **magma.** The same term is also used by some geologists and **physiographers** to denote the mechanical erosion of the surface of the earth, particularly by rivers and glaciers A better term for this purpose, however, is **corrasion.**

In the common usage, corrosion refers to the destructive conversion of metal into oxides and metallic salts under the influence of certain chemical reactions between the metal and the corroding agent Iron and steel are quite susceptible to corrosion, indeed, this is one of the principal defects of these metals Under ordinary conditions, iron is attacked by oxygen in the presence of water, with the resultant formation of the rust, which is an oxide of iron Air, especially moist air, is a corroding agent for a great many metals Generally speaking, acids are corrosive Metals exposed to a smoke-laden atmosphere are frequently very rapidly corroded by corrosive gases such as oxides of **sulfur** in the smoke Metals laid in or under the ground will also be rapidly destroyed in some soils, especially those containing acid wastes or salts Soil corrosion of buried pipes takes a heavy annual toll of the capital investment in buried pipes Corrosion in dry air is a very slow process, but rarely are metals exposed to an absolutely dry air, and the moisture contained in the atmosphere, together with its oxygen, causes corrosion, especially on **iron** and **steel** For this reason, other metals are frequently used where very damp air is to be expected **Copper** and **lead** seem to be able to resist moist atmospheres

In combating corrosion, the surface of the metal may be protected by **paints,** plates, or other surface coatings Or again, the metal may be **alloyed** in such a way as to render it corrosion resistant In most cases corrosion is merely a slow, obvious destruction of investment in a metal, but there are instances where the potential destructive action greatly exceeds that caused by the corrosion alone For example, in pressure vessels such as the steam boiler, corrosion in the boiler itself may hold potential threat of destruction for an entire plant, and endanger lives It is possible for corrosion to occur at many places in the piping leading to boilers or heaters, but usually it occurs in the boiler itself The trouble is ordinarily found to be due to an acid condition of the boiler feedwater, or to dissolved oxygen contained by it The raw water used may be acid from surface pollution, or from sub-surface drains Usually this can be detected and readily remedied A more serious factor is the oxygen dissolved in water Under the high temperature conditions existing in the boiler itself, this oxygen becomes extremely active in attacking metal surfaces The operators of large high-pressure boilers well know the necessity of removing oxygen from feedwater through the employment of deactivators or deacrators

The ordinary user of a metal has at his disposal several means for minimizing corrosion One of the more common is the application of a protecting surface of corrosion resisting metal **Zinc** is one such metal Galvanized iron is iron with a thin layer of zinc applied to it by dipping in molten zinc or by electrical means Cadmium, nickel, tin and chromium are metals often used as protective coatings, generally applied by **electroplating.** (R M F, F T M)

CORROSIVE SUBLIMATE Mercury.

CORSITE. An orbicular **diorite** resulting from the segregation, in rounded concentric forms, of ferro-magnesian minerals (See **Iron** and **Magnesium**) It derives its name from its occurrence on the Island of Corsica, and is also sometimes called Napoleonite (E S C S)

CORTEX. This is the outer portion of a **stem** or **root,** bounded externally by the epidermis, and internally by the cells of the pericycle or by the endodermis It is composed mostly of **cells** which are very little differentiated Usually these are rather large, thin-walled **parenchyma** cells The outer cortical cells often contain **chloroplastids** and carry on **photosynthesis.** These are the collenchyma cells (R M W)

CORTLANDTITE. Peridotite.

CORUNDUM (Ruby) (Sapphire) (Emery). The mineral corundum, Al_2O_3, **aluminum** oxide, occurs as well developed **hexagonal** crystals which may display prismatic, rhombohedral, pyramidal or tabular habits. The larger crystals are often rounded or barrel shaped Corundum shows both basal and rhombohedral partings, the fracture is conchoidal, hardness, 9, specific gravity, 3 95–4 10, luster, vitreous to adamantine, may be pearly on base, transparent to translucent Common corundum is gray, grayish blue or brown, but may be red, yellow or whitish, it is sometimes called adamantine spar Transparent corundum may be colorless or of various tints The highly prized ruby is deep red, the sapphire, blue Transparent yellow corundum is known as oriental topaz, if violet, oriental amethyst, if green, oriental emerald

Emery is a mixture of granular corundum of dark color, magnetite and hematite, sometimes with spinel **Quartz** may be present For a long time emery was supposed to be an ore of iron Until the introduction of artificial abrasives emery was much used for such purposes

Corundum is found as an accessory mineral in the crystalline rocks such as crystalline **limestones** and **dolomites, gneisses, schists** as well as in the **igneous rock** types **granite** and **syenite** Corundum syenites are found in Canada, especially in the Province of Ontario Rubies have long been mined in Upper Burma, both rubies and sapphires are found near Bangkok, Siam Numerous localities in India furnish gem stones of high quality

In the United States common corundum is found in New York, New Jersey, Pennsylvania, Virginia, North Carolina, South Carolina and Georgia Sapphires of gem quality near Helena, Montana, associated with alluvial gold in the Missouri River From the crystalline limestones and schists of the islands of Naxos and Samos in the Grecian archipelago most of the emery of commerce comes Other deposits are near Ephesus in Asia Minor, and in the town of Chester in Massachusetts The word corundum comes from the Hindu, *kurand,* emery is derived from the Greek name for this substance. (E S C S)

CORVUS. (The raven or crow) (Map, page 306). Corvus is a small **constellation** containing no particularly bright or interesting stars This group of stars has long been a friend to lovers of the sea because of its resemblance to the "fore and aft" sail of a cutter For this reason the constellation is frequently referred to by sailors as "the cutter's mainsail" On a clear moonless night the resemblance to the sail is very remarkable, even the "step" of the mast and a small "pennant" flying from the gaff being discernible (W K G)

CORYDALIS. Insecta, Neuroptera A large gray **insect** with four membranous wings and in the male sex with very long slender jaws The adult of the **hellgrammite.** Also called dobson fly

In botany, the term Corydalis is applied to a genus of plants occurring in the north temperate regions and in South Africa, which are sometimes found in cultivation All are herbs with small, somewhat irregular flowers. (A W L, R M W)

CORYMB. Flower.

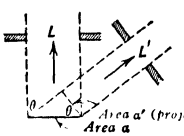
CORYZA. Acute coryza or the common cold A catarrhal inflammation of the upper respiratory tract of unknown origin but probably caused by a filterable virus (see **Filterable Virus**) Various *descriptive terms*

are used depending upon the particular portion of the tract involved, such as acute rhinitis, acute pharyngitis or acute laryngitis

Experiments indicate that chilling may precipitate an attack Susceptibility to infection is increased when the body is exposed to such sudden changes in temperature as may produce localized cooling of nose and throat

Diseases of the upper respiratory tract are often highly contagious and spread rapidly There is a definite seasonal variation of incidence, the peak usually occurring during the winter months Grippe and influenza are closely allied to the common cold The common cold in itself is not dangerous, but is often the forerunner of **pneumonia.** (R S M)

COSINE EMISSION LAW. A law relating to the emission of **radiation** in different directions from a radiating surface If a small, white-hot metal plate is viewed from a great distance, its apparent candle power, measured by a photometer, is greatest when it is perpendicular to the line of sight, and reduces to practically zero when it is turned edgewise If the observer now moves nearer, he finds that this change is due to the smaller angle subtended by the surface, that is, the smaller cross section of the beam proceeding from it in his direction, and that the apparent **brightness** of the surface is the same however it is turned To apply this, let the radiating surface, of area a, be emitting a luminous flux L (lumens) in the normal direction (see figure), and, in any other direction making an angle θ with the normal, the smaller quantity L' Then since the apparent brightness is unchanged, $L'/a' = L/a$ This gives $L'/L = a'/a$ But $a'/a = \cos\theta$, hence $L' = L\cos\theta$, which means that the energy emitted in any direction is proportional to the cosine of the angle which that direction makes with the normal This is the "cosine emission law" of Lambert It applies to thermal radiation as well as to light, and to diffusely reflected as well as directly emitted radiation The law is true only for a perfectly diffusing surface, strictly, for a **black body.** (L D W)



Illustrating cosine emission law

COSMIC RAYS. A highly penetrating radiation apparently reaching the earth in all directions from outer space The existence of this radiation was first suspected from the discharge of **electroscopes** in air free from all known ionizing influences, the rate of discharge increasing as the electroscope was carried to higher altitudes The atmosphere apparently absorbs a measurable portion of the rays, but traces of their effect persist even at depths of many feet below water or below the ground Professor R A Millikan and his associates, who have studied the distribution and absorption of the rays very thoroughly, find that the rays are of nearly the same intensity from all parts of the **celestial sphere,** and that, as they proceed through an absorbing medium, they show evidence of unequal absorption rates Professor A H Compton and many others have shown that the rays are not of any one type, being probably in part true radiation and in part corpuscular, like radioactive emissions, and that they are influenced by the earth's magnetic field

Observations on the cosmic rays have been extended to nearly all parts of the earth's surface and many miles up into the atmosphere The most common detector is the electroscope, special forms of which, with automatic recording devices, have been perfected for the purpose Also used are various types of **counting tube** or ion counter and the Wilson **cloud chamber,** and Dr T H Johnson has devised an ingenious arrangement of counters (called a "hodoscope") making it possible to trace the actual path of a single cosmic particle or quantum

The origin of the cosmic rays is still entirely unknown Attempts to trace them to the **sun,** the **stars,** or to other recognizable celestial objects, have been equally unsuccessful Millikan advanced the theory that the rays are a result of the synthesis of certain types of **atom** in outer space and that they represent the "mass defect" energy of these atoms This was when the rays were supposed to be purely **electromagnetic radiation.** At present their complex character renders the question of their origin exceedingly difficult (L D W)

COSMOGONY. Milky Way; Historical Geology.

COSTAL. This term means pertaining to a rib or the region of the ribs Thus, costal cartilage is the cartilaginous portion of the ribs which joins them to the **sternum** Again, the term intercostal refers to the space between the ribs (R S M)

CO-TERMINAL ANGLES Angles.

COTINGA Aves, Passeriformes A group of Brazilian **chatterers** closely related to the bell birds (A W L)

COTTER. The cotter and the cotter pin are machine elements used for certain types of **fastenings** The cotter pin, so familiar to all, is a split pin of annealed iron or brass The stock from which the cotter pin is formed is semi-circular, so that when the two pieces are together, they form a shape which is readily passed through a circular hole The cotter pin is widely used for the locking of nuts subject to vibration, especially in critical fastenings whose failure, through loosening of the nut, is not to be countenanced Many such cases occur in the mechanism of vehicles propelled by engines and the like Thus the cotter-pinned bolt has become quite common through its employment on the automobile

A cotter is a wedge-shaped metal piece used for fastening two parts having a motion tending to load the cotter with compression or tension rather than with twist or bending The large connecting-rod bearing of a steam engine is often arranged with a detachable end cap held in place by a cotter (F T M)

COTTON. *Gossypium* species Malvaceae Many species of cotton plants are known, some native to warm regions of America, others growing wild in tropical Asia Cotton seeds are surrounded by an abundance of soft white fibers which when mature are very conspicuous These fibers have been known and used by man for years Cultivation of cotton in India has continued through twenty-six centuries Even before the discovery of America the natives of tropical America were growing Sea Island cotton and using its fibers At present the United States leads the world in cotton production, but other countries are rapidly increasing their production as demand for the product grows Brazil, Egypt, and India are important producers

The cotton plant of cultivation is a woody annual growing three or four feet tall It bears large palmate leaves and showy white flowers which turn pink as they grow older Outside the five-parted **corolla** and **calyx** is an involucre composed of three large green **bracts** having very irregular margins These bracts persist throughout the growth of the fruit The **stamens** of the cotton flower have their filaments united to form a hollow tube through which the stigmas must grow, this stamen structure is characteristic of the mallow family, or Malvaceae The fruit is a large dehiscent capsule of ovoid shape On dehiscence, or splitting open, at maturity, the soft white fibers which surround the five or six large dark brown or black seeds become visible The fibers are of two kinds, one relatively long, called lint, the other short and called fuzz The capsule of the cotton plant is generally called the cotton

boll The length of the lint fibers varies in different species Sea Island cotton, the native American species *Gossypium barbadense*, cultivated on coastal areas of the southern states, has the longest fibers of any cotton (1½ to 2½ inches long) Egyptian cotton fibers are slightly shorter than these Next comes upland cotton, which is mainly derived from *Gossypium hirsutum* This is the principal cotton plant of the southern states In these the length of the fibers varies considerably, but averages about one inch Asiatic cottons have still shorter fibers

Cotton cultivation is limited to regions having a growing season of six months or more of continuous high temperature Any soil having a proper moisture content is suitable for cotton, but a deep, well-drained loam soil is best One requirement is that excessive rainfall shall not occur during the period when the bolls are opening, since the cotton fibers are injured by moisture at that time During the growing season the cotton fields must be kept clear of weeds From five to six months is required before the production of fibers begins, after which fiber production continues for another three months or more

Picking of the lint and contained seeds is done almost entirely by hand, and requires much cheap hand labor during the picking season Recently machines have been introduced which bid fair to replace human labor The soft light fibers, after picking, are carted to the gins Previous to the invention of the cotton gin by Eli Whitney in 1793, the lint was removed from the seeds by hand, a slow and laborious process The invention of the gin greatly advanced the cotton-manufacturing industry The cotton gin of today is essentially the same as that of Whitney, a steel grate with narrow slits through which reach thin notched saws The rapid rotation of the latter causes lint to catch on their teeth The lints are pulled through the grating, after which brushes remove them from the saws This ginned cotton is then pressed into bales weighing about 500 pounds each

The uses of cotton are many First among them is the manufacture of cloth In this, cotton ranks first among textiles, far exceeding any other fiber Cloth may be woven entirely of cotton, as much is, or may be of cotton mixed with other fibers, as silks, linen and wool Cotton fabric forms an important part of automobile tires, being the base on which the rubber is held

Cotton fibers, especially the fuzz, are frequently used to stuff mattresses, pads and upholstered furniture Treated with chemicals which remove the thin coating of waxy substances which cover the fibers, the latter becomes **absorbent cotton**, which is capable of absorbing many times its weight of water

Cotton treated this way is almost pure **cellulose**, and so is in great demand by those industries using cellulose The pure cellulose of the fiber may be dissolved and then precipitated in sheets, giving the familiar thin transparent cellophane Or the dissolved cellulose may be pressed through fine holes and solidified, giving rayon or artificial silk If treated with concentrated caustic soda, cotton fibers take on a high degree of luster, resembling silk The product of this process is called mercerized cotton, after John Mercer, its discoverer

Treated with nitric acid under various conditions, cotton yields a long series of by-products Some of them are plastic substances known as pyroxylins If highly nitrated, cellulose becomes guncotton, used in the manufacture of explosives So-called artificial skin or collodion is one of these nitrated products Many varnishes and lacquers of recent development are made from cotton cellulose

Not all the derivative products of cotton come from the fibers Some, for example, are obtained from the seeds In preparing these, the hulls are first removed from the kernel within These hulls are used as fuel in the ginning mill, as food for cattle, and as fertilizer The kernels are heated and pressed to remove the oil in cotton During this pressing the kernels are wrapped in cloth to prevent anything but oil from being expressed The oil is purified to a soft white substance very similar to lard in appearance Cottonseed oil is used in making salad oils, butter substitutes, and soap After the oil is expressed, the seed cake may be used as food for stock or as a fertilizer. (R M W)

COTTONMOUTH. Reptilia, Sauria A poisonous **snake**, *Agkistrodon piscivorus*, of the southeastern United States Named from the whitish color of the inside of the mouth It frequents wet places, especially swamps, and is sometimes called the water moccasin.

This species is a pit viper, related to the copperhead and rattlers It reaches a length of six feet and is more aggressive than the copperhead but is said to be less deadly than popularly supposed Treatment of its bite is the same as for other **pit vipers** (A W L)

COTTON-MOUTON EFFECT. Electric and Magnetic Double Refraction.

COTTON STAINER. Insecta, Hemiptera *Dysdercus* A **bug** of Florida and adjacent states which punctures the bolls of cotton and causes staining of the fiber It develops in groups which can be jarred from the plants into vessels containing a little kerosene (A W L)

COTTONTAIL. Mammalia, Rodentia *Sylvilagus* Wild **rabbits** of several variable species, distributed from southern Florida to Mexico and north into Canada They are gray to brown and most forms have the tail white beneath An included species is the pontoon or marsh rabbit of Dismal Swamp The cane cutter or swamp rabbit of the south central states is another species that inhabits wet ground (A W L)

COTYLEDON Seed.

COTYLOSAUR Fossil Reptiles.

COUCAL Aves, Cuculiformes Ground birds (**Aves**) of several species, black or red and black in color, found in the Oriental, Australian, and Ethiopian regions **Cuckoos** (A W L)

COUDÉ. The Coudé is a modification of the **equatorial** form of mounting for an astronomical **telescope** designed for the purpose of providing a maximum amount of comfort for the observer The telescope itself is mounted in bearings parallel to the axis of rotation of the earth and forms the polar axis of the instrument The eyepiece is at the upper end and usually projects into a closed room Below the object glass a mirror is mounted in such a manner that it may be rotated about an axis perpendicular to the optic axis of the telescope Hence the mirror may be rotated about its own axis parallel to an **hour circle** (in the coordinate of **declination**) and is carried along with the rotating tube parallel to the coordinate of **hour angle** As the observer is seated in a comfortably heated room he looks down into the eyepiece and sees the field of view slowly rotating about the optic center of the field

The fundamental difficulty with the Coudé mounting may be traced to the fact that the mirror will introduce distortion Furthermore, unless the silver coating on the mirror is very perfect there will be a large amount of light loss For ordinary "star gazing" purposes the comfort of the observer makes the instrument a very popular one (W K G)

COUGAR. Mammalia, Carnivora Large North American **cats** of several species The Florida cougar, *Felis coryi*, lives in wild lands of central Florida, another species in Louisiana, and the western species, *F oregonensis*, is still found from the Rocky Mountains to the coast The species once found throughout the eastern half of the continent, *F concolor*, is now limited to the

wild mountainous areas of the east or is entirely extinct. The western species is called the mountain lion or puma and the eastern species was also called panther, painter and catamount (A W L)

COULOMB. The coulomb is the practical unit of quantity of electricity It is primarily an electromagnetic unit, the absolute coulomb being one-tenth of the abcoulomb or **abampere**-second The "international coulomb," however, is defined electrochemically, as the quantity of electricity transferred during the electrolytic deposition of 0 001118 gram of silver from a silver nitrate solution in a **coulombmeter** It is thus the basis of the international **ampere** The international coulomb is about 0 99905 of the absolute coulomb

The coulomb, while convenient in reference to electric currents and electrochemical processes, is far too large for electrostatic purposes, being approximately equal to 3×10^9 e s u of electricity If one could perform the impossible feat of charging two small spheres with one coulomb each, these charges, if placed one meter apart, would attract or repel each other with a force of about 9×10^{14} dynes or well over a million tons, and the potentials in the near vicinity of the charges would reach hundreds of billions of volts (L D W)

COULOMB'S LAWS. This term usually refers to the familiar laws of interaction between two concentrated electric charges and between two magnetic poles The force of attraction or repulsion between two charges (or poles) is directly proportional to the product of the charges (or pole strengths) and inversely to the square of the distance between them The similarity to the Newtonian law of **gravitation** will be readily noted

The experimental proof of these laws was carried out by means of the **torsion balance**, employing small, electrified balls or the poles of slender bar magnets In the electrical case, a far more precise proof of the inverse-square feature is based on the mathematical analysis of the experimental fact that at every point within a charged, hollow, spherical conductor, the electric field intensity due to the surface charge is exactly zero (L D W)

COULOMBMETER or COULOMETER. An electrolytic cell used for the measurement of the quantity of electricity passing through a circuit, also called "voltameter" A standard form, based upon the definition of the international **coulomb**, and depositing silver, has been developed at the Bureau of Standards (*Bulletin Bureau of Standards*, 13, 479, 1916) The more practical form for laboratory use employs copper electrodes in a bath of copper sulphate The thin copper cathode, between two heavy copper anodes, is removable for weighing, and since one coulomb deposits 0 000329 gram of copper, the weight of the copper deposit enables one to determine the quantity of electricity in coulombs The electrolyte recommended for this cell consists of 15 grams of crystalline copper sulphate, 5 grams of pure sulfuric acid, and 5 grams of pure alcohol, dissolved in 100 grams of distilled water (L D W)

COUMARIN. Bean.

COUMARONE. Furane and Related Compounds.

COUNTERBALANCING. Counterbalancing means simply the application of extra **mass** to a system in order to produce balance for the system as a whole, and to offset the unbalance arising from some particular part Rotating machinery, especially high-speed machinery, needs to be counterbalanced if the center of gravity of the rotating mass does not lie on the axis of rotation. Hoists are frequently counterbalanced so that a descending weight will supply some of the energy required for hoisting the non-useful load Numerous examples of counterbalancing will be found in everyday practice, but those cases associated with the counterbalancing of high-speed rotating machinery are the most imperative of solution See **Balance.** (F T M)

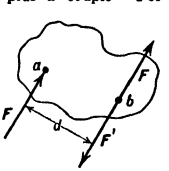
COUNTERSUNK. The head of a screw, **bolt, rivet,** or other **fastening** normally protrudes above the surface of the metal through which it passes There are some instances where this is undesirable, and countersunk heads are used The ordinary means of countersinking is to employ a fastening with a conical head, and to counterbore the hole to the same shape with the countersink reamer This is very difficult to do in thin metal stock, as it seriously interferes with the bearing power of the head on the metal However, it is not impossible of accomplishment except in the very thinnest sheets Where a fastening must pass through a surface having either very close clearance or actual bearing with another, the heads must be countersunk It is becoming the practice to countersink the rivets in the skin of an all-metal aircraft in order to eliminate the parasite drag of exposed rivet heads (F T M)

COUNTING TUBE. A type of **ionization chamber** adapted to detect the arrival of individual ionizing particles, such as **beta rays** or **cosmic-ray** particles The enclosure is commonly cylindrical with its thin metal wall serving as one electrode, preferably surrounded by a protecting envelope of glass The other electrode may be a needle-point projecting into the cylinder, as in the Geiger counter, or a fine, straight, axial wire, as in the Rutherford-Geiger and the Geiger-Muller counters These electrodes are maintained at a potential difference just too small to ionize the air between them without some additional assistance When an ionizing particle enters through the tube wall, the resulting ionization causes a momentary current This may be amplified to operate a suitable signal or even to record itself on a drum or tape See Hodoscope (under **Cosmic rays**) (L D W)

COUNTRY ROCK The general term used for the main mass of rock in which occur the **veins, dikes** or ore bodies which are of particular interest, or which are described in detail (R M F)

COUP DE POING. Paleontology of Man

COUPLE. As a usual thing the action of two forces on a body can be duplicated by a single force, equal to their **resultant,** acting at their **center of pressure** Two parallel forces of equal magnitude but opposite direction cannot be reduced to a single force They form a couple The effect of a couple upon a body is independent of the location of that couple with respect to the body The net action of several couples all in the same plane on a body is equal to the algebraic sum of the moments of the couples, the sign being determined from the direction of rotation which the couple tends to give The moment of a couple is the product of the perpendicular distance between the forces and one of the forces The action of any force, acting at any particular point on a body, upon another point lying in the plane of the force can be resolved into another force of the same magnitude acting at the desired point plus a couple For example, let F be any force acting at point a and b any other point at distance d from the line of action of F At point b place two equal and opposite forces F and F' which are parallel to the direction of the original force F Then F' at b and F at a form a couple Fd leaving F which acts through point b The effect on point b of the latter force and the couple is the same as the effect of the original force F acting at a Thus it is seen that it is possible to replace a force acting at a with an equal force acting at b, and



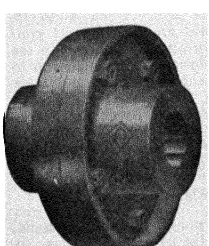
the couple *Fd*, where *d* is perpendicular distance from *b* to the force *F* in its original position. (F.T.M.)

COUPLING. A coupling is any means for joining two component parts into a unit system. There are a number of specific uses of the term.

Two electric circuits are said to be "coupled" if they are so placed or connected that variation of the current in one has an influence upon the other. In the most common type, known as inductive coupling, the effect is transmitted by the varying magnetic linkage which the one circuit (the primary) produces through the other (the secondary). This linkage consists of that part of the total magnetic flux set up by the primary which links with the secondary, multiplied by the number of turns of the secondary, and is hence expressed in maxwell-turns. The effect in the secondary of the varying primary current is in accord with the laws of **electromagnetic induction**, and is well illustrated by the alternating-current transformer. In another type, each circuit is provided with a condenser, the plates of one of which lie between those of the other, and the effect is transmitted electrostatically. This is capacitative coupling. Again, in what is sometimes called resistance coupling, the two circuits have a common branch, so that either may be regarded as a shunt from the other.

Pneumatic and hydraulic couplings are possible in certain special cases, but by far the most common usage of the word is descriptive of mechanical coupling. In this field the coupling may connect static or dynamic elements. As an example of the static coupling, there is the pipe coupling, one type of which consists of a hollow metal cylinder internally threaded so as to receive the threaded ends of adjacent lengths of pipe which are to be rigidly coupled. See **Pipe.**

Rotating shafts are fastened together with various types of couplings which will permit disconnecting the shafts for the purpose of disassembling. Such couplings can be classified as those in which the shafts are in line and are to be rigidly joined, and those in which the shafts are more or less out of line. The connection of a shaft to a coupling is generally accomplished either by key or set screw. A common style of coupling is that illustrated in the figure. This flanged coupling is split vertically so that when the two parts are disconnected, the flanged ends may remain on the separate shafts, thus obviating the necessity of removing the key every time the shafts are to be disconnected. Flexible couplings have interposed between the two halves of the couplings some flexible connector such as leather, rubber, or springs. These are designed to absorb shock as well as to correct slight irregularities in the alignment of the shafts. See **Universal joint.** (L.D.W., F.T.M.)



Flange coupling.

COURLAN. Aves, Gruiformes. A large Brazilian bird (**Aves**) which resembles the rails in appearance and habits. Also called the limpkin. (A.W.L.)

COURSE. This is a term which is used in navigation with several different meanings. The true course of a ship at any instant is the angle between the direction in which the ship is actually moving and the **meridian** on which the ship is located. It is this true course which must be used in the determination of **dead reckoning.**

The steered course, or course per **compass**, is the angle between the keel of the ship and the meridian established by the horizontal component of the **earth's magnetic field.** In case the magnetic compass is used the angle between the keel of the ship and the true meridian may be obtained by applying the proper **compass corrections.** In case the **gyro compass** is used certain small corrections must also be applied to obtain the true course. When the angle between the keel and the true meridian has been obtained the correction for **leeway** must be applied. This gives the direction of motion of the ship relative to the surface of the water. Finally applying a correction for the known direction of motion of the water (known commonly as current) we obtain the true course of the ship. As might be imagined, the necessity of so many corrections in transforming from the steered course to the true course of the ship is a fruitful source of error. Combining with these errors the errors introduced by the helmsman in the steering of the ship, we have the result that the value of the true course to be used in working up dead reckoning may be expected to be in error by as much as several degrees.

The term course is also used to indicate the path that the ship is attempting to follow on her passage. In case a ship is sailing a straight line as drawn between two points on a **mercator chart** she is said to be on a mercator or **rhumb line** course. When the rhumb line is due east or west it is a parallel of latitude and the ship is following a parallel course. If the ship is sailing the shortest distance between two points on the surface of the earth she is said to be on a **great circle course.** Usually a ship in a long passage follows a combination of all three courses, in which case she is said to follow a **composite course.** (W.K.G.)

COURSER. Aves, Charadriiformes. Long-legged birds (**Aves**) related to the plovers, found in Africa and southern Europe. One species is a desert bird. (A.W.L.)

COURTSHIP. The special behavior of animals in seeking mates.

Courtship varies from the complex behavior of birds and mammals to the random association of the sexes in many simpler animals, where meeting under proper conditions inevitably results in mating without evident preliminaries.

In its more complex aspects courtship almost invariably consists of some display on the part of the male which influences the female to accept or reject his advances, and is often accompanied by rivalry between males which may be settled by combat. The singing of male birds during the breeding season and the display of brilliant plumage by some species are well-known examples, and unusual evolutions in flight are little less familiar. Such behavior also occurs among the invertebrates, particularly among the spiders and some of the insects. Some of the South American birds, the **tinamous**, reverse the usual type of courtship. In these species the females court the males. (A.W.L.)

CONVALENCE. Valence.

COVELLITE. The mineral covellite, **cupric sulfide**, CuS, is **hexagonal**, usually in thin platey crystals, but may be massive. It has a hardness of 1.5–2; specific gravity, 4.6; luster, submetallic to resinous; color, dark indigo blue, sometimes showing a purplish tarnish, or if moistened may appear purple in color. Its streak is dark gray to black; it is opaque. Covellite is found associated with **chalcopyrite, bornite, cholcocite,** etc., and is believed to be chiefly of secondary origin. Covellite occurs in Serbia, Saxony, Sardinia, Argentina, Chile, Bolivia and Peru, and in the United States at Butte, Montana, and in Colorado, Wyoming and Utah. This mineral was named for Covelli, who discovered it in the lavas of Mt. Vesuvius. (E.S.C.S.)

COWBIRD. Aves, Passeriformes. 1. The yellow **wagtail** of England. 2. A dark colored bird, *Molothrus ater*, of southern Canada and the United States, related to the blackbirds, and several species of the same genus ex-

tending from Texas into South America. Most of these species deposit their eggs in the nests of other birds like the European cuckoo. They are named from their frequent association with cattle and before the settlement of North America the common species was called the buffalo bird. (A.W.L.)

COWPER'S GLAND. A gland of the male reproductive ducts of mammals whose secretion is part of the seminal fluid (**Reproduction**). (A.W.L.)

COWRY. Mollusca, Gasteropoda. Compactly oval shells with a long narrow aperture, smooth surface, and often bright colors.

There are many species of cowries, especially in the Pacific and Indian Oceans. The shells of some are used as money and for decorations. (A.W.L.)

COXA. The segment by which the leg of an **arthropod** is joined to the body. (A.W.L.)

COXAL GLAND. Excretory glands opening on the fifth segment of the body in the **king crab** and **scorpions. Coelomoducts.** (A.W.L.)

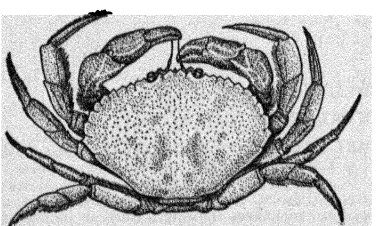
COXOPODITE. Biramous appendage.

COYOTE. Mammalia, Carnivora. **Wolves** of several smaller North American species, ranging from Iowa to California and from Mexico into Canada. The common coyote or prairie wolf, *Canis latians*, occurs in the northern prairie area, the plans coyote, *C. nebracensis*, throughout the great plains, and the mountain coyote, *C. lestes*, in the western mountain areas.

Coyotes sometimes destroy chickens and other small domestic animals. They have been relentlessly killed for their depredations and remain common only in sparsely settled regions. (A.W.L.)

COYPU. Mammalia, Rodentia. A large aquatic **rodent** of South America whose habits are like those of the muskrat. Its fur is the nutria of commerce. (A.W.L.)

CRAB. Crustacea, Decapoda. **Crustaceans** with a short broad **cephalothorax** and a small abdomen bent below it. The large pinchers and four pairs of legs are the only conspicuous appendanges. Most species of crabs are found in or near the ocean but some are terrestrial and others live in fresh water. The land crabs deposit

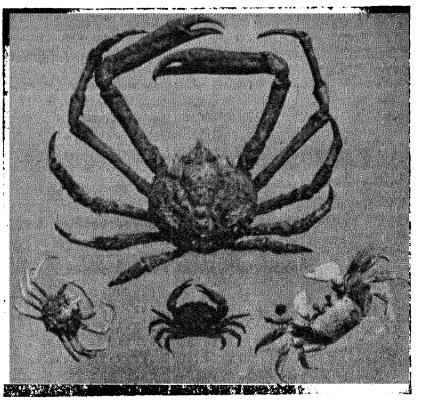


Crab.

their eggs in the water. The many species of crabs constitute a division of the order named the Brachyura from the short abdomen.

A number of species of crabs are used for food. Of these the edible crab of the Atlantic, which ranges from Cape Cod to Louisiana, and the edible crab of the Pacific Coast, are the most important species.

Many crabs have received common names which apply to one species or to a group of similar species. Among these names are spider crab, hermit crab, fiddler crab and land crab. (A.W.L.)



Above, male spider crab. Left, female spider crab. Right, **ghost crab. Center, mud crab. (From Mayer,** *Seashore Life,*) (Courtesy of *N. Y. Zool. Soc.*)

CRACKING PROCESS. Gasoline, as one of the products of crude oil, is required today in such quantities for motor vehicles that were the crude oil to be separated into its commercial components (such as petroleum ether, gasoline, kerosene, etc.) by **distillation** or **fractionation** through heating and condensation, there would be an uneconomic excess of the products other than gasoline. For petroleum, the natural crude oil, is made up of a complex mixture of **hydrocarbons,** which differ in composition and structure. When petroleum is distilled, the more volatile fractions, such as gasoline, are found to be composed, in general, of hydrocarbons of simpler molecular structure—that is, those having molecules which contain a comparatively small number of atoms. Speaking broadly, the hydrocarbon molecules having larger numbers of atoms are more largely concentrated in the less volatile petroleum products. In the cracking process these larger molecules are broken up to produce, in part, a greater yield of gasoline and other low-boiling fractions. One of the simplest methods of cracking is by heating under pressure. By efficient cracking gasoline yields of 60% or more have been obtained from certain crudes. (For further discussion of cracking, see **Hydrocarbons;** and **Gasoline.**) (F.T.M.)

CRAG IMPLEMENTS. Paleontology of man.

CRAIT. Reptilia, Sauria. A poisonous **snake** of India, *Bungarus caeruleus*, related to the cobras and adders. It is said to conceal itself in houses, and to this fact must be attributed its record of killing more human beings than any other snake, with the exception of the cobra.

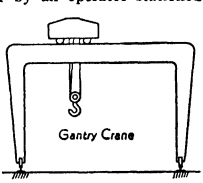
The name crait has also been applied to several related species of Oriental snakes, including the banded adder. (A.W.L.)

CRANBERRY. Heath Family.

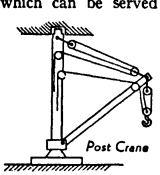
CRANE. Aves, Gruiformes. Large birds (**Aves**) with long legs and neck. They are superficially like the larger herons and the name crane is sometimes inaccurately applied to the latter birds, especially to the great blue heron. Cranes are found in Europe, Asia, North America and Africa.

In engineering, a crane is a hoisting machine in a particular category. It is not a simple matter to point an exact distinction between **hoists** and cranes, as they have not been clearly distinguished in common usage. However, cranes might be classified as those types of hoisting machines where vertical lift is not the primary

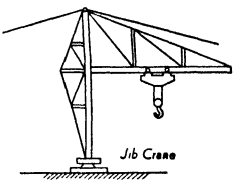
purpose (as it is, for example, in the case of an elevator) but where the lift is only that sufficient to allow proper clearances for those parts being transported by the crane The primary purpose of a crane is to lift a piece from one place and set it down in another, and so a degree of horizontal freedom is essential The horizontal movement may be accomplished in two ways, viz, the rectilinear motion of a traveling crane mounted on parallel rails, or the rotary motion of a pivoted swinging crane. The ordinary traveling crane is that most frequently found inside buildings The rails are laid on the walls or on a special steel framework inside the walls Rolling on the rails on each side is a wheeled carriage which carries the end of a **girder** bridging the distance between the rails This girder must be sufficiently strong to support by beam action the lifting capacity of the crane A rolling carriage containing the hoist is mounted on top of the girder so that it gives motion in a direction perpendicular to the main rails Thus every part of a rectangular floor area inside the walls may be reached by the crane This type of crane is widely used in factories and other plants where heavy objects must be transported about in a rectangular area If the crane is seldom used, it may be a hand-operated type, having chains reaching down to the floor level to be pulled by hand—one to roll the crane back and forth along the main rails, the other to pull the carriage from side to side and to operate the hoist Electrically operated traveling cranes usually have two motors, one to roll the crane along the main supports, the other to move the carriage on the crane girder and operate the hoist The control can be accomplished remotely from an electrical control panel, or by an operator stationed on a cab which travels with the crane The latter is generally the case when the crane is in almost continuous use In outdoor locations, where it is not convenient to erect a structure to carry the overhead rails, the crane can be equipped with legs which support it on rails at the ground level It is then a Gantry crane



The post crane is a simple type of rotary crane frequently used for unloading material from one transportation system and placing it on another The area which can be served by a crane of this type is more limited than in the case of the traveling crane, but it is a simpler, cheaper type As shown in the figure, the post is supported on pivots at the top and bottom It would be necessary to support the top by guy wires out of doors. The principal members are the post and the **boom** In the type shown, the radius of the circle in which the hook travels can be varied, but this is fixed in some post cranes, where the post and boom are connected by a simple tie rod member If the lower pivot of a post crane were made large and heavy, the top support could be eliminated The load would be carried by bending in the post, which would then be shortened and become the pillar of a pillar-type crane



The jib crane is better adapted for an all-steel rotary crane where the radius to be covered is larger than that to which the post or derrick type crane is suited The radius is varied by changing the position of the trolley on the jib beam The post and jib cranes may be swung about either by hand or by motors Cranes having a further degree of mobility are the locomotive and crawler types, which are self-contained units mounted, in the case of a locomotive crane, on a railway carriage, or in the case of the crawler crane, on caterpillar treads They are motivated by internal combustion or steam engines, and in structure are somewhat similar to a pillar crane (A W L, F T M)



CRANE FLY. Insecta, Diptera **Insects** which resemble mosquitoes in form but are usually much larger They have a V-shaped groove across the thorax and have no scales on the wings

The **larvae** of some species live in the ground and are sometimes injurious to the roots of grasses and grains These larvae are called meadow maggots or leather jackets They come to the surface at times and can be destroyed by the use of poison baits (A W L)

CRANIATA. Vertebrata.

CRANIUM. Skeletal system.

CRANK. Crankshaft, Bell Crank.

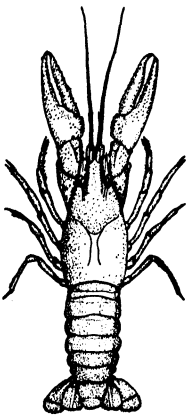
CRANKSHAFT. A crank is a bent arm which moves with rotary motion about its unbent end In order to provide a support for this rotation the crank is mounted on a crankshaft The crank and crankshaft form one of the important basic units of mechanism There has been found no simpler, more efficient way of transforming rotary to reciprocating motion, or vice versa The crank alone does not accomplish this, but in conjunction with the **connecting rod** and **slider**, it forms the basis of many such important machines as engines, pumps, compressors, and a host of other mechanisms A simple crankshaft of the overhung type is readily made from an arm (or disk) and a crank pin which is set into it at some radial distance from a crankshaft, which is the center of rotation This type is widely used where a crankshaft is to accommodate but one crank, and where the crankshaft bearing surface is entirely on one side of the crank Multiple cranks on the same crankshaft are obtained by fitting the crank pin between two crank arms, so that the connecting rod may swing freely without interference with the crankshaft Multiple throw crankshafts are made by building up the crank pin between two cranks, and by machining from a single forged piece It is the function of a crank to transmit the force at the crank pin into a torque at the crankshaft, the torque being equal to the component of crank pin pressure perpendicular to the crank radius multiplied by that radius Since crank pin pressure is not always exactly perpendicular to crank radius, it follows that a crank may carry some compression or tension as well It should never be loaded with bending by forces parallel to the crankshaft (F T M)

CRASPEDON. Velum.

CRASPEDOTE. Provided with a craspedon or **velum.** Applied to the medusae of many species of **Hydrozoa** in contrast with the jellyfishes (A W L)

CRAYFISH. Crustacea, Decapoda Fresh-water **crustaceans** resembling small lobsters, with which they are closely related They are widely distributed The term is applied to a limited extent to certain marine species which are more closely allied to the lobsters than to

the true crayfishes. In the United States **Cambarus** is a common genus East of the Rockies, and Astacus to the west.



Crayfish.

Crayfishes are eaten in Europe and to a limited extent in the United States. (A.W.L.)

CREAM OF TARTAR. Tartaric acid.

CREEP. The characteristics of metals at ordinary temperatures are well understood: proportional limits, yield points, ultimate strength, are terms which are familiar to many persons. At higher temperatures before the yield point is reached, there comes a creep point above which additional stress causes a slow flow, or "creep," of the metal. Some alloy steels have less creep than plain carbon steel but are more expensive. The tensile strength of steels drops rapidly for temperatures above 750° Fahrenheit, and most metals at 1000° Fahrenheit are subject to creep. The creep limit has arbitrarily been set as that at which the stresses (with factor of safety of at least three based on the yield point) produce a creep of 10^{-6} times the actual length, per hour. The theory of high-temperature design seems to be shaping itself into an acceptance of creep but with a proportionment of parts to limit the creep to certain predetermined rates. (F.T.M.)

CREEPER. Aves, Passeriformes. Small insectivorous birds (**Aves**) which cling to the trunks of trees or cliffs in seeking food. They are found in the Northern Hemisphere and are represented in North America by the brown creeper, *Certhia familiaris.* (A.W.L.)

CREODONT. Fossil mammals.

CREPUSCULAR. Active during twilight.

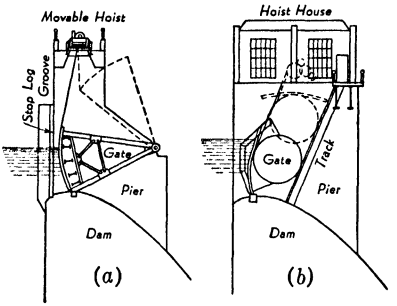
CREST GATE. The principal items of equipment to be used in conjunction with a dam, for the maintenance of desired water conditions, are crest gates, sluices, and spillways, and sometimes, by legal requirement, by-passes for fish or for logs. In order to control the head closely, crest gates are provided on the spillway sections, but where the spillway is a natural rock channel at one end of the dam it is convenient to effect the control by sluice gates. The different types of crest gates in use are summarized as follows:

1. Sliding gates.
2. Tilting gates.
3. Rolling gates.
4. Taintor gates.
5. Stationary flash boards.

Sliding gates are limited in capacity by the effort that is required to move them against frictional drag set up by heavy water pressure. When equipped with roller guides, as in the Stoney roller gate, the capacity per gate is much increased.

Tilting gates usually are so constructed that a predetermined rise of water against them automatically tilts them to the open position, then, after the water has fallen to its normal elevation, they automatically return to the closed position.

Rolling gates are supported on a cylindrical drum which can be rolled up a steep incline by various means. Chains, wrapped around the cylinder ends, are connected to hoists which roll the gates up an incline of 20 degrees to the vertical.

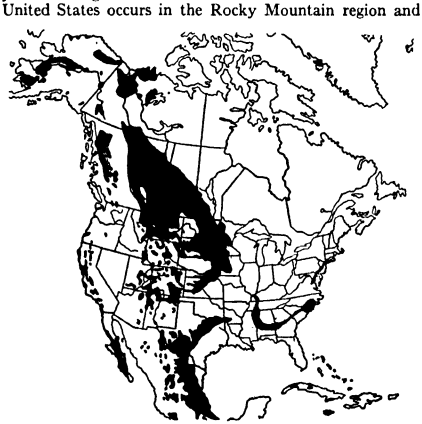


Crest gate. (a) Taintor. (b) Rolling.

The Taintor gate has been widely used in this country for crest control. The face of the Taintor gate is the circumference of an arc the center of which is at the pivot point. This causes the resultant of water pressure against the gate always to pass through the pivot so that, with the exception of pivot friction, it is necessary to handle only the weight of the gate itself when opening or closing it.

When no other control is exercised, it is good practice to use temporary flash boards on the spillway crest. Generally these are constructed of wood and held in place by iron pins which will bend over and release the flash boards should the water rise to a point where the maximum spillway capacity is needed to pass the flood. (F.T.M.)

CRETACEOUS PERIOD. The last major division in the **Mesozoic Era** of the geologic time-scale. Type locality, chalk (creta) cliffs of the English Channel. The period was named by A. d'Halloy in 1822. In 1877, Hill proposed that the Lower Cretaceous be erected as a separate system which he called the Comanchean. The Comanchean period began 110 million years ago and lasted for 25 million years. The Cretaceous Period began 85 million years ago and lasted for 50 million years. The greatest thickness of Cretaceous strata in the United States occurs in the Rocky Mountain region and



Map of North America showing the surface distribution (areas of outcrops) of Cretaceous strata. The large and small areas in the western interior of the continent very largely represent Upper Cretaceous deposits.

in California. During the Cretaceous Period there was also an extensive overflow of the waters of the Gulf of Mexico toward the southern interior of the United States, depositing there a great series of overlapping sediments. This is the type region of the Lower Cretaceous or Comanchean. While the Atlantic and Gulf continental margins were invaded by the Cretaceous Sea, the region of the **Appalachian geosyncline** had been reduced to a **peneplain** which may have been overlapped by marine sediments. In the Great Plains region were deposited fresh-water shales and sandstones with local swampy areas in which were formed numerous **lignites**, subsequently altered to bituminous coal. The Middle Cretaceous saw a great marine invasion of western North America from the Gulf of Mexico to the Arctic Ocean. Deposits of Cretaceous age are well represented in central and western Europe, with fairly continuous marine deposition throughout the entire period. Cretaceous deposits occur in South America, especially in Brazil. As further evidence that there was widespread invasion of the continents by oceanic waters during this period, marine sediments occur in southwestern Asia, China, Himalayas, Japan, Siberia, and Africa. Important mineral resources are of Cretaceous Age. In the United States the Cretaceous formations contain numerous important aquifers which underlie great semi-arid areas. Bituminous coal beds of average value occur in Alaska, Australia, British Columbia and Germany. Important oil pools occur in the Gulf region. The Cretaceous clays of the eastern United States are extensively used in the manufacture of china and building materials. The famous sulfide copper ores of Butte, Montana, occur in igneous rocks of Cretaceous and Early Tertiary age. Lower Cretaceous plants and animals were only slightly different from those of Jurassic time. Ferns, **cycads**, **ginkgoales** and conifers still predominate, and the principal marine invertebrates were **ammonites** and **belemnites**. During the Cretaceous there was a great expansion of the **pelecypods**, **gastropods**, and the modern type of fishes. The Mesozoic reptiles have reached their climax in the early Cretaceous and, except for a few large and bizarre forms, are on their way to extinction. The most remarkable types were **Triceratops** (horned dinosaur), **Tyrannosaurus** (tyrant dinosaur), **Tylosaurus** (marine lizard), and **Pteranodon** (crested pterodactyl, or flying reptile). Since uppermost marine Cretaceous does not occur in North America, there appears to have been a pronounced period of uplift and erosion, accompanied by mountain building, with the combined growth of the Cordilleran ranges. This period of diastrophism, which closed the Mesozoic Era in the western hemisphere, is called the **Laramide Revolution**. (R.M.F.)

CRETINISM. A disease originating in fetal life or shortly after. It is primarily due to lack of secretion of the **thyroid gland**. The victim is dwarf-like in appearance with an extremely low physical and mental development. In **goiter** districts treatment of pregnant women prophylactically with iodine is important in preventing birth of cretins. If the disease is recognized in infancy much can be done by giving thyroid substance to them. (R.S.M.)

CRIBELLUM. A perforated plate associated with the spinnerets of some spiders. Through it a peculiar form of silk is produced with the aid of the **calamistrum**. (A.W.L.)

CRIBIFORM ORGANS. Series of thin vertical calcareous plates found in the arms of some starfishes (**Asteroidea**). (A.W.L.)

CRICKET. Insecta, Orthoptera. **Insects** related to the katydids and grasshoppers and, like some of these forms, well known for their resonant singing. The true crickets constitute a family (Gryllidae) which contains the common or field crickets and in addition several other forms more or less different in appearance. The field crickets are black or brown species, some of which enter houses. Tree crickets are usually green with broad transparent wings. They frequent trees and shrubs. Mole crickets are thick-bodied brown insects whose forelegs are strongly developed for burrowing. In addition to these and a few other forms of crickets several inscets belonging with the katydids among the long-horned grasshoppers bear this name. They are the cave or camel crickets, the sand cricket, and the Mormon cricket. (A.W.L.)

Cricket.

CRINOIDEA. The sea lilies, feather stars, and basket stars, a class of the phylum **Echinodermata**. There are now only a few hundred species of these animals although several thousand fossil species are known.

The crinoids are distinguished from the starfishes and other echinoderms by the following characteristics: 1. The body consists of a disk, arms, and a stalk. 2. The mouth and anus are both directed upward. 3. The arms bear small lateral branches and in many species fork repeatedly.

Most of the living species lose the stalk when mature and become free-swimming. These forms, known as comatulids, are found in shallower waters of the ocean, where they swim or creep by means of the arms. The stalked species are found in deep water.

The classification of crinoids is of little interest save to specialists. Many families are recognized and they are sometimes grouped in three orders: Holopodida, Ptilocrinida, and Comatulida. The first includes a primitive attached form, the second the stalked crinoids, and the last the free species. (A.W.L.)

CRISIS. (1) The turning point of a disease, either toward recovery or death. Under certain conditions in various diseases this may occur dramatically—particularly in **pneumonia**. In some cases, instead of a gradual fall in temperature, requiring several days, the high fever suddenly drops and the acutely ill, delirious, toxic patient within a short time becomes quiet, of better color, breathes more easily and seems to be definitely on the way to recovery.

(2) A painful paroxysm or seizure in certain diseases, especially seen in syphilis of the spinal cord (**locomotor ataxia**). (R.S.M.)

CRISTOBALITE. Tridymite.

CRITICAL ANGLE. Total Reflection.

CRITICAL POTENTIAL. Electrons are commonly set into motion by an electric field, the energy thus acquired being proportional to the **potential difference** traveled through. If, when moving very rapidly, an electron encounters an atom or a molecule, the latter may be ionized or it may be merely excited; either process involving a change in the relation of one or more of the atomic or molecular electrons to the atom or molecule to which it belongs. Such a change requires a certain minimum amount of energy and unless the moving electron has at least this energy, the ionization or excitation does not take place. The critical potential corresponding to such a process is the potential difference necessary to give the moving electron the requisite energy. For example, the least energy which a cathode particle must have to excite the Kα x-radiation of nickel (wave length 1.662 angstroms) is 7426 **electric volts**, that is, the energy which would be given to it by applying a potential difference of 7426 volts to the x-ray tube. Hence 7426 volts is the critical potential for this excitation. (L.D.W.)

CRITICAL PRESSURE. When a fluid flows through an orifice or a nozzle, the volume of flow from a fixed initial pressure depends on the final pressure as long as that final pressure is in excess of a certain critical pressure If the final pressure is lower than the critical pressure, the amount of fluid passed will be the same as though the final pressure had been equal to the critical pressure The critical pressure is a constant proportion of the initial pressure For example, for air flow it is 53%, for saturated steam, 58%, and for superheated steam, about 56%

Critical pressure also denotes the pressure of a vapor at its critical point, the latter occurring at a temperature above which the vapor can exist only in the form of a gas Water, for example, has a critical pressure 3226 pounds per square inch (F T M)

CRITICAL SPEED. At certain critical speeds rotating shafts become dynamically unstable, even though they may be free from vibrations both above and below that speed If a shaft is allowed to persist in its critical speed, resonance effects may be built up which will cause large and dangerous vibrations The critical speed of a shaft is that at which its revolutions per second is the same as the frequency of its natural vibration A computation of the latter, taking to account all masses attached to the shaft, as well as the shaft itself, will serve to compute the critical speed Factors affecting the value of critical speed are the length of the shaft, its diameter, the type of bearings, and the elasticity of the material of which it is made In computing critical speed, the shaft is thought of as a beam laid horizontally between two supports at the bearing positions By application of the principles of the theory of structures, the deflection of this beam is computed under load imposed by the weights of itself and such parts as are attached to it Then the critical speed in revolutions per minute is obtained by dividing the number 187 7 by the square root of this deflection measured in inches (F T M)

CRITICAL STATE. For every pure substance there is a definite temperature (the critical temperature) and a definite pressure (the critical pressure) at which the liquid and the vapor are indistinguishable If the liquid substance is enclosed in a hermetically sealed tube with nothing above it but its own vapor, and the temperature is raised, the liquid expands and also evaporates, adding to the vapor, so that the density of the liquid decreases while that of the vapor increases Ultimately the two densities become equal (the common value being the critical density and its reciprocal the critical specific volume) The surface separating liquid and vapor then becomes invisible, though apparently the surface tension does not altogether vanish until a slightly higher temperature is reached The pressure attained in this process may be very great, for water it is about 217 atmospheres, the corresponding temperature being 374° C Above this temperature the substance is said to be a gas, and no amount of pressure will cause it to separate into two fluid phases (See **States of Matter**)

For certain purposes it is convenient to express the absolute temperature, the pressure, and the specific volume of a substance in terms of their respective critical values, i e, as abstract ratios T/T_c, p/p_c, v/v_c, called "reduced variables of state" If two gases have two reduced variables of state in common, the third variable will also be approximately the same for the two gases; a principle known as the "law of corresponding states" (L D W)

CRITICAL TEMPERATURE. Critical State.

CROCIDOLITE (BLUE ASBESTOS). The mineral crocidolite may be considered as a fibrous variety of the **monoclinic amphibole,** riebeckite It is also known as a massive mineral Its hardness is 4, specific gravity 3.2–3 3; luster, silky to dull; color, blue or bluish green It is found in Austria, France, Bolivia, South Africa (the variety known as tiger's-eye), and in the United States in Massachusetts and Rhode Island The name crocidolite is derived from the Greek, meaning woof, in reference to its fibrous appearance. (E S C S)

CROCODILE. Reptilia, Crocodilia Large aquatic **reptiles** of elongate slender form, with short legs, a long compressed tail, and skin armored with bony plates The crocodiles differ from the related **alligators** and **caiman** in the more tapering snout, although their jaws are much wider than those of the **gavial** Crocodiles are found in southern Asia, Africa, northern Australia, tropical South America, and in southern Florida Some species occur only in fresh water and others in salt marshes and estuaries The most common genus is *Crocodilus*

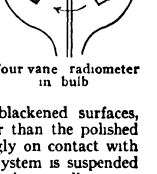
Crocodiles are much more aggressive and vicious than alligators and are dangerous to man (See also **Fossil Reptiles**) (A W L)

CROCODILIA An order of large **reptiles** of long slender build The skin is armed with bony plates and the long jaws bear many conical teeth set firmly in bony sockets The animals are chiefly aquatic They are found only in warmer regions and chiefly in fresh water, although some enter the ocean

The order includes **crocodiles, alligators, caimans,** and the **gavial** (A W L)

CROCOITE. The mineral crocoite, **lead** chromate, corresponds to the formula $PbCrO_4$, and forms prismatic **monoclinic** crystals, often acicular It is also found in columnar or granular masses It has a rather distinct cleavage parallel to the prism, and a less distinct cleavage parallel to the base It has a conchoidal fracture, is sectile, hardness, 2 5–3, specific gravity, 5 9–6 1, luster, adamantine to vitreous, color, red, streak, orange yellow, translucent Crocoite is a secondary mineral believed to be formed by waters containing chromic acid acting upon lead minerals like galena, with which it is associated It is found in Russia Rumania, Tasmania, Brazil, the Philippines, and Arizona It is not of commercial value The name crocoite is derived from the Greek word for saffron in reference to the color of the powdered mineral (E S C S)

CROOKES RADIOMETER. An apparatus devised by Sir William Crookes, consisting of pairs of light vanes mounted at the ends of opposite spokes of a very light, horizontal wheel poised on a pivot like a compass needle It therefore resembles a miniature paddle wheel One side of each vane is a polished metal surface, these surfaces being all directed the same way around the wheel, the other side is blackened The whole apparatus is mounted inside a glass or quartz bulb from which the air is partially exhausted When **radiation** from the sun or other hot source falls on the vanes, the wheel revolves in the direction toward which the polished surfaces are directed This motion is explained by the higher absorptivity of the blackened surfaces, which causes them to become warmer than the polished surfaces and thus to react more strongly on contact with the air molecules If a similar vane system is suspended by a fine quartz fiber and provided with a small mirror, the torque caused by the inequality of pressure is made observable and may be used to measure the intensity of the incident radiation Hence the term radiometer. (L D W)



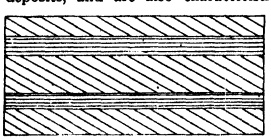
Four vane radiometer in bulb

CROOKES TUBE. Sir William Crookes was a pioneer in the study of electric discharge in gases In the **vacuum tubes** which he used, and certain forms of

which still bear his name, the pressure was reduced to such a point that the bright glow observed at higher pressures practically disappeared. The **cathode rays**, obstructed by but little residual gas, shot straight across the tube and, impinging upon the opposite wall, caused it to glow with greenish fluorescence. By placing an obstacle, such as a metal plate shaped like a Maltese cross, in the path of the rays he was able to demonstrate their rectilinear character by the shadow on the fluorescing surface. In one type of tube he interposed a light paddle wheel of metallic vanes in the path of the rays, and found it driven at high speed as if by a stream of air. It is, however, probable that the greater part of this effect is due to the heating of the bombarded surfaces and that the paddle wheel really operates as a **Crookes radiometer**. (L.D.W.)

CROP. A thin-walled expanded portion of the alimentary trace (See **Digestive System**) used for the storage of food prior to digestion. Crops are found in many animals, including **earthworms**, **insects**, and **birds**. (A.W.L.)

CROSS-BEDDING. Oblique lamination of certain beds in **aeolian** or water laid **sediments**, caused by current action, is called cross-bedding. Cross-bedded sediments are found especially in river and stream deltas, **alluvial fans** and cones, river sand bars and marine sand deposits, and are also characteristic of windblown deposits of all kinds. The different types of cross-bedding are useful criteria for helping to determine the physical (including climatic) conditions under which certain types of clastic sediments were deposited. In regions where the formations have been highly deformed, and possibly overturned, cross-bedding may also be used by the **stratigrapher** and structural geologist to determine the original order in which sedimentary strata were laid down. (R.M.F.)



Cross bedding (false bedding). (Field, *Laboratory Manual, Princeton University Press.*)

CROSSBILL. Aves, Passeriformes. *Loxia.* Small seed-eating birds (**Aves**) of the northern hemisphere whose mandibles cross at the tip when the mouth is closed. This adaptation enables them to open seeds and fruits, such as cones, very readily. (A.W.L.)

CROSSHEAD. This is a machine part having reciprocating motion and mounting a pin for the attachment of a connecting rod. In the crank and connecting rod mechanism which is employed to interchange reciprocating and rotating motion, the crosshead is the reciprocating part. It slides between crosshead guides which are attached to the frame. One end of the **connecting rod** is jointed to the crosshead by the wrist pin.

Piston and cylinder engines which are single-acting, that is to say, which have the gas or vapor on one side of the piston only, may have the wrist pin set directly in the piston. A crosshead is essential to a double-acting engine. The piston rod of a double-acting engine must go through a stuffing box or a packing gland in the end of a cylinder, a thing which is impossible for the swinging connecting rod. Some large single-acting engines also have a crosshead so that the wear due to the side thrust of the connecting rod will occur on the easily adjustable crosshead guides instead of the cylinder walls. (F.T.M.)

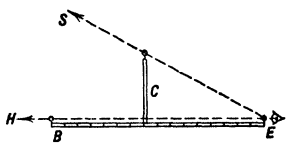
CROSSOVER. Heredity.

CROSS PRODUCT OF TWO VECTORS. Vector Product of Two Vectors.

CROSS-RATIO. Anharmonic Ratio.

CROSS-STAFF. Both the cross-staff and the **astrolabe** were used by navigators for the purpose of measuring **altitude** of celestial objects in the period prior to the invention of the **sextant** in the eighteenth century. The astrolabe was the more compact of the two, but the use of the cross-staff was simpler and the results slightly more accurate, particularly for small altitudes.

The principle and use of the instrument is illustrated in the accompanying figure. A "cross" with a peep sight in its upper end slides along a rod *EB*. Holding the cross vertical, the observer sights from *E* along the rod toward the **horizon** at *H*, and slides the cross along until the object under observation appears through the peep sight in the cross. The graduations on the rod indicate directly the value of the angle *HES*, which is the desired apparent altitude. The instrument may also be used to measure the angular distance between any two objects.



Cross-staff.

Tradition says that Columbus used a cross-staff during his voyages. Within recent years the instrument has been used to some extent for teaching purposes in elementary courses in astronomy. (W.K.G.)

CROSSTALK. This is the undesirable operating condition of a telephone communication system where the electrical effects of one circuit induce an undesired current in another. In the case of a phantom telephone circuit, crosstalk will be troublesome unless the lines are perfectly balanced electrically, and the loading coils have the same resistance, inductance, and capacitance. Considerable care must be taken in the manufacture of the loading units in order to minimize crosstalk. See **Phantom Circuit.** (F.T.M.)

CROTON. Spurge Family.

CROTON BUG. Insecta, Orthoptera. A European **cockroach**, one of the two chief pests of this kind in the United States. Its name is said to be due to its association with water pipes from the Croton reservoir in New York City. (A.W.L.)

CROTONIC ACID. Alcohols and Ethers.

CROTONIC ALDEHYDE. Aldehydes, Ketones, and Related Compounds.

CROWS. Aves, Passeriformes. Large birds (**Aves**) of the northern hemisphere and Africa. They are black or black and white in color. Together with the ravens,

rooks, magpies, jays, and other species they make up the **crow** family (Corvidae).

The importance of the common crow of North America, *Corvus brachyrhynchus*, has been debated. He does some good in destroying vermin and insects, but the

farmer and conservationist are both against him for his destruction of fruit and grain and the eggs and young of other birds (A W L)

CROWN SHEET. Locomotive.

CRUCIBLE. A crucible is a vessel made of heat resistant material and employed to hold a material that in itself is at high temperature, or is to be subjected to high temperature Crucibles will range in size from the small laboratory types to large ones having a capacity of several tons of molten metal They are roughly cup or barrel shaped, and are made of some material such as clay In the laboratory, platinum, iron, and porcelain crucibles are used In the iron and steel industry, clay crucibles have been used, but at the present time most manufacturers employ the graphite crucible, which is made half and half from graphite and fire clay, well-mixed, molded, and burned to vitrification The crucible may be used to hold a material being melted or burned, as in some processes for making steel, where the raw material is put in the crucible, which is then set in a hot furnace until the contents are melted Or a crucible may be used to receive molten metal, which has been produced elsewhere, as from a brass furnace or cupola, in which case it is the means for conveying it from the point of melting to the point of casting, serving thus as the intermediate reservoir between the furnace and the mold (F T M)

CRUDE OIL. Petroleum; and Hydrocarbons.

CRUSH BRECCIAS. Autoclastic.

CRUSTACEA. The lobsters, crabs, barnacles, shrimps, and many other species, constituting a class of the phylum **Arthropoda** A large majority of the 25,000 known species are aquatic

The Crustaceans are distinguished from other classes of the phylum by the following characters 1 The body is divided into **cephalothorax** and abdomen 2 The eyes are compound 3 Two pairs of **antennae** are present 4 Jointed appendages are found on the abdomen in many species 5. Respiration is usually accomplished by gills

The principal economic importance of crustaceans is due to the value of some species as food Lobsters, shrimps, and some of the crabs are caught in large numbers for the market and are regarded as delicacies Although formerly cheap, the lobster has been caught in such large numbers on the New England coast that it now has to be protected by law and brings high prices. The smaller crustaceans are important as food for fishes

Barnacles have long been a nuisance for their part in the fouling of ship bottoms

The following brief outline indicates the complexity of classification of the crustaceans

Subclass **Branchiopoda** At least four pairs of broad fringed appendages on the thorax **Carapace** usually present

Order Phyllopoda Appendages similar, numerous Fairy shrimp

Order Cladocera Usually with a bivalve carapace **Water fleas**

Subclass **Ostracoda** With a bivalve carapace Thorax with only two pairs of appendages or less *Cypris*

Subclass **Copepoda** No carapace Thorax with five pairs of appendages *Cyclops* and the parasitic fish-lice

Subclass **Cirripedia** Sessile as adults Barnacles and parasitic forms

Subclass **Malacostraca** Carapace normally present Many appendages on thorax and abdomen

Order Leptostraca Like Phyllopoda but abdominal appendages slender

Order Hoplocarida Larger predacious species **Mantis shrimps.**

Order Syncarida A small group of rare forms.

Order Mysidacea. Also very limited

Order Cumacea A few small marine species

Order Tanaidacea Small marine order, sometimes included in the following

Order Isopoda Marine, fresh-water and terrestrial forms Oval and flattened No carapace The sow-bugs, pill-bugs or wood-lice and other species

Order **Amphipoda** Related to the preceding but body high and narrow

Order Euphausiacea **Cephalothorax** covered with a shield Marine species Thoracic appendages biramous

Order **Decapoda** Cephalothorax with shield Thoracic appendages with one branch **Lobsters, crabs, crayfishes, shrimps,** etc (A W L)

CRYPTOBRANCHUS. Hellbender.

CRYOLITE. Cryolite, **sodium aluminum fluoride,** Na_3AlF_6, crystallizes in the **monoclinic** system but in forms that closely approach cubes and **isometric octahedrons** It is usually found massive Cryolite has an uneven fracture, is brittle, hardness, 2 5, specific gravity, 2 95–3 0, luster, vitreous to greasy, color, snow white but may be colorless, reddish or brownish, translucent to transparent The only considerable occurrence of cryolite is at Ivigtut, Greenland, where veins of this mineral are associated with granites and gneisses Small occurrences of cryolite have been noted in the Ilmen Mountains, Russia, and at Pike's Peak, Colorado Cryolite has its chief use in the electrolytic production of aluminum, but small amounts are employed in the manufacture of opalescent glass

The name cryolite is derived from the Greek words meaning frost (ice) and stone in reference to its translucency (E S C S)

CRYPTOCRYSTALLINE. When the texture of an **igneous** rock is so finely **crystalline** (that is, made up of such minute crystals) that the individual crystals can only be distinguished in a thin section by transmitted **polarized light,** the rock is said to be cryptocrystalline Among the **sedimentary** rocks, **chert** and **flint** are cryptocrystalline Lava flows, especially of the **acidic** type such as **felsites** and **rhyolites,** may have a cryptocrystalline ground mass as distinguished from pure **obsidian** (acidic), or **tachylite** (basic), which are natural rock glasses (R M F)

CRYPTOMONADIDA. An order of one-celled animals containing species of constant body form, with **flagella. Mastigophora** (A W L)

CRYPTOZOA. Paleobotany.

CRYPTURIFORMES. An order of ground birds (**Aves**) resembling the game birds They range through South America and north into Mexico, and are called partridges by inhabitants of these countries The tinamous (tinamus) (A W L)

CRYSTAL. Crystallography.

CRYSTAL ANALYSIS. Crystal Structure.

CRYSTAL AXES. Crystallography.

CRYSTAL FORM. Crystallography.

CRYSTAL PLANE. Crystallography.

CRYSTAL OSCILLATOR. Piezo-electricity and Pyro-electricity.

CRYSTAL STRUCTURE. Long before the epochal experiments performed at the suggestion of von Laue by Friedrich and Knipping, it was inferred that the structure manifestly existing in crystals is due to an orderly arrangement of **atoms** or **molecules.** The ideal crystal is traversed by systems or "families" of parallel cleavage planes in various directions, three or more of which de-

termine the normal external shape of the natural crystal It is easy to imagine that these planes form a space lattice of equal polyhedral cells fitting together to fill the space, much as do the cells of a honey-comb or an egg-crate, and further, that each of the individual cells represents a characteristic unit grouping of particles, a structure built of atoms or of ions, perhaps the molecule itself

Dr Max von Laue (Munich) in 1912 hit upon a method of verifying and elaborating this theory He knew from the density and atomic weights, that the number of atoms in a cubic centimeter of rock salt, for example, is about $4\,488 \times 10^{22}$, and that therefore, if they are equally spaced in all three directions, their distance apart is $2\,814 \times 10^{-8}$ cm or 2 814 angstroms Certain **quantum theory** calculations had already indicated that x-rays have wave lengths of this order It occurred to von Laue that if a beam of x-rays were directed upon a crystal and the crystal turned into a suitable position, one might observe **interference** maxima analogous to those produced with light by a **diffraction grating.** This proved to be the case, and the result verified beyond question the existence of regular spacings between reflecting planes of some sort, presumably plane arrays of atoms or ions

Subsequent analysis of the problem by Bragg resulted in a formula analogous to that for interference of light reflected by thin plates If the reflecting layers are spaced at equal distances d, and if the wave length of the incident x-rays is λ, the angle θ between rays and layers necessary for an interference reflection maximum is given by **Bragg's law,** viz, $\sin\theta = n\lambda/2d$, in which n is an integer By slowly turning the crystal, the various plane-families are brought into suitable orientations for the production of maxima The result is a Laue pattern of black spots on the photographic plate placed beyond the crystal to catch the reflections Another method, developed by Hull and by Debye and Scherrer, secures the necessary angular variation by crushing the crystal to powder and relying upon the fortuitous orientation of the fragments, the pattern in this case being a system of concentric rings

While it is very easy, when one knows the structure of the crystal and the wave length of the rays, to predict the diffraction pattern, it is quite another matter to deduce the crystal structure in all its details from the observed pattern and the known wave length This can be done, however, and we now have determined the arrangement and spacings of atoms in nearly all known crystals Stereoscopic models of many typical crystals are to be found in an excellent album prepared by von Laue and Mises, entitled *Stereoscopic Drawings of Crystal Structure* (L D W)

CRYSTAL SYSTEMS. Crystallography.

CRYSTALLINE CONE. A glassy body between the cornea and the sensory portion of each component of the compound **eye** in some species of insects (A W L)

CRYSTALLINE STYLE. A digestive secretion of certain **bivalve** mollusks It consists of protein bearing an amylolytic ferment and is produced in a continuous rod by a pouch of the intestine One end projects into the stomach and is worn away by contact with a gastric shield and mixed with the food. (A W L)

CRYSTALLIZATION. The phenomena, which are involved in the production of crystals, suggest consideration of the following topics.

1 Crystals proper See **Crystallography.**
2. The process of crystallization See below
3. The converse process of crystal disappearance See **Dissolving.**
4 The prevention of crystal formation. See **Colloidal State, Condensation Processes** (6)
5. Solutions proper. See **Solutions and Solubility.**

The Process of Crystallization Crystals are formed (1) from solution, (2) from fusion, (3) by sublimation

(1) The formation of crystals from solution, starting with an unsaturated solution, takes place when a solution is evaporated or cooled below the saturation point, except as retarded by supersaturation. Supersaturation is prevented by the addition of seed crystals of the substance Since, in the case of the majority of soluble substances, solubility increases with increase of temperature cooling below the saturation point favors the formation of crystals In very few cases, such as sodium sulfate above 32 4° C, calcium sulfate (slightly soluble), calcium hydroxide (slightly soluble), solubility decreases with increase of temperature, and the above statement would not apply A case of wide scope and great importance is that of crystal formation by **precipitation** upon mixing two solutions Actually, this is the same as for substances of greater solubility, since the substance precipitated is first formed in solution and the excess above the saturation point separates as precipitate As a rule the crystals are larger and more perfect the slower their growth Conversely, when small crystals are desired, rapid stirring and quick cooling are practical The smaller the crystals of a given substance, the purer the material generally is Small crystals may be increased in size by allowing them to stand in the mother liquor before separation

(2) The formation of crystals from fusion takes place when the melted substance is cooled sufficiently slowly near and below the fusion point If the cooling is rapid the fusion may result in the formation of an undercooled liquid of rigidity corresponding to a solid Glasses whether artificial, such as glass, vitreous enamels, and slags, or natural, such as vitreous rocks and minerals, e g, obsidianite, are under-cooled liquids Rocks and minerals which have cooled sufficiently slowly from fusion form crystals, for example, granite

(3) The formation of crystals by sublimation takes place when the vapor of a substance is condensed as a solid without passing through the liquid phase in so doing This occurs when the temperature of the condenser is below that of the melting point of the substance See Vapor Pressure

The heat of crystallization is in amount the same as the heat of solution of a given substance but of opposite sign (R K S)

CRYSTALLOGRAPHY. This branch of physical science deals with the external shapes of crystals and with the geometrical relations between the atomic planes within them If a solid crystal is broken, it is found to have separated along certain "cleavage planes" into polyhedral fragments Even when crushed to powder, the minute grains show this characteristic Measurements upon the variously shaped pieces reveal that if they were fitted together again, the planes would all be found to belong to one or another plane-family, the members of any one of which are all parallel

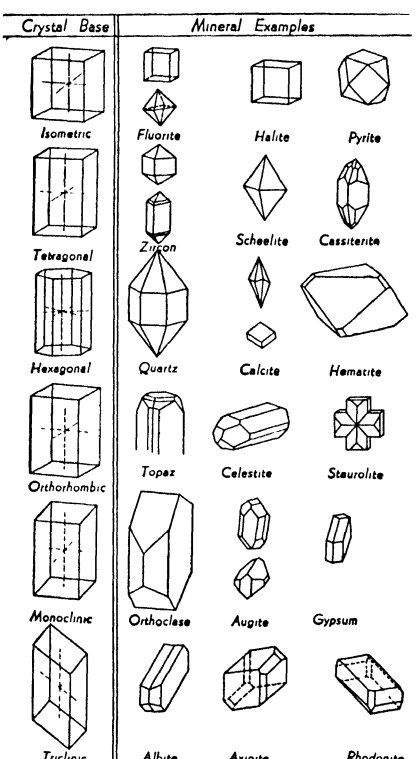
In most crystal systems each of the more prominent crystal faces belongs to one of three plane-families intersecting along what are called the crystal axes (In the hexagonal system there are four) These may be conveniently used as coordinate axes, X,Y,Z, though they are not generally at right angles Hauy discovered that if the ratio of the intercepts of two crystal planes on one of these axes is a simple fraction, such as $3/5$, the ratios of the intercepts on the other axes are likewise simple This suggests that the two intercepts on any one axis are multiples of a common unit The units are, however, generally different for the different axes, bearing to each other ratios called the axial ratios

It is more convenient to use the reciprocals of the intercepts For example, a plane might have intercepts equal to 10000, 15000, and 6000 of the respective units. The reciprocals have the ratios $\frac{1}{10000} \cdot \frac{1}{15000} \cdot \frac{1}{6000}$,

which in lowest terms are 3 2 5 These smallest integers are the Miller indices of the family to which this plane belongs, and the family is thus designated (325) The family (201) is parallel to the *Y* axis but intersects the *X* and *Z* axes (The hexagonal system has four Bravais-Miller indices for each plane-family)

Close study of the angles, indices, and axial ratios long since made it clear that every crystalline substance has a structure built upon a space "lattice" characteristic of the substance We now know that this is due to the regular arrangement of the atoms, molecules, or ions composing the substance (See **Crystal Structure**) The same study shows that the lattice structures of all crystals may be classified into fourteen types, which are divided into six "systems" as follows

1 **Isometric.** Three axes of equal length which intersect at right angles, with axial ratios all unity
2 **Tetragonal.** Three axes which intersect at right angles Two horizontal axes of equal length, and a vertical axis which is either longer or shorter than the horizontals (Only one axial ratio is unity)
3 **Hexagonal.** Four axes which intersect at right angles, three coplanar axes at 120°, and one at right angles to them The two horizontal axes of equal length, and the vertical axes either longer or shorter than the horizontals
4 **Orthorhombic.** Three axes of different lengths which intersect at right angles, and none of the axial ratios unity
5. **Monoclinic.** Three axes of different lengths, two of which intersect at right angles, the third oblique to one of the others
6 **Triclinic.** The axes of unequal length and all oblique to one another, and none of the axial ratios unity The angles between axes are less than 90°, and are unequal



Illustrating the six crystal systems and specific examples of each system Field, *Outline*, Barnes & Noble

Practically all minerals are crystalline, although perfect natural crystals are seldom, if ever, found Because of the laws of crystallography, however, a crystallographer can usually determine the crystal form of a known species from a fragment of the original crystal, provided that at least two of the crystal faces are visible Crystalline aggregates are said to be **cryptocrystalline** when the individual particles are proved to have crystalline structure but their crystal faces are exceedingly small or indistinguishable A mineral is "pseudocrystalline" if its external form does not correspond with its crystalline structure (L D W , R M F)

CTENIDIAL FILAMENTS. Slender processes of the ctenidia of mollusks (**Mollusca**) (A W L)

CTENIDIUM A projection of the body wall of mollusks (**mollusca**), lying in the mantle cavity and usually serving as a gill Ctenidia are slender filaments or leaf-like plates (A W L)

CTENOPHORA. The comb jellies or sea walnuts, constituting a small phylum of marine animals related to the coelenterates and sometimes included in that phylum The phylum includes the peculiar **Venus' girdle,** a transparent ribbonlike animal whose longitudinal axis is across the middle of the slender body

The ctenophores differ from the coelenterates in the following structures 1 The alimentary tract opens to the exterior at the end of the body opposite to the mouth 2 The body bears rows of ciliated (See **Cilium**) plates, the combs which give the animals one of their common names These are organs of locomotion 3 **Colloblasts** or adhesive cells take the place of **nematocysts.**

Classification

Class Tentaculata With a pair of long tentacles
Order **Cydippida.** Body spherical to cylindrical Tentacles long
Order **Lobata** Tentacles replaced in adult by fringe of short tentacles around mouth
Order **Cestida** Body ribbonlike Venus' girdle
Class Nuda Tentacles absent Body conical to ovoid (A W L)

CUBIC EQUATIONS A cubic equation in one unknown is a **polynomial equation** of the third degree, and has the general form

$$a_0x^3 + a_1x^2 + a_2x + a_3 = 0.$$

The general cubic equation $y^3 + py^2 + qy + r = 0$ may be reduced by the substitution $y = x - \frac{1}{3}p$ to the normal form $x^3 + ax + b = 0$, where $a = \frac{1}{3}(3q - p^2)$, $b = \frac{1}{27}(2p^3 - 9pq + 27r)$

The normal form $x^3 + ax + b = 0$ has roots x_1, x_2, x_3 given by

$$x_1 = A + B,\ x_2, x_3 = -\tfrac{1}{2}(A + B) \pm \tfrac{1}{2}\sqrt{3}\,i(A - B),$$

where $i = \sqrt{-1}$, and

$$A = \sqrt[3]{-\frac{b}{2} + \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}},\quad B = \sqrt[3]{-\frac{b}{2} - \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}}.$$

If a and b are real, and

(*a*) if $\frac{b^2}{4}+\frac{a^3}{27}>0$, there are one real root and two conjugate complex roots,

(*b*) if $\frac{b^2}{4}+\frac{a^3}{27}=0$, there are three real roots of which two are equal,

(*c*) if $\frac{b^2}{4}+\frac{a^3}{27}<0$, there are three real and unequal roots.

In case (*c*), where $\frac{b^2}{4}+\frac{a^3}{27}<0$, the above formulas for the roots are not in convenient form for numerical calculation; a trigonometric transformation reduces them to better form, thus: if $\cos\phi=\sqrt{\frac{b^2}{4}\div\left(-\frac{a^3}{27}\right)}$, then the roots are

$$x_k=\mp 2\sqrt{-\frac{a}{3}}\cos\left(\tfrac{1}{3}\phi+k.\ 120^\circ\right)\ (k=0,\ 1,\ 2),$$

where the upper sign is to be used if $b>0$ and the lower sign if $b<0$.

If $\frac{b^2}{4}+\frac{a^3}{27}>0$, the real root is given in convenient form for numerical calculation by the trigonometric form

$$x=\pm 2\sqrt{\frac{a}{3}}\cdot\cot 2\phi,$$

where

$$\tan\phi=\sqrt[3]{\tan\psi}\quad\text{and}\quad\cot 2\psi=\sqrt{\frac{b^2}{4}+\frac{a^3}{27}},$$

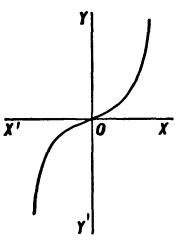
and where the upper sign is to be used if $b>0$ and the lower sign if $b<0$.

If $\frac{b^2}{4}+\frac{a^3}{27}=0$, the roots are

$$x=\mp 2\sqrt{-\frac{a}{3}},\ \pm\sqrt{-\frac{a}{3}},\ \pm\sqrt{-\frac{a}{3}},$$

where the upper sign is to be used if $b>0$ and the lower if $b<0$. (L.L.S.)

CUBIC FUNCTIONS. A cubic function is a **polynomial function** of the third degree, which is therefore of the form ax^3+bx^2+cx+d, where a, b, c, d are **constants** (independent of x) and x is the **variable.** (L.L.S.)



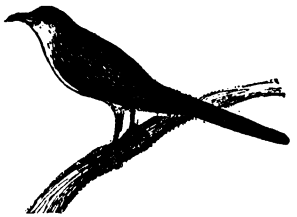
Cubical parabola.

CUBICAL PARABOLA. This is a curve obtained by plotting the **graph** of the equation $a^2y=x^3$. Its shape is shown in the accompanying figure. (L.L.S.)

CUBOMEDUSAE. An order of **jellyfishes** of roughly cuboidal form. (A.W.L.)

CUCKOO. Aves, Cuculiformes. Birds (**Aves**) of many species found in all continents. They take their common name from the call of the European cuckoo, *Cuculus canorus.* This species, like some others of the family, is well known for its habit of leaving its eggs in other birds' nests.

Some species are known by other names, including koel, coucal and malkoha. North America has two species, the yellow-billed, *Coccyzus americanus,* and black-billed, *C. erythrophthalmus,* and the related ani and road-runner of the south and southwest. (A.W.L.)


Yellow-billed cuckoo. A long slender bird, grayish brown above, whitish below, with white marks on the ends of the tail feathers; lower part of beak yellow.

CUCKOO WASP. Insecta, Hymenoptera. Small **wasps** which lay their eggs in the nests of solitary wasps and bees. Usually metallic blue or green. Family Chrysididae. (A.W.L.)

CUCULIFORMES. The order of birds (**Aves**) which includes the **cuckoos,** anis, **road-runners,** quezal, and related species. (A.W.L.)

CUCUMBER. *Cucumis sativus.* **Gourd Family.**

CUCUMIS. Gourd Family.

CUCURBITA. Gourd Family.

CUESTA. Scarp.

CULM. Mississippian Period. Also the stem of a grass. **Grass Family.**

CULTURE. The growth and propagation of microorganisms by artificial means outside of the body. This is done in various media such as agar, bouillon, gelatin—either plain or enriched with blood, tissue or dextrose. The material from the patient usually cultured is blood, urine, tissue, any body secretion or material taken directly from the site of infection, such as an abscess. (R.S.M.)

CULVERT. An artificial waterway for carrying water under an obstruction, such as a highway or railway, is a culvert. The culvert is a drainage structure that completely encloses the opening for the water, and is covered by a fill over which the roadway passes. It is differentiated from the bridge by virtue of the fact that it conveys water while the latter spans an opening. It is composed of a barrel (the essential part) and head walls at the ends of the barrel. The latter prevent erosion of the soil adjacent to the culvert and divert the water into the barrel. Head walls are not always employed. Culverts are constructed of **concrete,** cast iron, **brick,** terra cotta, and corrugated sheet metal. Small ones are usually circular, or rectangular in shape. Larger culverts may be arched over a curved invert. (F.T.M.)

CUMACEA. An order of **crustaceans** made up of a few marine species of small size. (A.W.L.)

CUMMINGTONITE. The mineral cummingtonite is a variety of **amphibole** which is essentially (Mg, Fe) SiO_3, the amounts of **magnesium** and **iron** varying as they replace one another. Cummingtonite is generally restricted to material containing from 50% to 70% $MgSiO_3$. The name *grünerite* has been applied to cummingtonite which contains more than 50% of the $FeSiO_3$ molecule. Cummingtonite usually occurs as a brown fibrous to lamellar mineral. It derives its name from Cummington, Massachusetts. (E.S.C.S.)

CUMULATIVE METHOD. Physical Measurements.

CUMULOSE The term proposed by Merril in 1897 for **sediments** composed almost, if not entirely, of **carbonaceous** material, such as **peat**, lake mucks, etc (R M F)

CUPOLA. In geology, cupola is the term proposed by R A Daly in 1911 for a subsidiary dome-like protrusion in the roof of a **batholith.** Cupolas are supposed to be the reservoirs for the concentrated rising gases of the batholithic **magma** and may serve as the loci for **volcanoes.**

In engineering, the cupola is the furnace commonly employed in foundries for the melting of cast iron In principle, the cupola is similar to, but simpler than, the **blast furnace.** Like the latter, it has a sheet metal shell and is lined with refractory brick It is similar, also, with respect to the admission of air through tuyeres, but unlike the blast furnace, it rarely uses preheated air, nor is there any attempt to save the heat in the waste gases Accordingly, it is not necessary to provide the air-lock at the upper end, as on the blast furnace The top of a cupola is simply a stack discharging the products of combustion to the atmosphere The cupola is fed with materials from an opening in the side above the line to which the charging is carried It has an iron notch and a slag spout, and a hearth much like the blast furnace

When it is ready to be charged, the hearth is lined with a refractory material such as sand, containing sufficient clay to bind it together to keep it from floating on the iron A certain amount of kindling wood is then charged, on which is placed a bed layer of coke to an amount sufficient so that when the kindling has burned out and the coke has settled to the bottom of the cupola, it will form a bed extending above the tuyeres As soon as the bed charge is well lighted additional charges of coke, scrap, pig iron, and limestone are added until the upper limit of charge depth is reached This is allowed to burn some time under the influence of a small quantity of air so as to "soak" thoroughly the contents with heat The cupola is then ready for the "blast" A blower is started, and air is rapidly forced through the tuyeres, resulting in a very high rate of combustion, and the production of a high temperature just above the tuyeres As the coke burns out, and the iron sinks into this high temperature region, it is melted, falls in drops and streams to the hearth, and runs out through the iron notch The cupola operator allows a certain amount of this iron to run out at the beginning of a heat, as it is usually not sufficiently liquid to pour well He then closes the iron notch with a bott, which is a cone of clay designed to cork the opening The melting continues and molten iron is accumulated in a pool over the hearth As successive charges sink lower inside the cupola, fresh charges are added to the extent of the iron required for that particular run The operator judges this amount of iron accumulated by knowing the characteristics of his cupola, and noting the elapsed time of melting between successive tappings When tapping a cupola, the clay bott is carefully cleaned out until only a thin wall remains between the iron notch and the interior pool This is broken with a long tapping chisel As the molten iron gushes forth it is caught in **crucibles,** in which it is carried to the molds When a crucible has been filled the flow is stopped by inserting another bott in the tapping hole This succession of tappings goes on until all the molds have been poured Some cupolas are sufficiently large to melt at a rate equal to that at which the iron can be used, and the iron notch is not plugged Iron is allowed to run continuously from the spout, fresh crucibles being placed under the spout as soon as the preceding one is filled Although a blast furnace is often operated continuously for days at a time, a heat in an average cupola in a jobbing foundry usually consumes only two or three hours, and in a production factory rarely exceeds eight to ten hours. (R M F, F T M)

CUPR(IC), (OUS). Copper.

CUPRITE. The mineral cuprite, **cuprous** oxide, Cu_2O, occurs as **isometric** crystals, usually **octahedrons,** but may be cubes, **dodecahedrons** or modified combinations It also is found as a massive, earthy material Its fracture is conchoidal to uneven, brittle, hardness, 3 5–4, specific gravity, 5 85–6 15, luster, submetallic to earthy, color, red, nearly transparent to nearly opaque Its streak is shining brownish red Cuprite is a secondary mineral resulting doubtless from the oxidation of copper sulphides It is often found associated with native copper, **malachite** and **azurite.**

Cuprite is a fairly common mineral, and of the many localities in which it occurs may be mentioned the Province of Perm, Russia, Chessy, France, Broken Hill, New South Wales, Corocoro, Bolivia, Andacollo, Chile. Bisbee, Arizona, and Del Norte County, California The name cuprite is derived from the Latin cuprum, copper (E S C S)

CUPRUM. Copper.

CURARE POISON. Strychnine.

CURASSOW. Aves, Galliformes Birds (**Aves**) of a few species found in northern South America They are about the size of turkeys and are arboreal in habit Excellent as food and sometimes domesticated (A W L)

CURETTAGE The scraping of an organ, a bony cavity or some other portion of the body with a curet—a spoon-shaped sharp edged instrument It is commonly spoken of in relation to the uterus, where the lining of the organ is removed with a curet either for diagnostic examination such as for cancer, or as a procedure to terminate pregnancy (R S M)

CURIE POINT. Curie-Weiss Law.

CURIE-WEISS LAW. It is well known that iron and other ferromagnetic substances do not exhibit magnetic properties at high temperatures The change with rising temperature is gradual, but at a certain temperature, known as the Curie point, occurs a transition from ferromagnetic to paramagnetic properties, and likewise a change in the dependence of the magnetic susceptibility upon the temperature (See **Magnetism**) P Curie stated in 1895 that above this point the susceptibility varies inversely as the absolute temperature But this was found to be not generally true, and was modified in 1907 by P Weiss to state that the susceptibility of a paramagnetic substance above the Curie point varies inversely as the excess of the temperature above that point At or below the Curie point, the Curie-Weiss law does not hold (L D W)

CURIE. The curie is a unit used in measuring the amount of emanation from **radium.** It is that amount which is in radioactive equilibrium with 1 gram of radium (R S M)

CURL OF A VECTOR FUNCTION. Let $\mathbf{v}$ be a **vector function** of position, with rectangular components v_1, v_2, v_3 The vector expression

$$\nabla \times \mathbf{v} = \hat{\mathbf{i}}\left(\frac{\partial v_3}{\partial y} - \frac{\partial v_2}{\partial z}\right) + \hat{\mathbf{j}}\left(\frac{\partial v_1}{\partial z} - \frac{\partial v_3}{\partial x}\right) + \hat{\mathbf{k}}\left(\frac{\partial v_2}{\partial x} - \frac{\partial v_1}{\partial y}\right)$$

$$= \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ v_1 & v_2 & v_3 \end{vmatrix}$$

is called the curl of $\mathbf{v}$, and is denoted by curl $\mathbf{v}$. It is also sometimes called the rotation of $\mathbf{v}$ and denoted by rotation $\mathbf{v}$.

If $\mathbf{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$ is a variable vector and $\mathbf{a}$ is a constant vector, then

$$\text{curl } \mathbf{r} = \nabla \times \mathbf{r} = 0,$$
$$\text{curl } (\mathbf{r} \times \mathbf{a}) = \nabla \times (\mathbf{r} \times \mathbf{a}) = -2\mathbf{a},$$
$$\text{curl } (r\mathbf{a}) = \nabla \times (r\mathbf{a}) = \frac{\mathbf{r} \times \mathbf{a}}{r}.$$

Let $\mathbf{u}$ and $\mathbf{v}$ be vector functions of position, and let u be a scalar function of position, then

$\text{curl } (\mathbf{u} + \mathbf{v}) = \nabla \times (\mathbf{u} + \mathbf{v}) = \nabla \times \mathbf{u} + \nabla \times \mathbf{v} = \text{curl } \mathbf{u} + \text{curl } \mathbf{v}$,

$\text{curl } (u\mathbf{v}) = \nabla \times (u\mathbf{v}) = (\nabla u) \times \mathbf{v} + u(\nabla \times \mathbf{v})$,

$\text{curl } (\mathbf{u} \times \mathbf{v}) = \nabla \times (\mathbf{u} \times \mathbf{v}) = \mathbf{u}(\nabla \cdot \mathbf{v}) - \mathbf{v}(\nabla \cdot \mathbf{u}) + (\mathbf{v} \cdot \nabla)\mathbf{u} - (\mathbf{u} \cdot \nabla)\mathbf{v}$,

$\text{curl } (\text{curl } \mathbf{v}) = \text{curl}^2 \mathbf{v} = \nabla \times (\nabla \times \mathbf{v}) = \nabla(\nabla \cdot \mathbf{v}) - (\nabla \cdot \nabla)\mathbf{v} = \text{grad } (\text{div } \mathbf{v}) - \nabla^2 \mathbf{v}$,

$\text{curl } (\text{grad } u) = \nabla \times (\nabla u) = 0$,

$\text{div } (\text{curl } \mathbf{v}) = \nabla \cdot (\nabla \times \mathbf{v}) = 0$.

Let $\mathbf{v}$ be a vector function of position, let δ be a small region of space and also its volume, surrounding a point P, and let ω be the bounding closed surface of δ and let $d\sigma$ be an element of ω; let $\hat{\mathbf{n}}$ be the unit normal vector (outward drawn) at any point of ω. Then the curl of $\mathbf{v}$ is defined by

$$\text{curl } \mathbf{v} = \lim_{\delta \to 0} \frac{1}{\delta} \int_{\omega} \hat{\mathbf{n}} \times \mathbf{v} \, d\sigma. \qquad \text{(L.L.S.)}$$

CURLEW. Aves, Charadriiformes. Shore birds (**Aves**) of several species with long legs, a moderately long neck, and a long curved beak. Related to the snipes. (A.W.L.)

CURRANT. Berry.

CURURO. Tucotuco.

CURVATURE OF A PLANE CURVE. The curvature of a plane curve is defined by $\frac{d\phi}{ds}$ where ϕ is the inclination angle of the tangent to the curve and ds is the differential of arc length.

The reciprocal of the curvature is called the radius of curvature at the point.

If the equation of the curve in **rectangular coordinates** is $y = f(x)$, the radius of curvature is given by

$$R = \left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2} \Big/ \frac{d^2y}{dx^2}.$$

If the equation of the curve is $r = f(\theta)$ in **polar coordinates**, the radius of curvature is given by

$$R = \frac{\left[r^2 + \left(\frac{dr}{d\theta}\right)^2\right]^{3/2}}{r^2 - r\frac{d^2r}{d\theta^2} + 2\left(\frac{dr}{d\theta}\right)^2}.$$

The center of curvature of a curve at a given point is a point on the normal at a distance from the point of contact equal to the radius of curvature. The circle of curvature is a circle with center at the center of curvature and radius equal to the radius of curvature.

The coordinates of the center of curvature are, in rectangular coordinates:

$$\alpha = x - \frac{dy}{dx}\left[1 + \left(\frac{dy}{dx}\right)^2\right] \Big/ \frac{d^2y}{dx^2},$$
$$\beta = y + \left[1 + \left(\frac{dy}{dx}\right)^2\right] \Big/ \frac{d^2y}{dx^2}. \qquad \text{(L.L.S.)}$$

CURVE FITTING. Empirical Equations.

CURVE TRACING. Locus of an Equation.

CURVES, IN A PLANE. A plane curve may be represented by a single **equation** in two **variables** interpreted as **rectangular coordinates** or as **polar coordinates.** Instead of this, it is sometimes desirable to use two equations which express the coordinates of a variable point on the curve in terms of a third variable or parameter; these equations are then called the **parametric equations** of the curve.

To find the points of intersection of two curves whose equations are given: solve the given equations as a simultaneous system, arrange the real solutions in corresponding pairs, and these will be the coordinates of all the points of intersection. (L.L.S.)

CURVES, IN SPACE. Curves in space which do not lie in one plane are called skew curves, or twisted curves, or space curves. Such curves are frequently thought of as the intersection of two **surfaces.**

Space curves are generally represented by **parametric equations,** by which the **rectangular coordinates** x, y, z of any point of the curve are expressed as **functions** of a parameter.

The **cylinders** whose elements intersect a given curve and are parallel to one of the coordinate axes are called projecting cylinders of the curve.

If a given space curve is represented by parametric equations $x = f(t)$, $y = g(t)$, $z = h(t)$, the tangent line to the curve at a point $P_1(x_1, y_1, z_1)$ corresponding to $t = t_1$ has the equation

$$\frac{x - x_1}{f'(t_1)} = \frac{y - y_1}{g'(t_1)} = \frac{z - z_1}{h'(t_1)}.$$

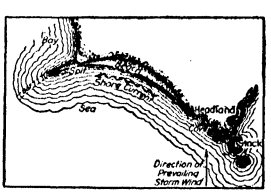
The length of arc of this space curve is given by

$$s = \int_{t_0}^{t_1} [f'(t)^2 + g'(t)^2 + h'(t)^2] dt. \qquad \text{(L.L.S.)}$$

CUSCUS. Phalanger.

CUSP. A tapering projection, such as the projections on the crown of a tooth or one of the pointed segments of a cardiac valve. (A.W.L.)

CUSPATE FORELAND. A coastal **headland** of triangular shape, with its apex seaward and its sides concave. (R.M.F.)



Sketch map illustrating erosion of a headland and development of shore current, beach, spit, bar, cove, and stacks, and cuspate foreland. (After W. H. Hobbs.)

CUTICLE. For the use of this term in botany, see **Leaf.** In zoology, cuticle is the outermost layer, the integument. (See **Integumentary System.**) As applied to the skin of the vertebrates this layer is composed of cells of ectodermal origin but in the invertebrates it indicates a noncellular layer secreted by the underlying cells. A cuticle of the latter type occurs in the parasitic flatworms, the rotifers, the roundworms and annelid worms, and the arthropods. The cuticle of insects is usually called the **cuticula.** (A.W.L.)

CUTICULA. 1. The thickened plate at the free end of some epithelial cells. 2. The layer of scales covering a hair. 3. The noncellular layer covering the bodies of some invertebrates. Some entomologists call the outer and inner layers of the chitinous cuticula of insects the epidermis and dermis. The terms **epidermis, dermis, cuticle** and **cuticula** are loosely used. (A.W.L.)

CUT-LIP. Pisces, Teleostei. A small fresh-water fish, *Exoglossum maxillingua,* common from the St. Lawrence to Virginia. The nigger chub. (A.W.L.)

CUT-OFF. The term cut-off generally refers to a particular point in a **cycle** at which a mechanism cuts off some flow to or from the cycle. The steam engine

cut-off is that percent of stroke accomplished by the piston when the inlet valve closes and prevents more steam entering the cycle from the boiler Up to the point of cut-off, the pressure of the steam against the piston is fairly constant, but when cut-off has occurred, the steam acts expansively with decreasing pressure The cut-off of a Diesel cycle is the fraction of the stroke accomplished when supply of fuel oil to the cylinder is stopped (F T M)

CUTTINGS. Propagation.

CUTTLEFISH Mollusca, Cephalopoda Mollusks, related to the squids but forming a separate family (Sepiidae) Used as food in the Oriental region The shell is the cuttlebone of commerce and the ink sac secretes the pigment sepia. (See also **Invertebrate Paleontology**) (A W L)

CUTWORM. Insecta, Lepidoptera **Larvae** of many species of **owlet moths** (Noctuidae) They hibernate when partly grown and in the spring often cut off young plants at the ground In severe attacks they can be killed by poisoned baits (A W L)

CUVIERIAN ORGAN. A defensive organ found in some sea cucumbers (**Holothuroidea**) It is a modified part of the respiratory tree attached to the **cloaca,** and made up of tubes covered with sticky material When irritated the animal contracts violently and ejects this structure through the ruptured wall of the cloaca In the sea water the sticky material forms long adhesive threads which entangle the enemy (A W L)

CUXIO. Mammalia, Primates A **monkey** of the Amazon valley, also called the black saki (A W L)

CYANAMIDES. Cyanamide (NC NH_2 or HN C: NH) is a white solid, melting point 44° C, boiling point 140° C at 20 mm pressure, transformed at 150° C into cyanuramide, tricyantriamide ($(NC\ NH_2)_3$) Cyanamide reacts (1) as a base with strong acids forming salts, (2) as an acid forming metallic salts, such as calcium cynamide ($CaCN_2$) Cyanamide is formed (1) by reaction of cyanogen chloride (CN Cl) plus **ammonia** (ammonium chloride also formed), (2) by reaction of thiourea plus **lead** hydroxide (lead sulfide also formed)

When calcium cyanamide is boiled with water, dicyandiamide ($(NC\ NH_2)_2$), melting point 207° C is formed (along with calcium hydroxide) Fusion of dicyandiamide with **sodium** carbonate plus **carbon** produces **sodium** cyanide plus **ammonia** (also some tricyantriamide) Diethylcyanamide ($(C_2H_5)_2N$ CN) is a colorless liquid, boiling point 180° C at 748 mm pressure, and when hydrolyzed yields diethylamine ($(C_2H_5)_2NH$) plus ammonia plus carbon dioxide Diphenylcyanamide (C_6H_5N C NC_6H_5) when hydrolyzed yields **aniline** plus carbon dioxide Benzylcyanamide ($C_6H_5CH_2NH$ CN) is a white solid, melting point 43° C (R K S)

CYANIC ACID AND CYANATES, AND RELATED COMPOUNDS, cyanic acid, isocyanic acid, fulminic acid, cyanuric acid, cyamelide, fulminuric acid) Cyanic acid (HCNO or HOCN) is a colorless, odorous, liquid, soluble in water and in ether, volatile with decomposition when heated, passing at ordinary temperature into a mixture of cyanuric acid ($(HNCO)_3$) and cyamelide ($(CONH)_x$), white solid, which on vaporizing yields cyanic acid, when cyanic acid vapor is rapidly cooled in a freezing mixture, cyanic acid, liquid, unstable, is obtained, when the vapor is condensed above 105° C, cyanuric acid

$$((HNCO)_3 \text{ or } CO\langle \begin{matrix} NH—CO \\ NH—CO \end{matrix} \rangle NH)$$

is obtained Cyamelide dissolves in **sulfuric acid** unchanged and addition of water causes precipitation of cyamelide, passes into cyanuric acid when warmed with concentrated sulfuric acid, finally into **carbon dioxide** plus **ammonia;** dissolves in **sodium** hydroxide solution forming sodium cyanate Sodium cyanate is prepared by heating **sodium** cyanide and an oxide such as **lead** monoxide (PbO) trilead tetroxide (Pb_3O_4), or lead dioxide (PbO_2), addition of water and separation of the sodium cyanate solution from the lead oxide by filtration Sodium cyanate solution upon boiling changes into sodium carbonate plus urea ($CO(NH_2)_2$)

Ammonium cyanate ($CNONH_4$), white solid, formed by reaction of sodium cyanate and **ammonium** sulfate solutions is transformed to **urea** upon being heated at 100° C This reaction was carried out in 1828 by Wohler, and is the first record of a so-called inorganic substance being transformed outside a living organism into a so-called organic substance. The following esters are known.

Methyl iso-cyanate (CH_3NCO), boiling point 44° C
Ethyl cyanate (C_2H_5OCN), decomposes on heating
Ethyl iso-cyanate (C_2H_5NCO), boiling point 60° C
Phenyl iso-cyanate (C_6H_5NCO), boiling point 166° C.

Ethyl cyanurate $C_3H_3O\ C\langle \begin{matrix} N—C(OC_2H_5) \\ N—C(OC_2H_5) \end{matrix} \rangle N$

Ethyl iso cyanurate $CO\langle \begin{matrix} N(C_2H_5)—CO \\ N(C_2H_5)—CO \end{matrix} \rangle N(C_2H_5)$

Fulminic acid (HONC) and the fulminates are violently explosive Utilizing this property, mercuric fulminate ($Hg(ONC)_2$) $\frac{1}{2}H_2O$) is used as a detonator for other explosives Mercury fulminate is made by the reaction of **ethyl alcohol** and **mercuric** nitrate in excess of **nitric acid,** from which insoluble mercuric fulminate separates Silver fulminate ($Ag(ONC)$ is more explosive than mercuric fulminate, and is used in the manufacture of fire-crackers Free fulminic acid may be obtained by reaction of potassium fulminate and excess of ether It volatilizes with the ether upon distilling, and changes rapidly to metafulminic acid Related to fulminic acid, is fulminuric acid ($(HONC)_2$ or NO_2 CH(CN) $CONH_2$) (R K S)

CYANITE. Kyanite.

CYANOGEN. Cyanogen ($(CN)_2$) is a colorless gas of marked characteristic odor, very poisonous, density 1 8 (air equal to 1 0), melting point —28° C, boiling point —20° C, soluble, when passed into water at 0° C, cyanogen forms **hydrocyanic acid** plus **cyanic acid,** but at ordinary temperatures the reaction is complex With **sodium** hydroxide solution, there is formed with cyanogen sodium cyanide plus sodium cyanate, with dilute sulfuric acid oxamic acid ($COOH\ CONH_2$), oxalic acid (COOH COOH) By reaction with tin and hydrochloric acid, cyanogen is reduced to ethylene diamine ($CH_2\ NH_2\ CH_2\ NH_2$). Cyanogen reacts with hydrogen to form hydrocyanic acid, and with metals, e g, zinc, copper, lead, mercury, silver, to form cyanides Cyanogen, (1) when burned in air produces a violet flame forming **carbon dioxide** and **nitrogen** in the outer part and carbon monoxide and nitrogen in the inner part, (2) when exploded with **oxygen** produces carbon dioxide or carbon monoxide and nitrogen depending upon the ratio of oxygen to cyanogen (2 volumes oxygen plus 1 volume cyanogen yields 2 volumes carbon dioxide plus 1 volume nitrogen; 1 volume oxygen plus 1 volume cyanogen yields 2 volumes carbon monoxide plus 1 volume nitrogen) The flame spectrum contains characteristic bands in the blue and violet. By means of the electric spark, the electric arc or a red hot tube, cyanogen is decomposed into carbon plus nitrogen When heated at ordinary pressure at about 300° C, or under 300 atmospheres pressure at about

225° cyanogen is converted into paracyanogen, a brown powder, also formed when mercuric cyanide is heated. Cyanogen is prepared (1) by reaction of **sodium** cyanide and **copper** sulfate solutions, whereby one-half the cyanogen is evolved as cyanogen gas and one-half remains as cuprous cyanide. From the filtered cuprous cyanide, by treatment with ferric chloride solution, cyanogen is evolved with accompanying formation of ferrous chloride, (2) by heating mercuric cyanide solid, or a mixture of mercuric chloride and sodium cyanide solutions, mercury and mercurous, respectively, being formed, (3) by heating ammonium oxalate ($COONH_4 \cdot COONH_4$) with phosphorus pentoxide, water being abstracted. Small amounts of cyanogen are present in blast furnace gas, and raw coal gas. (R.K.S.)

CYANOSIS. A blue color of the skin and blood caused by insufficient **oxygen** being carried in the blood. This is commonly seen in severe **heart** disease or heart malformations, **pneumonia,** or any severe toxic **infection.** It is also seen as a result of poisoning with gases, or as a result of drugs which interfere with respiration or the rate of absorption of oxygen by the blood. (R.S.M.)

CYANURIC ACID. Cyanic Acid and Cyanates.

CYBOTAXIS. A condition in which certain liquids, under **x-ray** examination, give evidence of structure resembling that of crystals. By passing a beam of x-rays through various alcohols and other organic liquids, G. W. Stewart and his collaborators have obtained one, two, or even three diffraction maxima or halos, somewhat like the diffraction rings produced by powdered crystals. These suggest that molecules are temporarily arranged in rows, layers, or stacks like bricks in a pile and that they have one, two, or even three different dimensions or spacings, corresponding, in accordance with **Bragg's law,** to the different angles of diffraction observed.

A closely related property is exhibited by certain substances known as "liquid crystals," which appear to be intermediate between merely cybotactic liquids and true crystals. In these there appear to be large groups of molecules which, though able to move and turn about, retain their structural arrangement. Such mesomorphic substances manifest even some of the optical properties of crystals, which the former type do not. (L.D.W.)

CYCADLES. Paleobotany.

CYCADOFILICALES. Paleobotany.

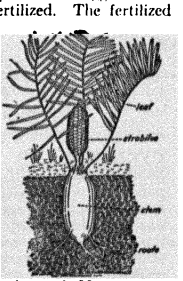
CYCADS. A group of **Gymnosperms** containing nine genera and less than a hundred species. They first appeared in late **Paleozoic** times, became a dominant group almost cosmopolitan in distribution in the **Mesozoic** period. Cycads are now limited to tropical or subtropical regions, often with a very restricted range. Some of the genera are found only in the New World, in Mexico and the West Indies; others occur only in the Old World, in Australia, Africa and various Islands of the Pacific Ocean. Because of their decorative habit they are frequently grown in cultivation in places outside their natural range. Many are grown as greenhouse plants in temperate regions.

A cycad, *Dioon edule.* (After Chamberlain.)

The appearance of the plants is quite uniform in all genera. The stem is either columnar and rarely branched or underground, and much enlarged. Columnar stems are usually from six to ten feet tall, but some species grow much higher. These stems are generally thickly clothed in the persistent leaf-bases, which sometimes give an indication of the age of the plants. As determined by the number of leaf bases many are several hundred years old. Internally the stem contains a very large pith and a thick **cortex** with a narrow cylinder of wood between them. The leaves form a large crown at the top of the stem. They are pinnate except in one Australian genus, *Bowenia,* which has bipinnate leaves which are thick and leathery. The primary root is large and extends deep into the ground.

All Cycads are **dioecious** plants. The ovulate cones are usually very large. The different genera have cones which show a very distinct series, ranging from those of *Cycas revoluta* with loosely arranged leaf-like **sporophylls** to the compact cones of Zamia. The large **ovules,** or megasporangia, are covered by a single thick integument. The male cones are much smaller and always formed of compactly massed sporophylls, each of which bears many sporangia, or pollen sacs. The pollen grains are very numerous and light. Pollination is effected by wind, though insects are frequently seen on the male cones, and may play some part in the pollen transfer.

The pollen grains are caught in a sticky fluid, which covers the micropyle of the ovule. As this sticky substance dries, it shrinks, drawing the pollen grains down through the micropyle. Each pollen grain then puts out a pollen tube which digests its way through the mass of nuceller tissue which surrounds the **gametophyte,** and reaches a small chamber which is formed at the micropylar end of the gametophyte and the **nucellus.** Meanwhile two sperm cells have been forming in the pollen tube. Each is very large and has a spiral band of cilia wound about its anterior end. Freed from the pollen tube, these sperm pass to the gametophyte, where union with the egg occurs. Sperm and egg nucleus presently unite, and the egg is fertilized. The fertilized egg divides to form a mass of cells which is known as the proembryo. At the base of this proembryo is a group of cells which becomes the true **embryo.** The embryo is pushed down into the tissue of the gametophyte by the elongation of a group of cells known as the suspensor. The mature seed of a Cycad has an outer fleshy coat which is variously colored. Inside this there is a hard stony layer which in turn surrounds another layer which is fleshy at first but soon becomes thin and dry. Within is the gametophyte which contains the embryo. Cycad seeds germinate as soon as they are mature.



A cycad. Mature sporophyte of *Zamia* bearing a carpellate strobilus. (From Smith, Overton, Gilbert, Dennis ton, Bryan and Allen, *Textbook of General Botany.* Macmillan Co.)

Apart from their value as decorative plants or as curiosities, few products of importance are obtained from the Cycads. Their leathery leaves remain green for some time after removal from the plant. They are therefore often used on Palm Sunday and for funeral purposes. The seeds of many of them are edible, as is also the central portion of the stem of *Cycas* species. Cycads are sometimes confused with palms.

Cycads probably originated in very early times from some primitive ferns. Even today certain cycads closely resemble ferns. Cycads are "living fossils" which continue to exist in a very restricted range. (See **Paleobotany.**) (R.M.W.)

CYCLE. A series of changes executed in orderly sequence, by means of which a mechanism, a working substance, or a system is caused periodically to return to the same initial condition, constitutes a cycle Many complicated machines or assemblages of machines work in definite cycles An important form of cycle is the heat engine cycle, in which a series of thermodynamic changes in a working medium periodically return the system to the same themodynamic level This working medium may be a gas, as in the **Otto** and **Diesel** cycles, or a vapor, as in the steam cycle See also **Carnot cycle,** for an example of a general ideal cycle A vapor cycle is so named from the fact that it is conceived as using the same vapor over and over, passing it around what might be thought of as a closed loop of equipment, and subjecting it to various thermodynamic changes by means of which useful mechanical energy is produced from heat The distinction between vapor and engine cycle should be recognized An engine cycle considers only the changes occurring within an engine, but a vapor cycle involves, in addition, all changes in the vapor state from the point of leaving the engine until it is again ready to enter it See **Rankine Cycle, Regenerative Cycle, Reheat Cycle.** (F T M)

CYCLE OF EROSION. The work of rivers and streams is erosional, transportational and depositional.

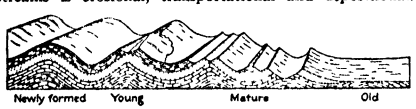
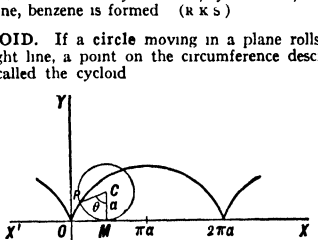


Diagram to illustrate successive stages in the normal cycle of erosion in a region of folded rocks (After G H Ashley)

The erosional work of rivers and streams sculptures the surface of the earth into a variety of forms So long as the land surface remains above sea level it is subject to such agents of denudation as wind, rivers and glaciers The principle agent of denudation is running water (rivers and streams) The river **erosion** pattern of any region will depend upon 1, climate, 2, relative hardness and solubility of the formations, 3, structure, 4, the degree to which the erosive process has completed its work, with or without interruptions caused by **diastrophism.** The stream pattern of a region is not only indicative of the structural control, but also of the stage in its erosional history (R M F)

CYCLOHEXANE. Cyclohexane, hexahydrobenzene, hexamethylene (C_6H_{12}) is a colorless liquid, boiling point 81° C Cyclohexane is formed by reaction of **benzene** and **hydrogen** in the presence of a **catalyzer,** finely divided nickel, heated Intermediate products of the hydrogenation are cyclohexadiene, dihydrobenzene, (C_6H_8) and cyclohevene, tetrahydrobenzene (C_6H_{10}) By regulated oxidation of cyclohexane, cyclohexene, or cyclohexadiene, benzene is formed (R K S)

CYCLOID. If a **circle** moving in a plane rolls along a straight line, a point on the circumference describes a curve called the cycloid



Cycloid

If the given line is the X-axis, and the origin is the point on this line at which the fixed point on the circle touches the X-axis, the **parametric equations** of the cycloid are

$$x = a(\theta - \sin\theta), \quad y = a(1 - \cos\theta),$$

where θ is the angle turned through by the radius of the circle and a is the radius of the circle The rectangular equation of the cycloid is

$$x = a\cos^{-1}\left(1 - \frac{y}{a}\right) \pm \sqrt{2ay - y^2},$$

which is not ordinarily convenient for use

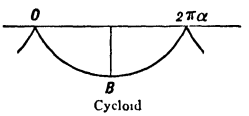
The area of one arch of the cycloid is $3\pi a^2$ and the length of one arch of the cycloid is $8a$, where a is the radius of the rolling circle

The teeth of gears are often cut with faces which are arcs of cycloids, so that there is rolling contact when the gears are in mesh

The inverted arch of a cycloid has the following two mechanical properties

(1) If two particles sliding without friction start from any two points of the curve at the same time, they will reach the lowest point at the same instant

(2) A particle sliding without friction will travel from O to B in less time than along any other curve connecting O and B Hence, the cycloid is sometimes called the curve of quickest descent (L L S)



Cycloid

CYCLONE. **Winds.**

CYCLOPROPANE. **Anaesthesia;** and **Hydrocarbons.**

CYCLOSTOMATA. The round-mouthed **eels, hag fishes** and **lampreys.** A class of the phylum **chordata** made up of marine and fresh water species resembling slender fishes in form but without hinged jaws

The principal characters of the class are 1 The **notochord** is persistent 2 Cartilaginous neural arches indicate the development of a vertebral column 3 There are no paired fins 4 The mouth is a funnel shaped depression with chitinous (See **Chitin**) teeth 5 External gill openings are separate

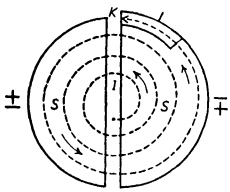
The two principal subdivisions of the class are listed both as subclasses and as orders in modern classifications

Subclass Myxinoidea (Hyperotreta) The **hag fishes.** Marine species with a poorly developed oral depression Gill openings far behind head

Subclass Petromyzontia (Hyperoartia) **Lampreys.** Marine and fresh water species with a well developed oral funnel Gill openings immediately behind head (A W L)

CYCLOTRON. This name has been given to the magnetic resonance accelerator, a device developed in 1931 by Lawrence and Livingston for imparting very great velocities to electrified particles without the necessity of excessive voltages The particles (such as protons or helium nuclei) are released in the region between two large, flat, hollow, semicircular segments S, S, of thin metal placed with their diametric edges closely parallel, as if one had cut a pill-box in two along a diameter and slightly separated the halves (See figure) These segments are given a high-frequency alternating potential difference, producing a rapidly oscillating field in the interspace I between them, and thus causing a free particle to be pulled first one way and then the other. A strong, uniform magnetic field is applied perpendicular to the plane of the segments The result is that, as a particle darts into one of the segments, it follows a semicircular path of radius proportional to the speed (as in a **mass spectrograph**) and re-enters the interspace on the

other side of the center The time required for this semicircular journey depends only upon the intensity of the magnetic field, and does not change with the velocity of the particle and the radius of its path Now if the field is adjusted so that this time equals one-half of the electric oscillation period, the particle will always emerge into an electric field so directed as to pull it along its own path, and in this way its speed increases at each crossing of the interspace Thus, starting near the center, the particle spirals outward with speed increasing each half-turn, until it finally escapes into a receptacle K near the outer edge The apparatus must, of course, be in a vacuum



Diagrammatic plan of cyclotron Ions released in interspace I, traverse hollow sectors S in semicircles, and are finally utilized or allowed to escape at K

The first cyclotron imparted over 1,200,000 **electron-volts** of energy to protons with an applied voltage of only 4000 volts, more recent installations have produced 5,000,000 electron-volts Such fast-moving particles are of great value in nuclear research, being used to bombard the atoms of substances placed in the receptacle K (L D W)

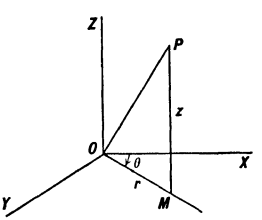
CYDIPPIDA. An order of **Ctenophora.**

CYGNUS. (The swan) (Map, page 306) Cygnus is one of the most striking and interesting **constellations** of the northern sky It represents a swan flying with outstretched wings and legs trailing out behind It is also frequently referred to as the northern cross Lying, as it does, in one of the most impressive portions of the northern **milky way,** the constellation contains many interesting objects The brightest star (alpha Cygni) known as Deneb, is one of the most distant of all of the bright stars, its intrinsic brightness being about 1000 times that of the sun Beta Cygni is one of the most striking of all of the **double stars** both components being bright, one blue and the other orange, and easily separated by a small telescope No physical connection has been determined between the components and it probably is not a true **binary.** Another interesting member of this constellation is the relatively faint star, marked 61 on large star maps This is the first star whose distance was measured in 1838 by the astronomer Bessel Bessel's determination of the **stellar parallax** of this object opened a field of astronomic research which has done much to solve many of the problems of general cosmogony (W K G)

CYLINDER A cylindrical surface is a **surface** generated by a straight line which moves parallel to itself and intersects a given **curve.** A cylinder is a solid bounded by a cylindrical surface and two parallel planes which cut all the elements of the surface The volume of a cylinder is equal to the area of its base times its altitude, for a right circular cylinder of altitude h and radius of base r, the volume is $V = \pi r^2 h$ The lateral area of a cylinder is equal to the perimeter of a right section times its lateral edge, for a right circular cylinder of altitude h and radius of base r, the lateral area is $A = 2\pi rh$ The **locus of an equation in rectangular coordinates** of higher degree than the first in which one variable is lacking is a cylindrical surface whose elements are parallel to the axis along which that variable is measured

Because it is comparatively easy to form, by usual means of manufacture, and because its shape is very well adapted to the resisting of internal bursting pressure, the cylinder is a very common engineering shape While, of course, anything of cylindrical shape might truly be called a cylinder, it is customary to apply the term to that part which, in conjunction with a closely fitting internal **piston** will provide an enclosed space the volume of which may be varied by motion of the piston Expansion of volume of a working medium is the basis of all of our commercially employed power cycles, and the cylinder and piston have an important place in this field Engine-type prime movers are characterized by cylinders and pistons, and the widespread employment of the **internal combustion engine** for personal transportation in the United States has made the cylinder a part familiar to many persons The cylinder of an internal combustion engine or an air compressor needs to be cooled while the machine is in operation in order to keep the interior wall temperature low enough so that a lubricating oil film may be maintained between the piston and the cylinder Air cooling and water cooling are resorted to for this purpose, the former for finned, the latter for jacketed, cylinders Water **pumps** and steam **engines,** by the nature and temperature of the working substance enclosed in their cylinders, do not need to be cooled The cylinder should be made of some hard metal having good wearing characteristics and be machined and honed to a bright finish and exact size Nickel, cast iron, and steel have been extensively used for internal combustion engine cylinders Cylinders may be made of brass, bronze, or other special materials when the working medium is corrosive to iron or steel (L L S, F T M)

CYLINDRICAL COORDINATES. The cylindrical coordinates of a point in space are three numbers which determine the position of the point, they are useful in mathematical problems dealing with cylinders and cones



Cylindrical coordinates

Let P be any point in space, and referred to a system of **rectangular coordinate** axes Let M be the **projection** of P on the XY-plane, let $r = OM$ $\theta = \angle XOM$ be **polar coordinates** of point M in the XY-plane, and let $z = MP$ be the third rectangular coordinate of P

The cylindrical coordinates of point P are the three numbers r, θ, z

The relation between rectangular and cylindrical coordinates of a point in space are given by

$$x = r\cos\theta,\ y = r\sin\theta,\ z = z$$

(L L S)

CYLINDRICAL HARMONICS. **Bessel Functions.**

CYME. **Flower.**

CYMOPHANE. **Chrysoberyl.**

CYPRESS. **Conifers.**

CYST. 1 A capsule containing foreign material or retained secretions of the body For example, a blood cyst is filled with blood An echinococcus cyst is one occurring from infection with the parasite, *Taenia Echinococcus* An implantation cyst developed from a section of skin which has become enfolded or planted in deeper structures A sebaceous cyst is formed by the retention of the products of a plugged sebaceous gland 2 The resting form of an organism in a protective covering 3 The vesicular portion of the bladderworm stage of a **tapeworm.** (R S M, A W L)

CYSTICERCOID. A small **bladder worm** in which the scolex fills the interior. (A W L)

CYSTICERCUS. Bladder worm.

CYSTINE. Aldehydes, Ketones, and Related Compounds.

CYSTITIS. An infection, chronic or acute, of the urinary **bladder.** It is marked by burning, painful and frequent urination, and is often accompanied by such other constitutional symptoms as are found in any infection. (R S M.)

CYTOGENIC GLAND. An organ which produces and discharges **cells,** such as the reproductive glands. (A W.L.)

CYSTOIDS (Cystids). Invertebrate Paleontology.

CYTOPLASM. Cell.

CYSTOSCOPY. Examination of the inner surface of the urinary **bladder** by means of a cystoscope:—An instrument which is passed through the **urethra** where, by use of lights and lenses, a view of the inner bladder wall may be obtained (R S M.)

CYTOSOME. Cell.

D

DAB. Pisces, Teleostei. *Limanda.* British and American flat fishes (**Pisces**) of several species. Edible (A.W.L.)

DABCHICK. Aves, Colymbiformes. The little **grebe,** *Podicipes fluviatilis,* an aquatic bird of the Old World, and the pied-billed grebe, *Podilymbus podiceps* of the New World. (A.W.L.)

DACE. Pisces, Teleostei. Various fishes (**Pisces**) of the family Cyprinidae, which contains also the **minnows** and **carps.** Among the North American species are a minnow called the red-bellied dace (*Chrosomus erythrogaster*), the common **shiner, redfin,** or dace (*Luxilus cornutus*), and two other small fishes, the long nosed dace (*Rhinichthys cataractae*) and the black nosed dace (*R. atronasus*). (A.W.L.)

DACITE. The name of a somewhat variable group of extrusive **igneous** rocks similar to the **rhyolites** but richer in **plagioclase feldspar.** Typical dacites are **felsitic** to **porphyritic** in texture Dacites are the extrusive equivalents of the quartz-rich varieties of diorites and are sometimes classified as quartz-bearing **andesites.** The porphyritic types usually occur toward the center of the thicker dacite flows, **dikes** and **sills,** as well as the marginal zones of **laccoliths.** Dacites are common in the Cordilleran province of North, Central and South America. The term, dacite, was proposed by G Stache of Austria for lavas in the old Roman province of Dacia. (R M F.)

DACTYLOPODITE. **Biramous appendage.**

DACTYLOZOOID. A form of **polyp** found in colonial **Hydrozoa** which captures prey and brings it to the mouth. (A W L.)

DADDY LONGLEGS. **Arachnida.**

DAKIN'S SOLUTION. An antiseptic aqueous solution of **sodium** hypochlorite, modified with **sodium** bicarbonate, used in the irrigation of infected wounds The solution was introduced during the World War by Henry Dakin, a New York chemist. (R S M)

D'ALEMBERT'S PRINCIPLE. The principle, first pointed out by d'Alembert in 1742, that **Newton's** third law of action and reaction holds for forces acting upon bodies entirely free to move as well as upon fixed bodies in **stationary** equilibrium In the former case the "reactions" concerned are due solely to inertia. Thus, in the act of throwing a **ball,** one pushes upon the ball with a certain force, and the inertia of the ball causes it to **push back** on the hand with an equal force The condition of the system during such a process is said to be one of **kinetic equilibrium** From this point of view, obviously, any system of bodies must always be in equilibrium, either kinetic or static (L.D W.)

DALTON'S LAW. The well known law of partial pressures in mixed gases and vapors If several gases not reacting chemically upon each other are introduced into the same container, the pressure of the resulting mixture is equal to the sum of the pressures which would be observed if each gas were separately enclosed in that container. We may, for example, regard the **atmospheric** pressure as the sum of a nitrogen pressure, an oxygen pressure an argon pressure, a carbon dioxide pressure, a water vapor pressure, etc. The same principle holds for mixtures of the saturated vapors of two or more liquids evaporating in the same closed space, provided one liquid does not dissolve the vapor from the other (as water dissolves ammonia). Like other gas laws, this law is approximately valid only within limits. (L D.W.)

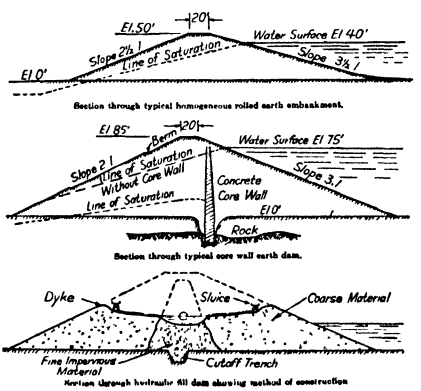
DAM. The primary function of the dam is to fill the gap in the natural reservoir line left by the stream channel. The most desirable sites are usually those where this gap becomes a minimum for the required storage capacity Topographical and geological conditions at the site may be expected, in most cases, to dictate the choice of the type of dam The best economic arrangement is often a composite structure such as a masonry dam flanked by earth embankments The dam further serves to divert the water to the intake works.

Dams may be classified as follows:

1. Timber dams.
2. Rock-fill dams.
3. Earth dams.
   - Plain.
   - Core wall
   - Hydraulic fill.
4. Masonry dams.
   - Gravity, solid and hollow.
   - Arch, single and multiple.

Timber dams —The timber dam is rarely used because of its short life and the limitation in height to which it may be carried It is conceivable that in a location where timber is plentiful and cement costly and difficult to transport, and where only a submerged diversion dam is contemplated, the timber dam would be the most economical to construct, even taking due account of its lack of permanence

Rock-fill dams —The rock-fill dam is an embankment of loose rock with either a water-tight upstream face of concrete slabs or timber, or a water-tight core Where suitable rock is at hand in plentiful amount, a minimum of transportation of materials can be realized with this type of dam Like the earth embankment, it resists damage from earthquake shock very effectively.



Earth dams.

Earth dams.—The earth dam is constructed as (a) a simple homogeneous embankment of well-compacted earth, (b) the same, but with a water-tight core or an upstream face pavement, (c) a **hydraulic fill** in which hydraulic segregation is relied upon to produce a water-tight core.

Masonry dams.—Masonry dams are of either the gravity or arch type. Stability is secured in the gravity dam by making it of such a shape and size that it will resist overturning, sliding and crushing at the toe. In the arch dam stability is obtained by a combination of arch and gravity action. If the upstream face is vertical the entire weight of the dam must be carried to the foundation by gravity while the distribution of the normal **hydrostatic** pressure between vertical cantilever and arch action will depend upon the stiffness of the dam in a vertical and horizontal direction. When the upstream face is sloped the distribution is more complicated. The normal component of the weight of the arch ring may be taken by arch action while the normal hydrostatic pressure will be distributed as explained above. Hence, for the gravity type, good impervious foundations are essential, but, for the arch type, firm, reliable support at the abutments (either buttress or canyon side wall) is more important. The most desirable site for an arch dam is a narrow canyon with steep side walls of sound rock. When situated on a suitable site, the gravity dam inspires more confidence in the layman than any other type. It has mass that lends an atmosphere of permanence, stability, and safety. When built upon a carefully explored foundation with stresses calculated from completely evaluated loads, the gravity dam probably represents the art of dam building at its highest point of development. This is an attribute of no mean significance because, due to flood disasters and their tremendous potentialities, fear of flood is a keenly developed human instinct. This factor has led to the adoption of the gravity section in some instances where an arch dam would have been the more economical construction.

(a) *The Solid Gravity Dam*

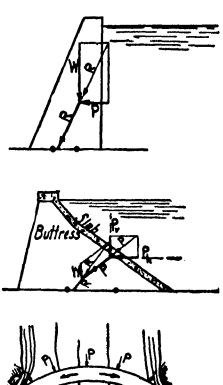
W is large enough, with respect to *P*, to incline *R* sufficiently to fall within the middle third.

(b) *The Hollow Gravity Dam*

The slab is inclined enough to produce a vertical water pressure P_v which inclines *P* sufficiently to overcome the effect of a small *W*, so that *R* falls within the middle third.

(c) *The Arch Dam*

Water pressure on the upstream face has the effect of shortening the dam, thereby creating resisting compressive stresses within the dam and tightening it against the abutments.



Comparison of stabilizing forces in dams.

Gravity dams are classified as *solid* or *hollow*. The solid type is the more widely used of the two, although the hollow dam is frequently the more economical to construct. Most forms of hollow dams have been patented by Ambursen and others. The gravity dams can also be classified as *overflow* and *non-overflow*. If the dam is to serve as a spillway section, its down-stream face is ordinarily made an ogee curve with the curvature such that there will be no tendency of the water to leave the surface of the concrete, even with maximum water elevation at the crest.

Two types of single arch dams are in use; namely, the constant angle and the constant radius dam. The constant radius type employs the same face radius at all elevations of the dam, which means that as the channel grows narrower, as at the bottom, the central angle subtended by the face of the dam becomes smaller. In a constant angle type of dam, this subtended angle is kept a constant and the variation in distance from abutment to abutment at various levels taken care of by varying the radii. The safety of an arch dam is dependent on the strength of the side wall abutments, hence the arch should not only be well seated on the side walls, but the character of the rock in bearing be carefully inspected to determine its ability to take the enormous thrust that will be set up as the water rises. The multiple arch dam consists of a number of single arch dams with concrete buttresses as the supporting abutments. The multiple arch dam does not require as many buttresses as the hollow gravity type, so is very economically constructed. It requires good rock foundation because the buttress loads are heavy. (F.T.M.)

DAMMAR. Resins.

DAMPING. This term usually refers to the checking of a motion due to friction or similar cause. It is of especial significance in connection with the diminishing amplitude of an oscillation, as that of a pendulum swinging in the air or that of the electricity vibrating in an oscillating circuit. Unless energy is supplied during each cycle, the amplitude of such a vibrator falls off at each successive oscillation by an amount commonly expressed in terms of the decrement or damping factor, which is the ratio of any one amplitude to that next succeeding it in the same sense or direction. In (so-called) logarithmic damping, this decrement is constant; in an oscillating electric circuit, its value is an exponential e^{δ}, in which δ, the logarithmic decrement, is a constant depending upon the effective resistance, inductance, and capacitance of the circuit. (See **Electric Oscillations and Waves.**)

An important instance of damping is found in the reading of an oscillating index, like a balance pointer, on a scale. If one may assume that the amplitude falls off by equal amounts at each swing ("linear" damping), in order to find the equilibrium position one has only to average an even number of readings at one extreme and an odd number at the other, and then find the mean of the two averages. (L.D.W.)

DAMPING OFF. This is a disease of plants, especially young seedlings, caused by species of a primitive **fungus,** *Pythium*. The fungus has a slender, branching, non-septate **mycelium** containing many minute nuclei. At the apex of a branch of this mycelium an **oögonium** is formed. This is a spherical body containing many nuclei. One of these nuclei stays at the center of the oögonium; the others migrate to the periphery. From the tip of another branch of the mycelium a multinucleate **antheridium** is formed. The antheridium grows to the surface of the oögonium, and develops a slender conjugation tube which penetrates the oögonial wall. Through this tube a nucleus enters the oögonium and fuses with the central nucleus of that body. The latter now becomes an **oöspore,** a thick-walled object which may remain for a long time without change. Eventually it puts out a germ tube, at the tip of which a **zoösporangium** forms. The protoplasm within the zoösporangium becomes multinucleate. This protoplasm then escapes from the zoösporangium, but is retained for some time within a thin membrane. In this membrane the protoplasm breaks up into minute kidney-shaped zoö-

spores, each of which has two laterally attached cilia. The zoospores escape from the sporangium and swim about actively for a time Each then encysts, that is, secretes about itself a thick wall After a time the encysted zoospore forms a short germ tube from which a single zoospore escapes and swims about This process of encysting and emerging as a zoospore may be repeated several times

In those species which can parasitize plants, a zoospore comes in contact with a root hair It passes into the **protoplast** of this root hair and then enters the cortical tissues of the root There it grows through the tissues, completely destroying them and quickly causing the death of the plant. Because of the extremely rapid growth of the parasite, once it enters the tissues of the host, the latter dies very suddenly, the top dropping over and collapsing Often whole flats of seedlings succumb in a very few hours after the fungus appears Adequate moisture is necessary for the fungus to grow, abundant moisture favors it greatly, and insufficient moisture retards it Control of this pest is therefore largely a matter of reducing the moisture available as much as possible (R M W)

DAMSEL FLY. Odonata.

DANBURITE. The mineral danburite, $CaB_2(SiO_4)_2$, **calcium boron silicate,** crystallizes in the **orthorhombic** system in prismatic forms somewhat resembling the mineral topaz Its fracture is subconchoidal, it is brittle, hardness, 7–7 2, specific gravity, 2 97–3 02, color, colorless, yellowish white, yellow, dark wine yellow and brownish yellow, luster, vitreous to greasy, translucent to transparent It is found at Danbury, Connecticut, from whence its name was derived, Saint Lawrence County, New York, Switzerland, Japan and Madagascar (E S C S)

DANDELION. *Taraxacum officinale* Composite Family.

DARLINGTONIA. Insectivorous plants.

DARTER. 1 Pisces, Teleostei Small fishes (**Pisces**) constituting the family Etheostomidae They have a small swim bladder or none, hence they rest on the bottom when not in active motion 2 Aves, Pelecaniformes *Anhinga* Long necked diving birds (**Aves**) with long sharp beaks, found in all continents Also known as snake birds, anhingas and snake necks, and certain species as the wryneck and water turkey They resemble the cormorants (A W L)

DART SAC. A structure associated with the female genital duct of **snails.** It secretes a calcareous dart which is shot by muscular contraction into the body of another snail when the two approach each other prior to mating (A W L)

DASH-POT. The dash-pot is a device for effecting a quick, jerking, mechanical motion In its usual form it consists of a **cylinder** with a closely fitting piston As there are no inlet ports on the cylinder, motion of the piston increasing the volume creates a **vacuum** in the cylinder This vacuum, amounting to from 10 to 13 pounds pull on every square inch on the piston, will, in the case of a large piston, produce a pull on the piston rod sufficient to overcome considerable resistance, and literally dash the piston back to the point from which the vacuum was started Although a spring could be considered potentially capable of performing the same service as a dash-pot, it is inferior for some jobs There is always a certain amount of resilience or springiness not possessed by the dash-pot, a tendency for fatigue of the metal, and of stiffness when used for large forces. (F T M)

DASYURE. Mammalia, Marsupialia *Dasyurus* Arboreal pouched animals (**marsupialia**) of the Australian region They are long-tailed forms with short legs resembling the civets and are carnivorous The dasyure family includes also the thylacine or Tasmanian wolf, the Tasmanian devil, the phascologales, the pouched mouse, and the banded anteater All are carnivorous or insect-eating (A W L)

DATE. *Phoenix dactylifera* Palm.

DATE LINE. International Date Line.

DATOLITE. Datolite, **calcium boroxy silicate,** $Ca(BOH)SiO_4$, occurs in **monoclinic** crystals of varied habit, mostly short stout prisms, but often in highly modified forms Datolite reveals no cleavage, its fracture is conchoidal to uneven, it is brittle, hardness, 5–5 5, specific gravity, 2 9–3 0, luster, vitreous to dull, color, white to gray or may be greenish, yellowish, or brownish It has a white streak and is transparent to translucent usually, but has been observed opaque Datolite is a secondary mineral being found in veins and cavities associated with **zeolites** and **calcite,** particularly in the **basic igneous** rocks It has been found in the Harz Mountains, Germany, in the Trentino district, Italy, in Norway and Tasmania In the United States it has been found in the Triassic **traps** of the Connecticut River Valley in Massachusetts and Connecticut, and from similar rocks in New Jersey In Michigan Datolite has been found associated with the copper bearing rocks of Keweenaw County This mineral derives its name from the Greek word meaning to divide, in reference to the granular structures of some of the massive varieties (E S C S)

DAVISSON-GERMER EXPERIMENT. In 1927, Davisson and Germer conducted a research, the results of which furnished a remarkable confirmation of the basic postulate of **wave mechanics** De Broglie had suggested about 1925 that **electrons** have in some respects the characteristics of waves, and deduced, for the wave length equivalent to a moving electron, the expression $\lambda = h/mv$, in which m and v are the mass and speed of the electron and h is Planck's constant If the electron is moving, for example, with a speed corresponding to 65 **electron volts** of energy, the corresponding "de Broglie wave length" is 1 52 angstroms, which is in the x-ray range This led Davisson and Germer to try whether electrons might be reflected from crystals after the manner of x-rays They used a single crystal of nickel cut parallel to the (111) planes, and upon varying the electron speed at a fixed angle of incidence, they found not only a distinct "regular" reflection but also a series of diffraction maxima strikingly similar to those obtained with the same crystal for x-rays of varying wave length The differences observed were satisfactorily explained as due to the refraction of the nickel for the electron waves (L D W)

DAW. Jackdaw.

DAY. Time.

DEAD MEN'S FINGERS. Porifera A branching **sponge,** *Chalina arbuscula,* found off the Atlantic coast of the United States Its branches are rounded finger-like projections of white or light gray color (A W L)

DEAD RECKONING. If the **latitude** and **longitude** of a ship are known at some particular instant, the position of the ship may be deduced at any subsequent time if the **course** and **distance** the ship has sailed from the original position are both known The position determined in this manner was originally known as the deduced position and was entered in the ship's log book in a column headed by the abbreviation "ded" This abbreviation was so frequently pronounced as "dead" that the term dead reckoning has almost completely superseded the original term

When a ship leaves a port its latitude and longitude at a given instant are obtained by direct observation of some prominent shore landmark. This point is known as the point of departure. Let us assume for simplicity that the ship continues on a steady course with constant speed for a given length of time. The speed of the ship in **knots** multiplied by the elapsed time will give the distance traveled in **Nautical miles**. If this distance is not more than three hundred miles, the surface of the earth may be considered as a plane without introducing any error larger than those present in the determination of the course and distance. We now have the simplest of navigational problems to solve, which is known as **plane sailing**, and has given rise to the colloquial expression for any easy problem. In this problem we have a right triangle to solve. The hypothenuse of this triangle is the distance, one leg is the difference of latitude between departure and the point arrived in (frequently referred to as northing or southing) and the other leg is the **departure** (easting or westing). The course gives the angle between the hypothenuse and the difference of latitude leg and the triangle may be solved by plane trigonometry or by use of **traverse tables**.

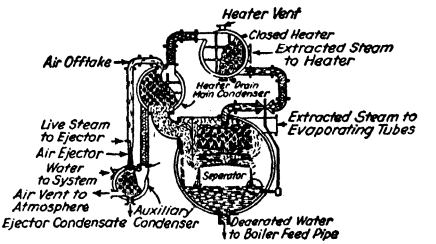
Since the nautical mile may be considered as equal to one minute of arc measured along a meridian, the north or south leg of the solved triangle may be applied directly to the latitude of the point of departure to give the latitude arrived in. The case of the easting or westing the distance is given in nautical miles measured along a small circle on the surface of the earth and must be reduced to the equator by dividing by the cosine of the mid-latitude between the point of departure and point arrived in. This use of the mid-latitude gives rise to the term **middle latitude sailing**. The equatorial distance, expressed as minutes of arc, may be applied directly to the longitude of the point of departure to obtain the final longitude.

Any time that the position of the ship is accurately determined by observation of celestial objects, or by bearings on some well-charted object, this position is taken as a new point of departure for dead reckoning until a new position is accurately determined.

In case a ship is frequently changing course, as in the case of a sailing vessel beating up to windward, the easting or westing, and northing or southing, must be determined for each tack. The addition of the quantities, will give the difference in latitude and departure to be used in working up the dead reckoning. Such a problem is known as **traverse sailing**.

The position of the ship as determined by dead reckoning may be in error due to such causes as bad steering, faulty allowance of current, improper logging of distance, etc. An accurate position can only be obtained by observations of celestial objects (c.f. **nautical astronomy**), or by use of **radio compass** stations. (W.K.G.)

DEAERATION. As water dissolves, to a greater or less extent, many common gases, in the natural state it will contain a certain amount of dissolved gases, such as oxygen and carbon dioxide. Deaeration is the removal of this dissolved gas. Deaeration at the present is practiced where the gas that water contains would have undesirable effects. Often dissolved oxygen is objectionable because of its corrosive action. This is true in the case of the high pressure steam boiler, where a small amount of oxygen dissolved in the feed water may become quite active in attacking the boiler metal under the high pressure and temperature conditions there experienced. Steam boiler operators often treat their boiler feed water in the deaerators to remove this oxygen. These deaerators are either of the de-activating or the heating type. Deactivating types employ chemical means of deaeration. A representative deactivating deaerator consists essentially of a tank containing large surfaces of scrap iron. When water containing dissolved oxygen is brought into contact with this iron, most of the **oxygen** combines with the **iron**, and is thereby removed from the water. Deaerating action in a heating-type deaerator is obtained by first reducing the solubility of the gas through heating the water (under pressure); second, reducing the pressure and producing explosive boiling; and third, controlling the agitation of the water subsequent to the second action in a partially evacuated region. The figure shows a heating-type deaerator. Water drawn from a supply line circulates through the tubes of the auxiliary and main condensers. It then flows under the heater where it is heated to the desired temperature. The heated water flows down into the separator, where it boils violently, giving off the dissolved gases. Vapor and gases are carried off through the condenser, in which the vapor is condensed for return to the deaerator. The gases are removed by an air pump. (F.T.M.)



Elliott type "J" deaerator.

DEATH. The termination of vital processes in the organism. The physiology of death has been studied extensively and various explanations have been offered of its causes without furnishing true understanding. It often occurs through accident, but under entirely normal conditions also it takes place after a lapse of a period characteristic of the species. Following maturity the metabolic processes of the individual become slower through senility until at last some vital part fails completely. Only animals that reproduce by binary fission, notably the one-celled species, are immune from normal death. In these forms the identity of the parent is merged with that of its offspring and death is always accidental. (A.W.L.)

DEATH WATCH. Insecta, Coleoptera. A small **beetle** of the family Anobiidae which burrows in solid wood in buildings. By striking its head against the walls of the burrow it produces a sharp sound which can be heard in quiet places. It has been supposed, superstitiously, to foretell death. (A.W.L.)

DEATH'S HEAD MOTH. Insecta, Lepidoptera. A large European **sphinx moth** whose **thorax** bears a light mark shaped like a skull. (A.W.L.)

DEBRIDEMENT. The treatment of wounds, especially traumatic dirty crushing wounds, by means of excising all injured, contaminated or devitalized tissue. (R.S.M.)

deBROGLIE WAVE. Davisson-Germer Experiment; Wave Mechanics.

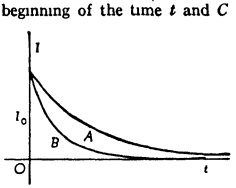
DECADE BRIDGE. Bridge.

DECALAGE. The wings of a biplane (See **Airplane**) are usually set parallel to each other. This is not absolutely necessary, and some designers have preferred characteristics obtained when the wings are set at a slight angle to each other. Decalage is the angle between the chords of the two wings of the biplane. It is rare for decalage to amount to more than two or three degrees. (F.T.M.)

DECAPODA. 1 The **shrimps and prawns, lobsters, crayfishes,** and **crabs,** constituting a large and important order of **crustaceans** The **thorax** is covered by a **carapace** and bears five pairs of appendages, the first pair chelate grasping structures and the remaining four formed for walking 2 The **cuttle-fish, squids** and related forms, constituting an order of **cephalopods** They possess ten arms, with stalked suckers provided with horny rims and have a well-developed internal shell (A W L)

DECARBURIZATION. During the **case hardening** process a hard surface is produced on steel by adding carbon to the surface layer of the part But then should the part be heated for some length of time to a temperature above the critical range, the skin will become decarburized and lose its case hardness. (P T M)

DECAY COEFFICIENT. Certain processes studied in physics progress at a rate diminishing in accordance with an **exponential** function of the time, such, for example, as phosphorescence and **radioactive** emission The falling off or "decay" of such a process may be represented by an equation giving the intensity at time t as $I = I_0 e^{-Ct}$, in which I_0 is the intensity at the beginning of the time t and C is the "decay coefficient" Closely related to C is the half-value period, which is the time required for I to fall to one-half its original value I_0, it is equal to $0.693\ 15/C$ Thus, if the half-value period of radium B is 1608 seconds, its decay coefficient C is



Typical exponential decay curves In B the decay coefficient is greater than in A

$$\frac{0.693\ 15}{1608 \text{ sec}} = 0.000431$$

reciprocal second This means that approximately 0.000431 of the substance existing at any instant disintegrates during the ensuing second The reciprocal of C, called the "decay modulus," represents the time required for I to diminish to $1/e$ or 0.3697 of its original value I_0 It is equal to 1.4427 times the half-value period, for the decay of radium B its value is therefore 2320 seconds (L D W)

DECIDUOUS PLANTS Plants which drop their leaves at the end of the growing season are called deciduous plants (R M W)

DECLINATION. The declination of a celestial object is the coordinate in the **equatorial** system of **spherical coordinates** measured in the plane of the **hour circle** through the object from the equator to the object In case the object is between the equator and the north celestial pole the declination is said to be north or positive (+), otherwise the declination is south or negative (—) Declination is ordinarily measured either with a **meridian circle** or an **altazimuth** instrument

The term declination is also used by navigators to refer to the **compass correction** due to the fact that the horizontal component of the magnetic field of the earth is not parallel to the true **meridian** (W K G)

DECOMPOSITION OF VECTORS INTO COMPONENTS Vector Addition.

DEDENDUM. Gear Teeth.

DEDIFFERENTIATION. A process of change from a more specialized to a less specialized condition (A W L)

DEER. Mammalia, Artiodactyla Hoofed animals which have solid bone antlers in the male or in both sexes. These antlers are shed each spring The deer constitute the family Cervidae

The typical deer are represented by the red deer of Europe, *Cervus elephas*, and the **elk** or wapiti, *C canadensis*, and Virginia or white-tailed deer of North America, *Odocoileus virginianus* The group also includes Asiatic species known as the shou and maral Asia is the home of many species of deer which fall into several groups known as the sambar group, the fallow deer group (*Dama*), the muntjacs (*Cervulus*), and the tufted deer (*Elephodus*) Several species not associated with these groups are also found in Asia, among them the chital or Indian spotted deer (*Axis axis*), the **reindeer** (*Rangifer*), and the Chinese water deer (*Hydropotes*)

The North American fauna includes the **caribou** (*Rangifer*), related to the reindeer, and the **moose** (*Alces americana*), which is related to the elk of Europe, in addition to the mule deer (*Odocoileus hemionus*) of the west and the Virginia deer (*O virginianus*) Mexico and Central and South America are the home of the brockets and guemals and of several other kinds of deer

Many species of deer are among the finest of game animals They have been hunted to extinction in some areas and have retreated readily before the advance of man, but through proper protection and management they are being maintained in many sections of the United States in satisfactory numbers The flesh is excellent (A W L)

DEER FLY. Insecta, Diptera Small **horse flies** with banded wings which are abundant in the eastern woods In the west the name is applied to **snipe flies** All species are annoying to man (A W L)

DEFICIENCY DISEASE Any disease due primarily to lack of a certain element, such as one of the **vitamins** Such diseases as **beri-beri, scurvy, pellagra,** alcoholic **neuritis, rickets,** etc (R S M)

DEFINITE INTEGRAL. Let $f(x)$ be a **continuous function** in an interval (a, b) Suppose this interval to be divided and redivided into parts in any manner such that as the process is continued the lengths of the parts all approach zero as a limit At any stage of the process let $\Delta x_1, \Delta x_2, \ldots, \Delta x_n$ denote the parts, and let z_1 denote any point in Δx_1, z_2 any point in $\Delta x_2, \ldots, z_n$ any point in Δx_n. Then form the sum of the products:

$$\sum_{i=1}^{n} f(z_i)\,\Delta x_i = f(z_1)\,\Delta x_1 + f(z_2)\,\Delta x_2 + \cdots + f(z_n)\,\Delta x_n.$$

As $n \to \infty$ and each $\Delta x_i \to 0$, this sum approaches a **limit,** which is independent of the mode of division of the interval (a,b) into parts Δx_i and the choice of the z_i in the sub-intervals Δx_i This limit is denoted by the symbol

$$\int_a^b f(x)dx,$$

and **is called** the definite integral of $f(x)$ between the **limits** a and b, a is called the lower limit and b the upper limit of the integral

The definite integral $\int_a^b f(x)dx$ **has the properties.**

(a) $\int_a^b f(x)dx = -\int_b^a f(x)dx,$

(b) $\int_a^b f(x)dx = \int_a^c f(x)dx + \int_c^b f(x)dx.$

If $\int_a^x f(x)dx = F(x)$, then $\frac{d}{dx}F(x) = f(x)$, so that $F(x)$ is an integral of $f(x)$

If $F(x)$ is any known integral **(indefinite integral)** of $f(x)$, then

$$\int_a^b f(x)dx = F(b) - F(a).$$

This is the fundamental formula for the evaluation of a definite integral in terms of the indefinite integral found by inverse **differentiation**

If the substitution $x = \phi(t)$ is made in the definite integral $\int_a^b f(x)dx$, we obtain

$$\int_a^b f(x)dx = \int_{t_1}^{t_2} f[\phi(t)]\phi'(t)dt,$$

where t_1 and t_2 are values of t such that $a = \phi(t_1)$, $b = \phi(t_2)$, and $\phi'(t)$ is the derivative of $\phi(t)$ with respect to t. (L L S)

DEFINITE PROPORTIONS, LAW OF. The proportions by weight of the different elements which make up a chemical compound are the same in every sample of this compound (See **Chemical Composition**) (R K S)

DEFLATION. In geology, deflation is the effect of the wind in transporting unconsolidated fine-grained **sediments** for considerable distances In 1895 dust fell in Missouri which must have come entirely from western Kansas and Nebraska, owing to the fact that the intervening country was covered with ice and snow Dust from the Sahara has been blown over Germany and England (transported by air 2000 miles) When the volcano Krakatoa exploded in 1883, the fine ashes were carried around the world several times by the currents of the upper air Some of the dust is said to have completed the circuit of the earth in fifteen days, causing a series of remarkable sunsets. (R M F)

DEFLECTION. In engineering there are two common uses of the term deflection—deflection under load and deflection angle in surveying

In general loads acting on an elastic structure cause a linear displacement of the several parts of the body, relative to their original position This is known as deflection Deflection is characteristic of all structures since all materials are elastic to a certain extent Figure 1 represents a beam which has been bent by the

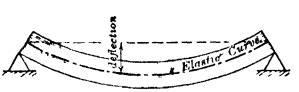


Figure 1 Deflection of a bent beam

action of an external load The deflections are the ordinates between the original and final positions of the **elastic curve** The amount of deflection depends upon the load, stiffness of the material and the dimensions of the beam The stresses cause the top fibers to compress and the bottom fibers to elongate Since Hooke's Law states that **stress** is proportional to **strain** (deformation) as long as the stress is below the **proportional limit**, the stress in the beam due to bending will be proportional to the deformation of the fibers The beam will come to rest or be in a state of equilibrium after the application of a load, when at every section the **moment** of the internal stresses equals the moment due to the external load

Deflection is an important element in the design of a load-carrying structure If strength is the limiting condition for which a beam is designed, the design should be tested for deflection to make certain that the displacements are within allowable limits Deflection rather than strength often governs the design This is especially true in the design of beams for buildings, where small deflections, only, are permissible, because of the tendency of the deflection of the beams to crack terrazzo floors, plastered ceilings, etc Solid rib and trussed bridges are also subject to deflection Large steel bridges and building trusses are always cambered (See **Camber**) to counteract the effect of deflections

The numerical value of the deflections of beams may be obtained by such methods as Double Integration, Conjugate Beam, Moment Areas and Work The deflections in rib and framed structures may be computed by methods of Work, Elastic Weights, etc The Williot-Mohr Diagram furnishes a graphical means for obtaining the deflection of trussed frames These methods are given in any standard structural textbook

In surveying, the angle between a line and the extension of the preceding line is called a deflection angle See Figure 2 When the survey is a closed **traverse** the sum of the deflection angles must equal 360 **degrees** **Circular curves** are frequently laid out by the method of deflection angles which is illustrated in Figure 3 Before it is possible to lay out points on the curve it

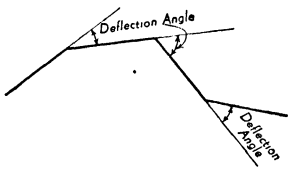


Figure 2 Deflection angle

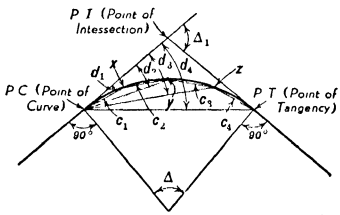


Figure 3 Layout of curve by deflection angles

is necessary to locate the P C, P I, and P T and obtain the central angle Δ which is numerically equal to the deflection angle Δ_1 Having the value of Δ_1, the deflection angles d_1 d_2, etc, may be calculated from the assumed **chord** lengths c_1 c_2, etc The **transit** is first set up over the P C and sighted on the P I The deflection angle d_1, which gives the direction of the line from P C to x, is then turned off by means of the transit The chord length c_1 is next measured on the ground by a steel tape (See **Chain**), which definitely fixes the positions of point x Point y may be located by turning off the deflection angle d_2, and measuring the chord c_2 from the point x Other points on the curve may be set in a similar manner From the geometry of the figure it can be seen that the deflection angle (d_4) to the P T is equal to one-half of the central angle (C W C, F T M)

DEFORMATION. The change in the shape of a body which accompanies a stressed condition is called deformation or strain The total amount of deformation in one direction is the total deformation Unit deformation is the deformation per unit of length Permanent deformation is known as set If an axial load is applied to a body, the length and lateral (cross-sectional) dimensions are changed **Poisson's** ratio is the ratio of lateral unit deformation to longitudinal unit deformation. (C W C)

DEGRADATION OF ENERGY. Available Energy.

DEGREE. The electrical degree is 1/360 of a cycle of alternating current representing an electrical revolution

The geometric degree most commonly used is the unit measured by the central **angle** subtended by 1/360 of the arc of a great circle This unit of angular meas-

urement has been extended to a great many practical uses, as, for example, the reading of compass bearings in degrees. A right angle contains 90 degrees; a minute is 1/60 of a degree, and a second is 1/60 of a minute.

The thermal degree represents molecular activity, in that temperature depends upon molecular velocity. Temperature is ordinarily measured by the expansibility of a gas or fluid. The unit of measurement is the degree of temperature. The two most commonly used scales are the Fahrenheit and Centigrade. In each, the difference in the positions indicated by the thermometer index, when subjected, first, to the temperature of melting ice, then to the temperature of boiling water, both under atmospheric pressure, is divided into a number of equal degrees. In the case of the Fahrenheit scale there are one hundred and eighty equal degrees, but for the Centigrade there are only one hundred. Thus a Centigrade degree is a larger unit than the Fahrenheit, the ratio being as nine to five. The melting temperature of ice is called zero on the Centigrade, and 32 degrees on the Fahrenheit scale, and the boiling point of water is 100 degrees on the Centigrade, and 212 degrees on the Fahrenheit scale. (F.T.M.)

DEGREES OF FREEDOM. This term has reference to the various ways in which a system may alter in respect to the configuration of its parts. For example, a system composed of three dimensionless particles has nine degrees of freedom; for it takes nine independent coordinates to specify the positions of the particles in space, and their arrangement may therefore be changed in nine different ways. A single rigid body, on the other hand, has six degrees of freedom, since it may have motions of translation in three coordinate directions and it may also rotate about any one of the three coordinate axes through its center of mass. Any actual motion of the body is in general made up of all six, its linear motion being the resultant of three linear components and its rotation the resultant of three angular components. Each molecule of a diatomic gas has seven degrees of freedom; viz., the six just mentioned for the molecule as a whole (regarded as a rigid body), and, in addition, one corresponding to the possible vibration of the two atoms toward and from each other. If the body is not rigid, the number of degrees of freedom may be virtually infinite. (L.D.W.)

DEGU. Mammalia, Rodentia. A small animal of Chile and Peru. It resembles the rat but has moderately long ears and a tufted tail. (A.W.L.)

DEHUMIDIFICATION. Removal of saturated vapor from a gas is known as dehumidification. Most dehumidification is concerned with the removal of water vapor from air. This may be done chemically by the exposure of air to a dehydrating chemical such as calcium chloride. This method is rarely practical unless small quantities of air are to be treated.

As air can contain only a definite amount of moisture when completely saturated at some particular temperature, and since the amount of this vapor held at saturation decreases with the temperature, air that is nearly saturated with water vapor may have its water content greatly reduced if its temperature can be reduced. Reduction of temperature may be accomplished through surface cooling by passing the air over cold radiators or through condensers, or cold water and air may be mixed together, as in the spray-type dehumidifier. (F.T.M.)

DEHYDROGENATION. Dehydrogenation is a chemical reaction involving removal of **hydrogen** from a compound. See **Reactions involving Oxidation-Reduction.** (R.K.S.)

DELIQUESCENCE AND WATER ABSORPTION. When a substance absorbs moisture upon exposure to the **atmosphere**, the substance is said to be deliquescent, and the phenomenon is known as deliquescence. At ordinary temperatures the vapor pressure of water is as follows:

Temperature, °C.	Water Vapor Pressure, in Millimeters of Mercury	
	At Saturation	At 50% Humidity
0	4.6	2.3
10	9.2	4.6
20	17.5	8.8
30	31.8	15.9
40	55.3	27.7

If the solution in water of a substance has a lower water vapor pressure than corresponds to that of the atmosphere at the given temperature, water vapor condenses in the solution from the atmosphere until the water vapor pressure of the solution equals the water vapor pressure of the surrounding atmosphere.

Substances that are ordinarily deliquescent are **sulfuric acid** concentrated, **glycerol**, **calcium** chloride crystals, **sodium** hydroxide solid, **ethyl alcohol** 100%. In an enclosed space these substances deplete the water vapor present to a definite degree. Other substances are used to accomplish this end by chemical reaction, e.g., **phosphorus** pentoxide (forming phosphoric acid), **boron** trioxide (forming boric acid).

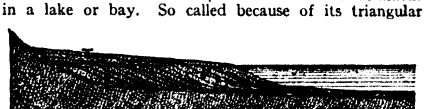
Water is absorbed from non-miscible liquids by addition of such substances as anhydrous **sodium** sulfate, **potassium** carbonate, anhydrous **calcium** chloride, solid **sodium** hydroxide.

See **Efflorescence** for the converse phenomenon. (R.K.S.)

DELIRIUM. A mental disturbance characterized by **illusions**, **hallucinations**, incoherent rambling speech, excitement and usually extreme restlessness. It occurs with high fever, especially in children, or with the **toxemia** of any severe illness. It is often present in various forms of insanity and also may result from drugs or abuse of alcohol. **Delirium tremens** is a variety of acute insanity marked by delirium with restlessness and marked emotional excitement. It may occur in the chronic alcoholic following a temporary excess or sudden withdrawal of alcohol. Although the cause is chronic alcohol addiction (See **Ethyl Alcohol**), some unknown factor determines whether a patient will develop this form of acute alcoholic insanity. It is particularly liable to develop in the alcoholic in **pneumonia**, in **erysipelas** or following trauma. In uncomplicated delirium tremens the mortality is about 15%. Following trauma, the mortality is 40–50%. (R.S.M.)

DELIRIUM TREMENS. Delirium.

DELTA. The terminal deposit of river-borne sediment in a lake or bay. So called because of its triangular

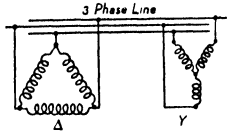


Ideal structure section of a delta. T, top-set beds; B, bottom-set beds; F, fore-set beds. (Modified after G. K. Gilbert.)

or delta-like ground plan. The cross-section or structure of a typical delta is shown in the accompanying sketch. Except in the case of small deltas only the top-set beds can be observed. In the case of **Paleozoic**, **Mesozoic**, and **Cenozoic** deltas it is extremely difficult to distinguish between the top-set, fore-set, and bottom-set beds, and the ultimate determination that a **sedimentary** formation is of delta origin depends largely on

tracing the original source and areal distribution of the sediments, and the presence or absence of marine and terrestrial fossils (R M F)

DELTA CONNECTION The Delta connection is one of the two most frequently used ways of connecting a polyphase **alternating current circuit.** The other is the Y connection A three-phase alternator or transformer has three coils These coils have six ends which must, in some way, be connected to the three wires of a three-phase circuit The Delta connection, as illustrated in the accompanying figure, has the coils connected at three points corresponding to the three-phase circuit When this is compared with the Y connection, it will become apparent that the line voltage in Delta connection equals the coil voltage, and that the line current in Y connections equals coil current. (F T M)



Δ connection and Y-connection compared

DELTA RAYS. When various substances are bombarded with **alpha rays,** they are found to give off **electrons,** which sometimes move with great speed, and to which Sir J J Thomson has given the name delta rays The delta electrons are thought to originate in a type of **ionization** of the bombarded substance, though by some it has been held that they are really thermions given off as the result of the very brief and very intense local heating of the body when the alpha particle strikes it The rays appear to be emitted mostly in directions at right angles to that of the alpha-ray beam Delta particles are themselves capable of causing ionization, as shown by the cloud tracks produced when alpha particles traverse a gas in a **cloud chamber** (L.D.W.)

DELUSION. **Hallucination.**

DEMAND. In the nomenclature of economics, demand is the number of units of a commodity which will be purchased at a given price It is the correlation of desire for the article, and ability to purchase it

In a narrower technical sense, demand is that number of commodity units a source of supply is caused to produce, manufacture, or otherwise create The maximum demand is an important index, especially in an industry unable to warehouse its product, and which, therefore, is required to have manufacturing capacity at least equal to the maximum demand (F T M)

DEMAND FACTOR. With reference to the electric service industry, demand factor is the ratio of a customer's maximum demand to his connected load, i e., to the sum of the full-load ratings of all the electrical equipment he has connected to the supply line. (F.T M)

DEMANTOID. **Garnet.**

DEMENTIA. A form of insanity marked by loss or diminution of willpower, memory and intellect The forms of dementia are manifold As a rule it is incurable A common form of dementia is that which occurs with old age called senile dementia Toxic dementia occurs with severe prolonged illness and also after the use of certain drugs This form is usually curable Other common forms of dementia occur in **syphilis** of the central nervous system, **epilepsy, paranoia,** and **dementia praecox.** (R S M)

DEMENTIA PRAECOX. **Schizophrenia.**

DE MOIVRE'S THEOREM. DeMoivre's theorem is a rather remarkable mathematical result discovered by the French mathematician Abraham DeMoivre (1667–1754)

DeMoivre's theorem gives any power of a **complex number** in polar form:

$$[r(\cos\theta + i\sin\theta)]^n = r^n(\cos n\theta + i\sin n\theta).$$

This formula holds when n is a positive or a negative integer It also holds when n is fractional, but may then be written in the more general form

$$[r(\cos\theta + i\sin\theta)]^{1/n} = r^{1/n}\left[\cos\frac{\theta + k\,360^\circ}{n} + i\sin\frac{\theta + k\,360^\circ}{n}\right],$$

where k takes the values of 0, 1, 2, . . , n—1 and where $r^{1/n}$ denotes the principal n^{th} root of r This formula gives the n, n^{th} roots of any number. (L L S.)

DEMOSPONGIAE. A class of **sponges** (Porifera) of complex structure, including the sponges of commerce and the fresh water sponges

The members of this class have siliceous spicules which are never six-rayed, a spongin skeleton, or a combination of spongin and siliceous matter Some species have no skeleton The body plan is of the **rhagon** type.

Three orders are recognized·

Order Myxospongida Simple sponges without skeletal structures

Order Tetraxonida Skeleton siliceous (See **Silicon**), sometimes with spongin Fresh water sponges are included in this order with many marine forms

Order Keratosa Skeleton of spongin fibers **Spicules** absent Commercial sponges belong here (A W L)

DENDRITE. **Neuron.**

DENDROCHIROTA **Holothuroidea.**

DENEBOLA Denebola (β Leonis) received its name because of its position in the **constellation** of Leo, the name Denebola being derived from an abbreviation of an Arabic phrase meaning "tail of the lion" In astrology Denebola is one of the unfortunate stars, portending misfortune and disgrace. (W K G)

DENGUE. "Breakbone Fever" or "Dandy Fever" An acute fever due to a filterable **virus** which is present throughout the circulation during the stage when fever is present It is common in many tropical countries, and sudden outbreaks or epidemics occur in subtropical or even temperate climates Several years ago there was a serious outbreak in the southern states, particularly in Florida In 1928 there were very widespread outbreaks in Greece and Egypt

Dengue is transmitted by mosquitoes of the species *Aedes Aegypti,* which have become infected by biting a dengue patient during the first 48 hours of his fever. Twelve days are required for the mosquito to be able to transmit the disease to another human, who in turn becomes ill four to ten days later **Yellow fever** is transmitted by the same mosquito, and since both diseases are often prevalent in the same locality, some have speculated that similar organisms are responsible for the two diseases However, in certain regions of the eastern hemisphere, dengue is common where yellow fever is unknown

The disease lasts seven to eight days It is characterized by the sudden onset of an acute fever with chill, severe headache and marked pain in the muscles and joints A skin eruption usually appears on the third day, the symptoms rapidly disappear and the patient seems well on the road to recovery However, 48 hours later the symptoms reappear and last for 36 or more hours Convalescence is protracted due to mental and physical weakness Complications are rare, and the disease seldom causes death There is no specific treatment It can, however, be prevented by anti-mosquito measures (R S M)

DENSITOMETER. An instrument for determining the blackening, or photographic density, of a developed photographic plate or film is known as a densitometer There is a great variety of types of densitometers, but the underlying principle of all of them is the same.

The intensity of the radiant energy from a source which is maintained as nearly constant as is possible, is compared by any of the methods of **photometry** with the intensity of the same radiation after it has passed through the portion of the photographic plate whose density is required The ratio of the intensity of the radiant energy after passing through the exposed plate to that from the source itself is known as the "transmission factor" of the exposed plate, and the common logarithm of the reciprocal of this is the plate density

$$\left(\text{density} = \log_{10} \frac{1}{\text{transmission factor}}\right).$$

The plate density is a complicated function of the intensity and quality of the **radiation** which produced the darkening of the plate

For the determination of the density of a very small area on a photographic plate, such as the image of a spectral line or a star, the instrument employed is usually referred to as a "microdensitometer" In such instruments the physical type of photometer, e g , one employing a **photoelectric cell** or a **thermopile**, is frequently employed (W K G)

DENSITY AND SPECIFIC GRAVITY. The density of a substance is its mass per unit volume, usually expressed in grams per cubic centimeter The specific gravity of the substance is the ratio of its density to that of water, usually at 4° C , or 20° C , or 60° F , in the same units, and is therefore an abstract number independent of units

To determine the density of a given substance, it is necessary only to ascertain the volume of a specimen whose mass is known by weighing This may be obtained from measurements on the dimensions of the specimen, or, in the case of a liquid, by the use of a **pycnometer** or specific gravity bottle For solids a more precise method is to measure the buoyant force, upon the specimen, of a liquid of known density in which it is immersed, or by enclosing it in a specific gravity bottle and determining the volume by displacement The Mohr-Westphal balance is especially designed to give densities of liquids by the buoyant force on a solid sinker of known volume The **hydrometer** may also be used for quick determinations of liquid densities The density of a gas is best obtained by enclosing it in a large, light bulb of known capacity and weighing the same, concurrently observing the temperature and pressure to which the gas is subjected, much as the pycnometer is used for liquids

A brief table of densities, all in grams per cubic centimeter, is appended For gases the densities are at normal temperature and pressure

Substance	Density	Substance	Density
Air	0 001293	Gold	19 3
Alcohol	0 794	Hydrogen	0 0000899
Aluminum	2 70	Iron	7 86
Carbon dioxide	0 001977	Lead	11 3
Chlorine	0 003214	Mercury	13 55
Copper	8 90	Nitrogen	0 001251
Cork	0 24	Oxygen	0 001429
Gasoline	0 67	Platinum	21 45
Glass	2 4–2 8	Silver	10 5
Glycerine	1 27	Water (4° C)	0 999973
			(L D W)

DENTARY APPARATUS. Aristotle's lantern. Tooth.

DENTINE. Tooth.

DENTITION. The form and arrangement of the teeth in **vertebrates** Teeth are so intimately related to the food that they are involved in the fundamental adaptations of the animal In connection with the study of the many adaptations of teeth terms have been coined which apply in some cases either to the **tooth** itself or to the entire dentition, while others apply to the dentition in general.

The primitive form of tooth is apparently that of the **sharks**, which has a principal sharp flattened point and in some cases fairly prominent lateral points These teeth are arranged in several rows and are renewed as needed In other fishes and in the amphibians teeth are also developed in large numbers and in some forms occur elsewhere in the mouth than on the jaws They are named for the part of the skull with which they are associated, as the **vomerine** teeth

In the **reptiles** and **mammals** the simpler condition of a row of teeth along each jaw prevails The teeth may be entirely conical as in the reptiles or of various types, as in the mammals, and may be indefinitely renewable or limited to one or two sets Where teeth are of more than one kind the dentition is said to be heterodont The forms of teeth include the sharply conical canines, the sharp-edged cutting incisors, and the broad grinders, which include premolars and molars Renewal is unlimited in the reptiles but in the more highly specialized mammals only one or two sets appear normally Monophyodont dentition consists of one set and diphyodont includes a temporary set of milk teeth which is replaced by a set of permanent teeth, as in man

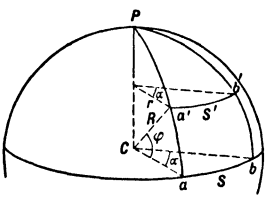
The numbers of teeth of different kinds are expressed in a dental formula as a distinctive characteristic of mammals In this formula the teeth of one-half of each jaw are listed in this order incisors, canines, premolars and molars, and those of the upper jaw are placed above those of the lower jaw Thus the dental formula of man is 2123/2123 and that of the woodchuck is 1023/1013 The zeros in the latter formula indicate the absence of canines

The position of the teeth in the jaw is also sometimes indicated by a special term When placed along the edge of the jawbone the dentition is said to be acrodont, and when placed along the inner margin, pleurodont. (A W L)

DENUDATION. Cycle of erosion.

DEPARTURE. Any **course** and distance covered by a ship may be resolved into two components at right angles to each other One of these components will be parallel to a **meridian** while the other will be along a parallel of **latitude** and is known by the term departure If the lengths of these components are expressed in **nautical miles** the component along the meridian may be immediately converted into difference of latitude because a minute of arc of latitude is practically equal to one nautical mile The component along the parallel of latitude, expressed in nautical miles and referred to as easting or westing, is known as the departure.

For the solution of various problems in **dead reckoning** and the **sailings** it becomes necessary to convert departure into difference of **longitude** The accompanying figure illustrates the problem In the figure we have S' a departure measured along the parallel of latitude φ between the meridians $Pa'a$ and $Pb'b$ The arc, S, of the **equator** represents the difference of longitude corresponding to the departure S'. Planes are passed through S' and S perpendicular to the axis of the earth, PC, and radii are drawn in these planes to include the angles subtended by S' and S Call R the radius of the earth and r the radius of the arc S' The angles subtended by S and S' must be equal and we have at once $S/R = S'/r$ By the definition of latitude (assuming



Departure

the earth as spherical) we have the plane angle $aCa' = \varphi$ and, from the definition of the trigonometric functions, $R/r = \sec \varphi$ Therefore we have $S/s' = R/r = \sec \varphi$, or $S = S' \sec \varphi$ Since S' is expressed in nautical miles, which are practically equivalent to a minute of arc on the equator, we have at once $S = S' \sec \varphi$ as the difference in longitude corresponding to the departure S', the difference in longitude being thus expressed in minutes of arc (W K G)

DEPENDENT SYSTEMS OF LINEAR ALGEBRAIC EQUATIONS Linear Algebraic Equations, Systems of.

DEPENDENT VARIABLE. Functions.

DEPRESSED EQUATION. Polynomial Equations.

DERIVATIVE OF A FUNCTION OF ONE VARIABLE. The rate of change of a function is expressed by the derivative of the function

Let $y = f(x)$ be a given **function** of one **variable** and let x_1 be a chosen value of x, and let Δx be an increment of x to be added to x_1, then Δy will denote the corresponding increment of y.

$$\Delta y = f(x_1 + \Delta x) - f(x_1).$$

Form the increment ratio $\Delta y/\Delta x$

$$\frac{\Delta y}{\Delta x} = \frac{f(x_1 + \Delta x) - f(x_1)}{\Delta x}.$$

Let $\Delta x \to 0$, then $\Delta y/\Delta x$ will usually approach a **limit** which is called the derivative of y with respect to x at the value $x = x_1$ Hence

The derivative of a function $f(x)$ is the limit approached by the ratio of the increment of $f(x)$ to the increment of x when the increment of x approaches the limit 0

The process of finding the derivative of a function $y = f(x)$ is called differentiation

The derivative of $y = f(x)$ with respect to x is denoted by various symbols, sometimes $D_x y$ is used, sometimes $\frac{dy}{dx}$, or $f'(x)$, or y'.

If $\lim_{\Delta x \to 0} (\Delta y/\Delta x)$ is formed at the point $x = x_1$, it is called the derivative at $x = x_1$, but if the limit is taken for the general point x, the result is sometimes called the derived function of $f(x)$

The rate of change of any function $f(x)$ with respect to the independent variable x is defined as the derivative $D_x y$ or dy/dx

Special interpretations of the derivative are

(1) As the **slope** of a curve If x and y represent rectangular coordinates of a variable point, and if a function $y = f(x)$ represents a curve, then the slope of the tangent to the curve at a point $x = x_1$ is represented by the value of the derivative of $f(x)$ at $x = x_1$

(2) As the speed of a moving particle If s denotes the distance traversed by a particle moving in a straight line in time t, then a function $s = f(t)$ represents the law of motion, and the derivative of $f(t)$ at $t = t_1$ represents the speed of the particle at the instant t_1

For a function $y = f(x)$, the ratio $\frac{dy}{dx}/y$ is called the relative rate of increase of y with respect to x, the product of this by 100 is sometimes called the percentage rate of increase

If $f'(x)$ is positive throughout an interval (a, b), then $f(x)$ continually increases as x increases from a to b If $f'(x)$ is negative throughout (a, b), then $f(x)$ continually decreases as x increases from a to b (L L S)

DERIVED CURVES. Higher Derivatives.

DERIVED FUNCTION. Derivative.

DERMAPTERA. The earwigs. An order of **insects** made up of species whose forewings, when present, are short leathery wing covers, and whose abdomen bears a pair of appendages like the jaws of a forceps at the tip The common name is based on the supposition that they enter the ears of human beings They are plant eating, insect eating, and probably in some species scavengers (A W L)

DERMATOLOGY. The science of the study, diagnosis, and treatment of the skin and its diseases A dermatologist is a doctor who specializes in diagnosis of diseases of the skin and their treatment (R S M)

DERMATOPHYTOSIS (Athlete's Foot). A contagious **fungus** infection most commonly seen on the foot, especially between the toes It is also seen in other parts of the body A widespread eruption may result due to absorption of the **toxins** of the fungus

The fungus is highly infectious for those that are susceptible to it It is spread by means of bathroom floors, swimming pools, Turkish baths, etc

Local applications are valuable in prevention and in milder cases In stubborn cases **x-ray** is necessary, followed by prevention of reinfection (R S M)

DERMATITIS. An irritation or inflammation of the skin due to infection, drugs—internal or external—heat, cold, x-rays, or radium It may also be seen in metabolic and deficiency states (R S M)

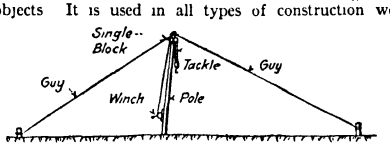
DERMESTID. Insecta, Coleoptera Any of the small **beetles** of the family Dermestidae, including the **buffalo carpet moth.** They damage clothing, woolen articles, and museum specimens (A W L)

DERMIS. 1 The corium or inner layer of the **skin** of vertebrates 2 The inner layer of the **cuticula** of insects (A W L)

DERMOLITH A term proposed by T A Jaggar in 1917 for ropy, wrinkled or **Pahoehoe** type of **basic** lava, such as occurs in the volcanic islands of Hawaii (R M F)

DERMOPTERA. An order of mammals containing only the **flying lemurs** of the Malayan region They differ from other mammals in dentition Like the flying squirrels, they have folds of skin along the sides which support them in the air Also called cobego, kaguan, and other names (A W L)

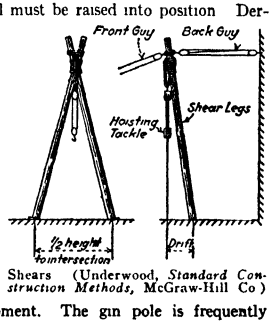
DERRICK. A derrick is a device for lifting heavy objects It is used in all types of construction work



Gin pole (Underwood *Standard Construction Methods*, McGraw-Hill Co)

when heavy material must be raised into position Derricks are used extensively in structural steel erection

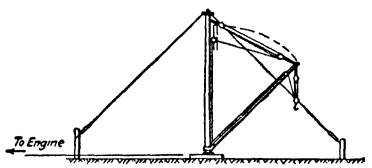
The simplest form of derrick is the gin pole which consists of a vertical or nearly vertical mast held in position by at least four twisted wire cables or ropes known as guys A pulley or some other form of hoisting tackle attached to the top of the mast completes the equipment. The gin pole is frequently



Shears (Underwood, *Standard Construction Methods*, McGraw-Hill Co)

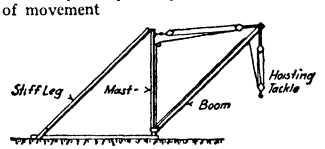
used in the erection of steel frames for small buildings when all of the members can be placed in position without moving the derrick, as a whole, vertically, to some point on the frame

The shears derrick is essentially a gin pole derrick which is constructed in such a manner that only two guys are necessary The "mast" is a v-shaped frame made of two poles which may, in some cases, be connected by transverse bracing Since this form gives it lateral stability only two guys are required This derrick is often used for the erection of heavy machinery which is lifted by means of hoisting tackles connected to the "mast" at the point of intersection of the poles



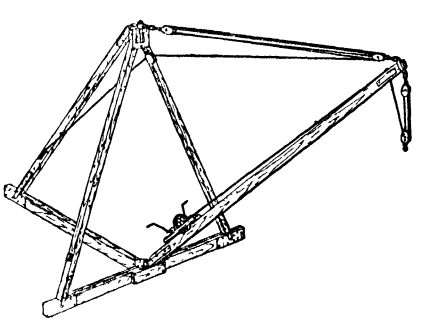
Engine operated guy derrick (Underwood, *Standard Construction Methods*, McGraw Hill Co)

The guy derrick is made up of a **boom** and a mast that are connected at the top by a **cable** which allows the boom to be raised or lowered The mast, which is longer than the boom, is held firmly in a vertical position by guys although the derrick, as a whole, may rotate through a horizontal angle of 360 **degrees** The load is applied to the boom by means of another cable which may be used to raise or lower the load without moving the boom in a vertical plane This type is used in the erection of large steel building frames since it can be readily set up at any floor level and has a large range of movement



Engine operated stiff leg derrick (Underwood, *Standard Construction Methods*, McGraw Hill Co)

The stiff leg derrick is similar to the guy derrick except that it does not require guy wires or ropes to support the mast and the boom has a horizontal swing of only about 240 degrees The mast is supported by struts set at right angles to each other The lifting action is the same as that for the guy derrick



A jinniwink—hand operated (Underwood, *Standard Construction Methods*, McGraw Hill Co)

The A-derrick or Jinniwink is a modification of the stiff leg derrick It is used for lifting comparatively light loads (C W C)

DESCARTES' RULE OF SIGNS. If in passing from one coefficient of a **polynomial equation** to the next, there is a change of sign from plus to minus or from minus to plus, this is called a variation of sign, a succession of two like signs, either both plus or both minus, is called a permanence of sign

Descartes' rule is The number of positive **roots** of a polynomial equation $P(x) = 0$ with real coefficients is not greater than the number of variations of sign in the polynomial $P(x)$, and the number of negative roots is not greater than the number of variations of sign in the polynomial $P(-x)$ (L L S)

DESMINE. Stilbite.

DESQUAMATION. The shedding of the superficial cells of the skin in scales or large pieces, a phenomenon which occurs in certain diseases, notably **scarlet fever.** (R S M)

DESTRUCTIVE DISTILLATION PRODUCTS. Coal, wood, bone, **petroleum** are the industrial raw materials most commonly subjected to the process of destructive distillation In this process the materials are heated to various degrees of temperature without access of air (pyrolysis) but with provision for recovery and collection of the products desired The reactions are complex due in large part to the complexity of composition of the material treated For the treatment of petroleum (See **Hydrocarbons**) The destructive distillation of coal, wood, bone and carboniferous shale will be discussed under the topics (1) Raw material, (2) Conditions of temperature and time of treatment, (3) Products

Coal, Destructive Distillation (1) Destructive distillation of coal is conducted primarily to produce coke or coal gas, and secondarily for coal tar, **benzene** and **toluene** from the coal gas and coal tar, and **ammonia** from the coal gas and water condensate Bituminous coals are found to be most suitable for this purpose These coals have a fuel value of 12,000 to 15,000 British thermal units (B T U) per pound, that is 24 to 30 million B T U per short ton (2,000 pounds) Reports of analyses made by the United States Bureau of Mines on samples of coking coal as received from 23 coal fields of the United States show

Moisture	1–10%
Volatile matter	25–38
Fixed carbon	71–47
Ash	2 5–9
Nitrogen	1 4–2
Sulfur	0 5–1 5

From such coals there would be obtainable

Furnace coke	60–80%	of the weight of coal
Coal gas	2700–3500	B T U per pound of coal
Surplus after heating retorts	1600–2100	B T U per pound of coal
Coal tar	6–12	gallons per ton of coal
Benzol	1 5–4	gallons per ton of coal
Nitrogen		
As ammonium sulfate	17–25	pounds per ton of coal
As sodium cyanide	1 8 (appr)	pounds per ton of coal

(2) Conditions Since coal and coke are poor conductors of heat, it is necessary that the thickness of the layer heated be such that the coking temperature, at the places in the charge that are most distant from the source of heat, shall be attained in an economical period of time In the history of the industry the horizontal depth of retort has been gradually diminished from 24 to 22 inches to 12 to 14 inches Since both of the

vertical side walls are heated to the desired high temperature, the heat must traverse from 12 to 11 inches (older types) to 6 to 7 inches (newer types) The thinner retorts result in a much shorter time—as short as 10 hours—for coking a charge A further result is that the coke near the heated walls is subjected to a high temperature for a shorter period of time than formerly The length of retort has been extended from 20 feet (older types) to 40 feet (newer types) The length is determined by mechanical considerations of removing the charge economically The height has been increased from 6 feet (older types) to 13 feet (newer types) The retorts are charged from the top, and discharged by pushing the coke out of one end by a pusher entering the other end

The heat is supplied by burning gas in flues between each retort, and batteries containing up to 90 retorts are in use In 1919 the United States Bureau of Standards reported tests made in Koppers retorts Temperature of 1225° C maximum to 1200° C minimum were observed in the heating flues and the operating temperature is close to these temperatures, in the center of the charge, and at distances of about 2 feet from the bottom and the top of the retort 1010° C and 980° C, respectively, in 10 5 hours—the coking time in retorts about 14 inches thick

The changes in composition of gas with time of heating of a given coal are reported by Bacon and Hamor (1922) from which the following is selected or calculated.

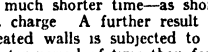
Hours Coal Carbonized	Methane	Hydrogen	Ethylene	Carbon Monoxide	Carbon Dioxide	Benzene	B t u per cu ft
2	36 7	42 5	4 0	0 9	3 3	1 8	605
4	34 5	48 8	3 1	2 9	2 3	1 1	570
6	33 6	50 1	2 8	3 0	2 2	1 0	560
8	33 7	51 8	2 5	3 4	1 4	0 6	560
10	31 2	47 1	1 8	2 8	2 3	0 4	480
12	33 4	50 7	1 9	4 2	1 5	0 4	525
15	33 2	53 4	1 8	3 9	1 9	0 3	525
19	26 1	55 8	1 2	4 7	1 1	0 0	450

(24 hours time of carbonization The amount of gas evolved at each stage of heating is not reported)

The recent types of retorts use **silica** brick for the walls These have been found most satisfactory on the basis of thermal, mechanical and economic considerations Two-thirds of the heat consumed passes through the walls of the retort to the charge, and one-third is lost from the flues, the total actually required being about 1225 (1100–1400) B T U per pound of coal carbonized Beehive ovens, in which coal was coked with loss of other products, and the small retorts used specially in making coal gas have been largely displaced by by-product recovery retorts as described

(3) Products (a) Coke The quality of coke depends upon the kind of coal used, the amount of moisture present in the coal, the fineness of the coal (the coal is pulverized to a fineness approximately 85 percent passing through ⅛ inch mesh), the width of the retort, and the temperature of the walls of the oven The time of coking is in practice determined by the above factors The ash present in the coal remains in the coke, and the percentage of ash is therefore higher in the coke than in the coal in proportion to the loss of volatilized matter For metallurgical purposes the **sulfur** and **phosphorus** contents of the coke are considerations As to the sulfur, this is present in three forms in the coal, namely, as organic sulfur compounds (from 0 5 to 2 percent of the coal), **iron** disulfide (pyrite) (from 0 1 to 8 percent), and **sulfates.** About two-thirds of the total sulfur is retained in the coke, and one-third removed in the volatilized matter Data regarding **phosphorus** is regularly examined by some operators.

Nitrogen exists in coal in two forms, namely, **amino** nitrogen (group $-NH_2$) and nitrogen-ring compounds



The total nitrogen in coal is 1 4 to 2 percent, of which 40 to 50 percent remains in the coke (possibly as a nitride of **carbon**), 18 percent is recovered from the volatilized matter as **ammonia,** 3 percent as pyridine and 1 percent as **cyanide,** while 25–30 percent escapes as free nitrogen in the gas The supporting or crushing strength of coke is an important consideration for metallurgical purposes (b) Coal gas The composition at various stages of heating, and the surplus amount after heating the retorts have been noted **Ammonia** is recovered by passing the gas through water and then distilling the solution, and the **benzene** and **toluene** by passing the gas through a non-volatile absorbing oil and then distilling the solution The benzene-toluene distillate makes up 90–95 percent of light oil, so called, the remaining 10 to 5 percent coming from the coal tar by distilling up to 170° C **Sulfur** compounds are removed by passing the gas through layers of hydrated **ferric** oxide spread over a large surface such as wood shavings, or by passing the gas through a solution of **sodium** carbonate (c) Light oil The light oil above mentioned, furnishes when distilled approximately the following materials and amounts

	Gallons per Ton of Coal Carbonized
Pure benzene	1 6 to 2 0
Pure toluene	0 4 to 0 6
Xylenes and light solvent naphtha	0 4
Unsaturated hydrocarbons	0 3
Heavy hydrocarbons and naphthalene	0 25
Wash oil, for benzene absorption from coal gas	0 35

(d) Coal tar Upon distillation, coal tar furnishes, in addition to the above-mentioned light oil, up to 170° C (0 2% of coal tar), approximately 10% of its weight distilling between 170 and 230° C (one-third **phenol,** two-thirds **cresylic acid**), 10% between 230 and 270° C (**anthracene** oil), and 55% pitch at 350° C When the distillation is conducted to 1200° C about 17% coke or retort carbon remains See **Coal Tar Products and Intermediates.**

Wood, Destructive Distillation (1) Destructive distillation of wood is conducted primarily to produce charcoal, **acetic acid** or **methyl alcohol** and secondarily for wood tar Certain deciduous or hard woods have been found most suitable for this purpose Freshly cut or green wood, usually contains about 60 percent water calculated on the weight of dry wood but this may reach as high as 100 percent Dry wood is mainly lignocellulose with little ash

ANALYSES OF SAMPLES OF WOOD DRIED IN OVEN AT 105° C

Kind of Wood	Cellulose	Lignin	Ash
Redwood	48 5%	34 2%	0 2 %
Western yellow pine	57 4	26 7	0 45
Longleaf pine	58 5		0 4
Western white pine	59 7	26 4	0.2
Sugar maple	60 8		0 4
Douglas fir	61 5		0 4
White spruce	61 9		0 3

The United States Forest Products Laboratory, Madison, Wisconsin, has conducted extensive researches in connection with wood, its treatment, and its uses Carbonization of wood in piles partially covered with earth

or in kilns where by-products are not recovered has been largely displaced by by-product recovery retorts. The production of acetic acid from **acetylene**, of **acetone** from acetic acid and from starch, and of methyl alcohol from **carbon monoxide** and **hydrogen** has been instrumental in furnishing severe competition for the wood distillation industry

(2) Conditions Klason (1908–10) reported very little decomposition of wood by heating rapidly to temperatures below about 250° C But chemical changes having notable effects on the strength of wood occur even below 100° C when wood is thus exposed over a long period of time Destructive distillation begins at 250° C, is exothermic (i e, evolves heat) at 280° C, and is finished at about 350° C, when practically all of the acetic acid, wood alcohol and wood tar have been evolved Above 350° C the charcoal decomposes into gas and tar leaving about 30 percent charcoal residue It is interesting to note that **cellulose** forms no methyl alcohol upon destructive distillation High vacuum rapid distillation of wood yields 44 percent wood tar, transparent, of light color and 20 percent charcoal, in contrast the yield when heated 14 days at atmospheric pressure is 2 percent wood tar, dark, and 40 percent charcoal

The yield of materials upon the destructive distillation of certain hard woods is as follows

Kind of Wood	Acetic Acid	Methyl Alcohol	Wood-tar	Char-coal
Beech	6 0%	2%	10%	41%
Maple	5 5	2	11	40
Ash	5 0	2	10	41
White oak	4 5	1 5	7	47

Coniferous or soft woods, upon destructive distillation, yield characteristic wood oils and wood tars, the recovery is complete from the contained volatile oils, about 75 percent complete from the contained rosin and slight from the fiber of the wood

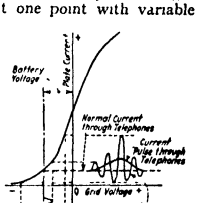
About 50 percent of wood ash is **potassium** carbonate

(3) Products (a) Charcoal is used as **fuel** and a reducing agent in metallurgy, where its low ash content and the absence of sulfur and phosphorus are important considerations Its porosity is great, and crushing strength low (b) Wood gas The composition of the gas evolved when wood is subjected to destructive distillation is of no commercial value It consists of about 60% **carbon dioxide**, 30% **carbon monoxide**, 3% each **hydrogen** and **methane**, and about 8,000 cubic feet are obtained per cord (128 cubic feet) of wood, that is, about 240 cubic feet per 100 pounds of wood The gas (about 135 B T U per cubic foot) is burned to furnish heat to the retorts (c) Water condensate In this is contained the **acetic acid**, wood **alcohol** (methyl alcohol to acetone in the ratio of about 100 to 8 parts by weight), other **ketones**, some **acetaldehyde** and ill-smelling oils The amount of crude pyroligenous acid, so called, is from 200 to 250 gallons per cord of wood Crude wood alcohol is obtained by fractional distillation, either with or without previous neutralization of pyroligneous acid, and the acetic acid then recovered by direct fractional distillation or by evaporation of the calcium acetate liquor (d) Wood tar From hard woods 7 to 10 percent of the weight of the wood, and from pine about 14 percent The tar is steam distilled to recover the acid contained The residue from this treatment is either burned as fuel for the retorts or distilled for various fractions of wood oils, wood tar, creosote (boiling point 200 to 220° C), and wood tar pitch 50 to 65 percent

Bone, Destructive Distillation (1) Bones, after removal of fat, consist of the two-thirds inorganic bone material, mainly **calcium** phosphate (56% calcium phosphate, 8% calcium carbonate, 1% each calcium fluoride and **magnesium** phosphate) and one-third organic bone material (osseine, **nitrogen**-containing) (2) Conditions When subjected to destructive distillation there is formed, gas, water condensate, bone oil, and bone charcoal (bone black) residue (3) Products (a) Gas contains **ammonia**. (b) Water condensate contains **ammonium** carbonate, sulfide, thiocyanate and cyanide An impure grade of ammonium sulfate may be obtained (c) Bone oil, 3 to 5 percent of the weight of bone, is dark brown to black, of offensive odor, and begins to distil when heated to 80° C **Pyridine** (C_5H_5N, boiling point 115° C) is present in the fraction collected below 120° C. and **pyrrole** (C_4H_5N, boiling point 131° C) in the fraction below 150° C Pyridine is recovered by separation as the picrate **Quinoline** (C_9H-N, boiling point 238° C) is also obtainable (d) Bone charcoal (bone black) consists of the **calcium** phosphate ash of bone impregnated with the residual carbon (10% carbon and 1% nitrogen) This material is used in decolorizing solutions, especially of raw sugar, on account of its adsorptive power for such materials, and as a black paint pigment

Carboniferous Shale, Destructive Distillation (1) Carboniferous shale, representing one of the greatest reserve supplies of fuel material, occurs in certain regions, for example, Colorado, in vast quantities (2) Conditions These have been extensively investigated and yields of 64 gallons (slightly more than 1 5 barrels) per ton of shale are reported Some 1500 tests were made by R D George (1921) of the Colorado Geological Survey S D Kirkpatrick has contributed a series of articles on the subject (Chemical and Metallurgical Engineering, 1924) J H Ginet (1923) reported cost of 87 cents per ton of shale, two-thirds of which is cost of mining The refined products obtainable from Colorado crude shale oil are stated to be as follows (3) Products (a) Gasoline, 15–17% of the crude shale oil, (b) Kerosene, 30–32%, (c) Gas oil, 18–26%, (d) Light lubricating oils, 15–18%, (e) Heavy lubricating oils, 10–12%, including paraffin wax Valuable contributions have been made by the Colorado School of Mines and the United States Bureau of Mines (R K S)

DETECTION Detection is a process of demodulation of an incoming electrical signal of a radio **receiver** A detector is the means of rectifying a damped or modulated incoming wave so that the current will flow in one direction through the telephone receiver or the speaker The earliest detectors were of the crystal form Galena, silicon, and carborundum crystals were employed They are one-way valves for electric current, passing it through much better in one direction than the other When one of these crystals is fused into a holding cup and a light spring caused to bear on it at one point with variable intensity, the crystal becomes a sensitive detector However, they are easily jarred out of adjustment, and are not suitable for the average radio receiver **The vacuum tube** has superseded the crystal on most radio receivers A three-element vacuum tube may act either as an **amplifier** or a detector The vacuum tube has a typical characteristic curve of plate current against grid voltage If the voltage on the grid is such that the incoming wave has a value of voltage which cuts across the vacuum tube characteristic at a relatively straight part of it, the plate current will reflect exactly, but to larger scale, the voltage variation



Action of a simple vacuum tube detector using a grid battery

impressed on the grid by the incoming signal The grid can be negatively biased to throw the incoming voltage to some other point on the characteristic curve By properly biasing the grid with a "C" battery, the incoming modulated wave may be caused to operate on the portion of the curve where the curvature is maximum As shown in the accompanying figure, the modulated incoming signal is given less amplification on one side of the symmetrical axis than on the other, thus producing an asymmetric wave The average value or center of these demodulated waves forms the unidirectional current which actuates the receiver The vacuum tube may also be used with the grid voltage such that the tube operates on the amplifying or straight line section of its characteristic curve A grid leak and a **condenser** in parallel in the plate circuit can accomplish the same purpose (F T M)

DETECTOR. Detection.

DETERMINANTS. A determinant is a certain type of mathematical expression which plays an important part in the study of systems of linear equations and related topics Determinants were first introduced by the German mathematician and philosopher G. Leibnitz (1646–1716).

A determinant of the second order is denoted by a symbol as

$$\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix},$$

and is defined as representing the expression $a_1b_2 - a_2b_1$.

A determinant of the third order is denoted by a symbol as

$$\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix},$$

and is defined by the expression

$$a_1b_2c_3 + a_2b_3c_1 + a_3b_1c_2 - a_1b_3c_2 - a_2b_1c_3 - a_3b_2c_1.$$

A determinant of the n^{th} order is defined as follows:

Take a set of n^2 numbers, called elements, and arrange them in the form of a square array, with n columns and n rows, thus

$$\begin{array}{cccccc} a_1 & a_2 & a_3 & \cdot & \cdot & a_n \\ b_1 & b_2 & b_3 & \cdot & \cdot & b_n \\ c_1 & c_2 & c_3 & & & c_n \\ \cdot\cdot & & \cdot\cdot\cdot\cdot\cdot & & & \\ \cdot\cdot\cdot\cdot\cdot & & \cdot\cdot & & & \\ l_1 & l_2 & l_3 & & & l_n, \end{array}$$

where the letter indicates the row and the subscript the column in which any particular element occurs

(1) With the elements of such an array form all products that can be formed by taking as factors one element and only one from each row and from each column of the array

(2) In each product arrange the factors so that the letters are in the same order as in the alphabet and then count the inversions of the subscripts If their number is even (or zero), give the product the plus sign, if odd, the minus sign

(3) Take the algebraic sum of all these plus and minus products, and represent it by the array itself with vertical bars at either side of it, thus:

(a) $$\begin{vmatrix} a_1 & a_2 \cdots a_n \\ b_1 & b_2 \cdots b_n \\ \cdots\cdots\cdots \\ l_1 & l_2 \cdots l_n \end{vmatrix}$$

The expression determined by (3) is called the determinant of the array, and it is denoted by the symbol (a) When there are n rows and n columns, the determinant is said to be of the n^{th} order

By an inversion in the preceding definition, we mean any case in which a larger subscript precedes a smaller one when the letters are arranged in their natural order

This definition includes those given in the preceding for the determinants of the second and third orders

The diagonal of elements $a_1, b_2, c_3, \ldots, l_n$ is called the principal diagonal of the determinant

The number of terms in the expression which defines the determinant of the n^{th} order is $n!$

The product of all the elements $a_1, b_2, \ldots, l_n$ lying in the principal diagonal is called the principal term All the other terms can be formed in order from the principal term by permuting the subscripts in all possible ways.

Some of the principal properties of determinants are the following

(1) The value of a determinant is not changed if its corresponding rows and columns are interchanged

(2) If two rows (or columns) of a determinant are interchanged, the sign of the determinant is changed, but its absolute value remains unchanged

(3) If all the elements of a row (or column) of a determinant are zero, the value of the determinant is zero

(4) If two rows (or columns) of a determinant are identical, its value is zero

(5) If all the elements of a row (or column) of a determinant are multiplied by the same number, the determinant is multiplied by this number

(6) If each element of a row (or column) is expressed as the sum of two or more numbers, the determinant can be expressed as the sum of two or more determinants, thus, for a determinant of the third order

$$\begin{vmatrix} a_1 + a'_1 & a_2 & a_3 \\ b_1 + b'_1 & b_2 & b_3 \\ c_1 + c'_1 & c_2 & c_3 \end{vmatrix} = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} + \begin{vmatrix} a'_1 & a_2 & a_3 \\ b'_1 & b_2 & b_3 \\ c'_1 & c_2 & c_3 \end{vmatrix}$$

(7) The value of a determinant is not changed if to each element of any row (or column) there be added the corresponding elements of any other row (or column) each multiplied by the same number

If in any determinant we strike out both the row and column in which any particular element lies, and then form the determinant of the remaining elements without changing their relative positions, the new determinant so formed is called the minor of that element

The evaluation of determinants is generally based on an expansion of the determinant in terms of minors by use of the following rule A determinant may be expressed as the sum of the products of each of the elements of any one of its rows (or columns) by their corresponding minors, each product having a positive or negative sign according as the sum of the row-number and column-number for the particular element considered is even or odd

If H_k is the minor of an element h_k of a determinant, where the element lies in the h^{th} column and k^{th} row, then $\overline{H}_k = (-1)^{h+k}H_k$ is called the co-factor of h_k

The expansion of the determinant may then be written in any of the forms

$$\begin{aligned} D &= a_1\overline{A}_1 + a_2\overline{A}_2 + a_3\overline{A}_3 + \cdots + a_n\overline{A}_n \\ &= b_1\overline{B}_1 + b_2\overline{B}_2 + b_3\overline{B}_3 + \cdots + b_n\overline{B}_n \\ &\quad \cdots \qquad\qquad \cdots\cdots\cdots \\ &= l_1\overline{L}_1 + l_2\overline{L}_2 + l_3\overline{L}_3 + \cdots + l_n\overline{L}_n \\ &\qquad \text{etc.} \end{aligned}$$

Any sum, such as $b_1\overline{A}_1 + b_2\overline{A}_2 + \cdots + b_n\overline{A}_n$, obtained by adding the products of the elements of any row (or column) with the co-factors of the corresponding elements of any other row (or column), is zero

The evaluation of determinants is based on the use of the preceding properties of determinants, particularly (7), and the expansion by minors, reducing the given determinant in order successively by one until its order is 3 or 2, when it can be directly evaluated by the definition of the second or third order determinant

The product D' of two determinants D_1 and D_2 of the same order is obtained thus multiply the elements of the i^{th} row of D_1 by the corresponding elements of the k^{th} column of D_2, the sum of the products thus ob-

tained is the element in the i^{th} row and k^{th} column of the product determinant D'.

One of the chief uses of determinants is in the solution and study of the properties of **systems of linear equations.** (L.L.S.)

DETONATION. This is the technical term descriptive of the knock or ping which, under certain circumstances, occurs in the cylinders of an internal combustion engine. Detonation is undesirable. It reduces power output, causes overheating, unduly stresses the cylinder head, and is generally objectionable from the noise and vibration standpoint. It decreases **thermal efficiency.**

Detonation has been extensively studied. Apparently it is due to spontaneous ignition of the explosive gasoline-air mixture in the cylinder head. Observers have noted that with no detonation, ignition of the charge starts at the spark plug and travels rapidly, but with a definite wave front, through the charge. However, when the engine is knocking, the inflammation proceeds normally only part way from the source of ignition, and then suddenly the remainder of the charge is ignited simultaneously at all points, accompanied by a sharp rise in pressure due to almost instantaneous expansion. The result is a heavy pressure wave striking the cylinder head a hammer-like blow. The explanation advanced for this sudden ignition of the entire charge is that the initial combustion increases the pressure of the rest of the charge, and its temperature, until it passes the point where ignition will take place spontaneously due to **adiabatic** compression.

Conditions affecting detonation might be discussed under three heads; viz., fuel characteristics, cycle characteristics, and engine characteristics. The rate at which a fuel burns when ignited is the first of the fuel characteristics. Since the ratio of air to fuel in the combustible mixture also affects the rate of burning, it has a bearing on detonation. The spontaneous ignition temperature of the fuel is another important characteristic. Turning next to the cycle upon which the **engine** is operating, we find the compression ratio and the time of ignition to be of great importance. The overcoming of detonation is of increasing importance, as compresson ratios of engines are raised in the effort to increase thermal efficiency. The driver of an automobile with manually controlled ignition knows detonation may be offset by retarding the spark. But this is undesirable, since it is accompanied by loss of power and overheating. One of the more important engine characteristics affecting detonation is the material of the combustion chamber. The more rapidly heat is conveyed away from the cylinder head, the less will be the chance of the initial combustion raising the pressure above that for spontaneous ignition. Thus aluminum cylinder heads and improved cooling efficiency offset detonation in high compression engines. Manufacturers' provisions for thus conducting heat away rapidly will be nullified by a heavy layer of heat-insulating carbon deposit in the cylinder head. Other engine characteristics of importance are the location of the spark plug and the shape of the combustion chamber.

After extensive experimentation it was found that certain substances had the ability to suppress detonation. How they act is not fully known. Amounts of suppresser as small as one molecule to 100,000 molecules of explosive mixture are effective in eliminating detonation. The detonating quality of a gasoline is one of its comparable characteristics. A scale called octane rating has been devised to measure this quality. The octane rating is the percent by volume of isooctane in a heptane-isooctane mixture (See **Hydrocarbon**), which exactly matches in anti-detonating property, an actual fuel under test in a standard test engine at standard conditions.

Lead tetraethyl in small quantities is effective as a knock suppresser. To prevent a lead deposit from forming in the cylinder head, ethylene dibromide is added to form a lead bromide which is powdery and is blown out through the **exhaust** ports. Gasoline so treated is called ethyl gasoline.

The term detonation in ordinary usage denotes any explosion. In the **explosives** industry, however, a detonator is an explosive or device used to initiate the explosion of another explosive, which can thus be less sensitive, and more safely handled and transported. (F.T.M.)

DETRITUS. General term for unconsolidated **sediments** derived from preexisting rocks by natural agencies. Derived from the latin word meaning worn. (R.M.F.)

DEUTERIUM. Symbol: D. Atomic number: 1. Atomic weight: 2, the second isotope of hydrogen. Discovery by Urey in 1932.

Oxide: Deuterium oxide (D_2O), heavy water.

See **Hydrogen; Water.** (R.K.S.)

DEUTEROCEREBRUM. The second region of the **brain** of an **arthropod,** derived from a pair of ganglia (See **Ganglion**) in the corresponding segment of the head. (A.W.L.)

DEUTOPLASM. Inert material stored in **eggs.** Yolk.

DEVELOPERS. **Photography.**

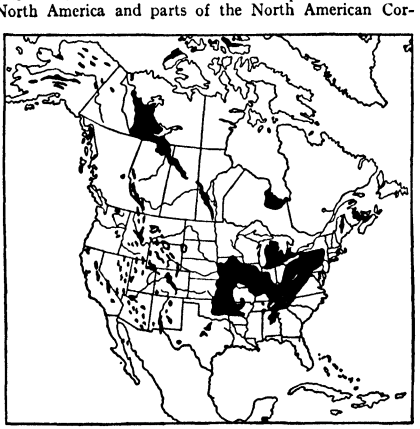
DEVELOPMENT. **Photography.**

DEVIL FISH. 1. Mollusca, Cephalopoda. Any **octopus.** 2. Pisces, Plagiostomi. The giant **ray.**

Both of these forms are said to be dangerous to man, and when we consider that they are predacious and that some reach large size we can readily believe that they may attack divers. One octopus of the Pacific ocean reaches a diameter of more than twenty feet and the ray attains an equal width. (A.W.L.)

DEVITRIFICATION. The process by which the natural rock glasses such as **Obsidian** and **Tachylyte,** develop minute but definite minerals, usually **quartz** and **feldspar.** (R.M.F.)

DEVONIAN. The name of a geologic period. Type locality, Devonshire, England and Belgium. The formations of this period were first studied and described by R. I. Murchison in 1839. The Devonian period began 330 million years ago and lasted for 50 million years. The Devonian formations are well exposed in eastern North America and parts of the North American Cor-



Map showing known areas of outcrops (surface distribution) of Devonian, Mississippian, and Pennsylvanian strata in North America.

dilleran In the **Appalachian Geosyncline** the Devonian is largely represented by an immense thickness of red and brown shales and sandstones of delta and estuarine origin, and the transition between the sediments of this system and that of the underlying Silurian is so gradual that the boundary is extremely difficult to locate by physical means alone In Britain the Devonian is represented by a marine limestone (facies) in the type locality, and a red non-marine sandstone (facies) to the north This red sandstone (facies) is referred to as the **"Old Red"** by British geologists The Scottish "Old Red" contains the famous fossil "fishes" described by Hugh Miller in 1851 These fish include two distinct groups, **Ostracoderms** and **Ganoids**, the latter being the supposed ancestors of the Amphibia or first terrestrial vertebrates The first undoubted evidence of terrestrial plants occurs in the Devonian, the late Devonian types being the progenitors of the **Carboniferous** forms In England, Scotland, Spitzbergen, western Russia, and Norway, occur great thicknesses of terrestrial, intermontane clastic sediments similar to those found in the **Proterozoic.** Highly fossiliferous marine sediments, including sandstones, shales and limestones are particularly well exposed in New York State Many of the limestone formations contain reefs composed principally of compound corals, **Bryozoa** and **Calcareous Algae.** Among the marine invertebrates **goniatites** and **Eurypterids** are particularly representative Other common marine types are corals, **Bryozoans** (reefs) and **Echinoderms, Pelecypods** and **Trilobites.** The spire-bearing Brachiopods (**Spirifers**), which started in the Silurian, reach their maximum development in genera and species in the Devonian The only fossil evidence of a terrestrial vertebrate rests upon a foot print (probably that of an amphibian) found in the Upper Devonian of western Pennsylvania Beginning with the middle and ending with the period, mountain building occurred in the New England States The principal economic products derived from the American formations are petroleum and natural gas, first exploited in 1859 in western Pennsylvania, New York, Ohio and West Virginia (R M F)

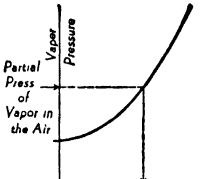
DEVONITE. The name given by Johannsen, in 1910, for a variety of **porphyritic basalt** containing **phenocrysts** of **potassium**-rich **plagioclase.** Type locality, Mt Devon, Massachusetts (R M F)

DEWBERRY. Rose Family.

DEW CLAW. Small hoofs of the rudimentary toes, found just above the functional hoofs in some of the even-toed hoofed animals. (A W L)

DEWLAP. The fold of skin which hangs below the neck in cattle (A W L)

DEW POINT. The temperature at which the air becomes "saturated" with water vapor, so that the relative **humidity** is 100 per cent It is the temperature at which the maximum vapor pressure of water would be equal to the actual partial pressure of the water vapor in the atmosphere (See **Dalton's law**) For example, let the temperature of the air be 20° C, and the relative humidity 60 per cent Then since the maximum vapor pressure of water at 20° C is 17.4 millimeters, the actual water vapor pressure is 0.6 of this or 10.4 millimeters The temperature at which 10.4 millimeters is the maximum vapor pressure of water is 12°. Hence if the air is cooled to 12° C., it will reach saturation and under suitable conditions dew will form; 12° C. is the dew point Likewise if the dew point is known to be 12° when the air is at 20°, it follows that the relative humidity is 60 per cent The dew point **hygrometer** depends upon this principle. (L D W)



Graphical location of dew point from vapor pressure curve.

DEW-POINT HYGROMETER. Hygrometers; Dew Point.

DEXTRIN. Carbohydrates.

DIABASE. Dolerite.

DIABETES MELLITUS. A disease of **metabolism** in which insufficient **insulin** is produced by the **pancreas.** The **hormone,** insulin, is needed to oxidize or burn **carbohydrates** so that the body may use them. When lack of insulin occurs the concentration of unutilized sugar is increased in the body, sugar appears in the **urine,** and symptoms characteristic of diabetes appear

The cause of diabetes is not known although several factors increase the likelihood of its development Obesity definitely increases the incidence of diabetes, especially when overweight is due to overindulgence in sweets—as is so often the case Each year, in the United States, the per capita consumption of sugar has increased and in a corresponding manner an increase in the number of diabetics has likewise occurred Certain races are more subject to this disorder, particularly the Jews, possibly since this race prefers a carbohydrate diet Infection, **heredity** and continual emotional disturbances may be factors in its development

In diabetes insulin is not produced in proper amounts because the insulin-producing cells in the pancreas (Islands of Langerhans) degenerate Banting and Best discovered that insulin was produced by the pancreas and first produced it in pure form The use of insulin in the treatment of diabetes has saved many lives and allowed the diabetic to lead a normal, useful life For use, insulin is extracted from the pancreas of large animals such as sheep, cattle and hogs

In the metabolism of carbohydrate in the body the first step is conversion into **glucose** which is absorbed from the intestinal tract into the blood stream A certain amount is broken down into simpler substances by means of insulin and is used by the body Any excess is stored in the liver and muscles as **glycogen.** At any time this glycogen store may be freed, rebuilt into glucose and used

Recently an insulin preparation that is more slowly absorbed has been prepared which necessitates only one injection each day (R S M)

DIAGENESIS. A term proposed by Gumbel in 1888 for the gradual and successive chemical physical changes which take place in **sediments** previous to or during their **consolidation.** Diagenesis may also include the numerous processes of **lithification** but is a useful term only when particularly applied to the more or less contemporaneous chemical alteration of sediments (R M F)

DIAGRAM FACTOR. This is a factor relating particularly to **piston** and **cylinder** engines Although it has a meaning applied to internal combustion engines, diagram factor is principally a dimension of the **steam engine.** Certain analyses of the steam engine, especially those concerned with predicting the performance of a given unit under stated steam conditions, are most easily made with the use of the diagram factor This factor is defined as the ratio of the actual **mean effective pressure** to the theoretical effective pressure; also as the actual work to the theoretical work The theoretical case is that of a steam engine having no compression, no **wire drawing,** and no clearance. (See **Rankine Cycle.**) The ratio of the area of this cycle to that of the actual engine operating between the same pressure limits, is

more or less typical for any one class of engine The accompanying table gives some values of diagram factor

DIAGRAM FACTORS

High-speed, simple automatic	0 70–0 85
Low-speed, releasing gear	0 80–0 90
Unaflows	
Full compression, condensing	0 75–0 85
Full compression, non-condensing	0 70–0 80
Controlled compression, condensing	0 85–0 90
Controlled compression, non-condensing	0 80–0 85

for steam engines Knowing the steam conditions, and the type of engine, the probable pressure and horsepower realizable can be closely estimated by calculating the theoretical quantities and multiplying them by the diagram factor In this light, diagram factor is a means of modifying theoretical calculations to bring them in line with actual experience

$$P_a = P_t \times f$$

$$IHP = \frac{2P_aLAN}{33{,}000}$$

P_a = actual mean effective pressure, in pounds per square inch
P_t = theoretical mean effective pressure, in pounds per square inch
f = diagram factor
IHP = indicated horsepower
L = stroke in feet
A = piston area, in square inches
N = rotative speed, in revolutions per minute

(F T M)

DIALLAGE. The mineral term for a **calcium-iron pyroxene,** similar in chemical composition to **diopside** but richer in iron oxide In addition to the typical prismatic cleavage of the pyroxene group diallage has a marked "cleavage" parallel to the vertical **pinacoids,** known as diallage parting Diallage is a common constituent of **gabbros.** The term Diallagite was proposed by Cloiseaux in 1845 for rocks particularly rich in diallage The term diallage is derived from the Greek meaning difference, and referring to the peculiar cleavages of this variety of **monoclinic** pyroxene (R M F)

DIALYSIS This is a process of removing crystalloids from **colloids** by means of semi-permeable membranes. (R K S)

DIAMAGNETISM. Magnetism.

DIAMETERS OF CONICS. The **locus** of the midpoints of all chords parallel to a given chord of a **conic section** is called a diameter of the conic, it is a straight line in each case

The diameter of the **parabola** $y^2 = 2px$ which bisects all chords of **slope** m is the line $y = p/m$ which is parallel to the axis of the parabola

The diameter of the **ellipse** $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ which bisects all chords of slope m passes through the center and has the slope $m' = -b^2/a^2m^2$ The diameter of the **hyperbola** $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ which bisects all chords of slope m passes through the center and has the slope $m' = b^2/a^2m^2$

Two diameters of an ellipse or hyperbola are called conjugate diameters if each bisects the chords of the given curve that are parallel to the other For the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$, the slopes of two conjugate diameters are related by $mm' = -b^2/a^2$, for the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$, the relation between the slopes of conjugate diameters is $mm' = b^2/a^2$. (L L S)

DIAMOND. In any enumeration of gem stones the diamond unquestionably stands in first place because of its remarkable brilliancy and great hardness as well as because of its relative rarity It is an allotropic form of **carbon.** Its luster is also "hard" in quality from which we have derived the term adamantine luster, through the Greek meaning, adamant, applied to diamonds and possibly other very hard substances, literally "unconquerable" In this connection it is interesting to note that the ancients confused hardness with strength or toughness, not understanding that minerals of considerable hardness may split or cleave easily in certain directions This unfortunate fallacy is believed to have been responsible for the unwitting destruction of more than one diamond

When colorless, water-clear, and flawless, diamonds are referred to as of the "first water" and are of the greatest value "Off color" stones, those with a slight tinge of yellow, are far less desirable although stones of a bright yellow, or of odd colors such as pink or steely blue, command large premiums, as they are highly prized

The diamond fields of India, now seemingly exhausted, yielded quantities of stones, probably all of those known previous to 1725 when diamonds were discovered in Brazil That country has produced many fine but mostly small stones

Diamonds were discovered in 1867 along the Orange River in South Africa, and since then Africa has been preeminent in the production of diamonds, in the seventies and eighties occurred a series of amazing discoveries of diamond fields and stones of extraordinary size Diamonds have also been found in Australia, Borneo, British Guiana, and Arkansas

Much as the matter has been studied there is no general agreement as to the genesis of the diamond It is found in **alluvial** deposits, both unconsolidated and consolidated, indicating the erosion of rocks containing diamonds not only during the present era but also in past geologic time In Africa diamonds are mined in a dark basic rock of the general nature of **peridotite** called **kimberlite** from the town of Kimberley The kimberlite occurs in vertical "pipes," resembling what once may have been volcanic necks or other types of igneous rock conduits It is supposed that the diamonds have been formed in and brought to the surface by the magma which was of the general nature of peridotite Undoubtedly high pressures, and possibly high temperatures as well, are necessary for the development of crystallized carbon in the form of diamonds (E S C S)

DIAPHRAGM. 1 The thin layers of muscle which suspend the insect heart within the body 2 The muscular partition between the thoracic and abdominal cavities of mammals

The mammalian diaphragm is important in **respiration.** (A W L)

DIARRHEA. Increased frequency and liquidity of bowel movements following an infection, or irritation of the gastro-intestinal tract (R S M)

DIASPORE. The mineral diaspore is a hydrous **oxide** of **aluminum** corresponding to the formula AlO(OH) occurring in prismatic **orthorhombic** crystals, usually somewhat flattened, or massive It displays good cleavage, conchoidal fracture, is brittle, hardness, 6 5–7, specific gravity, 3 3–3 5, luster, vitreous to pearly, color, white, grayish, greenish, yellowish, brownish or colorless, transparent to translucent Diaspore is found associated with **corundum, emery** and **bauxite,** being probably an alteration product of the oxide It has been made artificially Diaspore has been found associated with emery in the Ural Mountains, in Asia Minor, in the Island of Naxos, Greece, and in the United States at Chester, Massachusetts Its name is derived from the Greek word meaning to scatter, because of its decrepitation upon heating (F S C S)

DIASTASE. Enzymes.

DIASTEM. A term proposed for a slight hiatus, or loss of record, during the deposition of sediments. As diastems must be contemporaneous with sedimentation they are not to be confused with **disconformities.** (R.M.F.)

DIASTOLE. The stage of dilation of the heart or relaxation of the **heart** muscle. It is during this stage that the chamber of the heart is filling with blood. (R.S.M.)

DIASTROPHISM. A general term for all types and modes of deformation of the crust of the earth. See also **Epeirogeny** and **Orogeny.** (R.M.F.)

DIATHERMANCY. Thermal Radiation.

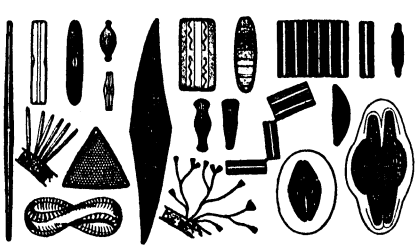
DIATHERMY. The generation of heat in the bodily tissues by means of high frequency electric currents. Two electrodes are placed on opposite sides of a portion of the body. The heat is generated by the resistance provided by the body tissues between these electrodes.

Medical diathermy is used in **neuritis,** sprains, **arthritis,** and in fracture cases, etc. Surgical diathermy (endothermy) is used operatively. Sufficient heat is produced at the skin surface either to actively cut the tissues with the current or to coagulate and kill tissue cells. By use of this method in certain conditions, warts, malignant growths, etc., there is less bleeding and less danger of spreading malignant cells. This method can, however, only be used in certain conditions. (R.S.M.)

DIATHESIS. Congenital predisposition toward any disease. (R.S.M.)

DIATOM OOZE. Oceanic Deposits.

DIATOMS. Bacillarieae. Diatoms are **algae** which are very commonly found in both fresh and salt waters. Often they occur in immense numbers, especially in the ocean. The feature which distinguishes them from all other algae is the siliceous (See **Silicon**) wall which encloses them. This is composed of two halves or valves, one of which fits over the other much as a cover fits onto a box. These siliceous walls are often beautifully marked with the finest and most regularly arranged patterns which make these algae objects of great beauty when seen under a microscope. Because of the regularity of these marks, these plants are often used as tests for testing the resolving power of a **microscope.** Within the wall, the simple **protoplast** contains several **chromatophores** which contain a brown pigment that masks the **chlorophyll** present.



Collection of diatoms showing variation in appearance. (From Kerner's *Natural History of Plants,* Blackie & Son.)

Many diatoms are distinctly unicellular organisms; others stick together to form long chains or are included in a gelatinous sheath which forms extensive branching aggregations. There are two large orders of diatoms, separated according to the shape of the cell. One, the Centrales, comprises those diatoms which are radially symmetrical; the other, the Pennales, those which are not radially symmetrical. Many of the Pennales are bilaterally symmetrical, others irregular. Many members of the Pennales move about in a gliding manner.

Two methods of reproduction are found in diatoms. The more common method is asexual. In this process the protoplast of the cell enlarges, pushing the two valves apart. Then the protoplast divides into two parts, each of which occupies one of the two valves. A new valve is formed over the exposed surface of the protoplast but inside the original valve of the cell. As a consequence the new valve is smaller than the original. As repeated divisions occur the size of the valve gradually decreases. This does not continue indefinitely however. To bring the cell back to its original size, auxospores are formed. When this happens the protoplast enlarges tremendously and escapes from its walls. It then divides and secretes about itself new walls which have the size of the original cell. Auxospore formation is often a result of sexual fusions. Sexual reproduction is accomplished by the fusion of two diatoms. There are several variations in the method in which this process occurs. Sometimes it is a simple fusion of two protoplasts to form one; in other forms, two amoeboid gametes are formed by each protoplast. **Gametes** from different protoplasts fuse, forming **zygospores.** Several other variations are known. Some of the Centrales form small biciliate gametes called microspores, which fuse.

The diatomes are a very important group of algae. Occurring in immense numbers as they often do, they are the main food substance of many animals, which in turn become food for higher organisms, including man. When a diatom dies and its protoplast disintegrates, the siliceous shell sinks to the bottom of the water. Gradually immense accumulations of diatom valves are formed on the ocean bottom. These may eventually be buried beneath other deposits. They become diatomaceous earth, often forming beds hundreds of feet thick and covering large areas. Diatomaceous earth is used as an **abrasive** and scouring agent, as a **filter,** and in many other ways. (R.M.W.)

DIATREME. A general term for volcanic pipes and circular vents, the result of the explosive action of **magmatic** gases. (R.M.F.)

DIAZO-COMPOUNDS. Azo-, Diazo-, and Related Compounds.

DIAZOAMINO-COMPOUNDS. Azo-, Diazo-, and Related Compounds.

DICHOTOMY. A system or method of branching in which the main axis divides into two branches, which may in turn branch in the same manner, as for example the **thallus** of an **alga** or an **hepatic,** or the root or stem of a **club moss.** (R.M.W.)

DICHROITE. Cordierite.

DICKCISSEL. Aves, Passeriformes. A small American bird, *Spiza americana,* related to the buntings. It is found in open country and is distinguished by its yellow breast and black throat patch. (A.W.L.)

DICOTYLEDONS. The larger of the two subclasses of **angiosperms** is the dicotyledons, containing over 100,000 species. The plants of this subclass have leaves, flowers and seeds distinctly different from those of **monocotyledons.** The leaves are generally broad and have netted veins; the parts of the flowers occur most frequently in fours or fives or multiples of these numbers. That is, there are four or five sepals, four or five petals, four or five (eight or ten, or more) stamens, and one to many pistils. The embryo of the seed has two cotyledons or seed leaves.

Many important food plants are members of this group, for example, **potato, cabbage, carrot, apples, oranges,** and **peanuts.** Other dicotyledons yielding economic products of great value are the various **rubber** plants, **cotton, flax, sugar** beets, and soy beans The number cultivated as ornamental plants is too great to enumerate

Dicotyledons vary in size from tiny annuals an inch or less in height to giant trees 350 feet tall They include herbaceous and woody members, annuals, biennials, and perennials They are found all over the world, wherever plants can grow (See also **Paleobotany.**) (R M W)

DICTYOKINESIS A process of subdivision of the Golgi apparatus of the **cell** during cell division, followed by the distribution of the resulting parts to the daughter cells (A W L)

DICTYOSOME Cell.

DICTYOSTELE. Stele.

DIDELPHIA Mammalia.

DIE A die is a specially prepared block of metal used in quantity production of parts by **casting** or **forging** In die casting it is a properly formed mold made of metal instead of sand Non-ferrous parts have long been die cast in these metal molds White metal and aluminum parts are usually so made The die cast part has a finely finished appearance, and the whole process may be set up in a semi-automatic machine

Much more strenuous service is faced by the die used in drop forging, where the metal is squeezed to the final shape without melting One die is recessed, the other has a raised face The faces are exactly the shape of the piece to be made, and fit each other so that a sheet of metal placed between them could be pressed to their shape Application of extremely high pressures to the metal causes it to flow sufficiently to take the impression of the die Naturally, the die must be very hard and tough to endure in this service Alloy steel dies are often used

Another form of die is the part used to create plastic flow of metal during a drawing process, such as **wire drawing.** This die is generally stationary, having in it a hole of the shape of the desired cross-section to be created in the stock For example, in wire drawing, the hole would be round The stock is pulled through the die and made to flow to the desired cross-section (F T M)

DIELECTRIC ABSORPTION. The persistence of electric polarization in some dielectrics after the removal of the polarizing electric field When a **condenser** with glass plates is connected with a **battery,** the charging current may last, though gradually decreasing, for some minutes or hours, and when the charged condenser is short-circuited, the discharge current may not cease entirely with the first rush After a Leyden jar has been discharged and allowed to stand disconnected for a time, another, smaller spark can usually be obtained from it This is called a "residual" charge

By melting mixtures of wax and allowing them to harden in a strong electric field, Eguchi (Japan, 1925) succeeded in obtaining dielectric absorption which persisted almost undiminished for several years Such a permanently polarized body, singularly analogous to a permanent magnet, has been termed an "electret" (L D.W)

DIELECTRIC CONSTANT. Dielectrics.

DIELECTRICS. A dielectric is a body through which, or a medium in which, electric attraction or repulsion may be sustained Thus glass is a dielectric, because unlike charges on opposite sides of a plate of glass attract each other, likewise two charged bodies immersed in oil or in nitrogen exhibit mutual electric force (though less than in a vacuum), hence these substances are dielectrics Dielectrics are always insulators, a good conductor completely screens off an electric field (See **Electric Screening**) The **condenser** is the usual form of apparatus for studying and comparing dielectrics

The explanation of most dielectric phenomena is found in what is known as "electric polarization" When a dielectric is placed in an **electric field,** it is believed that there is a slight shifting of the negatively charged particles (electrons), of which it is partly composed, in one direction and of the positive particles in the other, so that the body as a whole now has an electric moment where before it had none, the electric moment per unit volume being the measure of the polarization This may result partly from a rectilinear shift of electrons and atomic nuclei, and in many cases partly also from the orientation of "polar" molecules, i e, molecules which have a permanent electric moment of their own

In dielectrics of this latter type, the polarization is greater in the liquid than in the solid state, presumably because the polar molecules turn about more easily (The whole phenomenon bears a close analogy to the magnetization of iron, an analogy made still more striking by **dielectric absorption,** q v)

A notable result of the polarization of a dielectric is the reduction of the electric intensity due to any given distribution of electric charges It is shown in dielectric theory that if the intensity in a vacuum, called the electric displacement is denoted by D, that in a dielectric whose polarization is P is $E = D - 4\pi P$ The polarization P is apparently proportional to D Hence E is proportional to D, and the ratio D/E, which is greater than unity, is called the **dielectric** constant of the substance, and usually denoted by k It varies widely for different substances, as will be noted in the brief table below

Diflectric	k	Dielectric	k
Air	1 0006	Mica	5 7
Alcohol	28 4	Paraffin	2 1
Carbon dioxide	1 001	Porcelain	5 7
Glass (flint)	9 9	Rubber	2 2
Hydrogen	1 0003	Sulfur	4 0
Linseed oil	3 3	Water	81 1

A convenient measure of the dielectric constant is the ratio of the **capacitance** of a condenser filled with the dielectric in question to that of a similar condenser with the dielectric removed, leaving a vacuum The electric energy per unit volume in the polarized dielectric, for a given electric field intensity, is also proportional to the dielectric constant, therefore, if the dielectric constants of glass and air are in the ratio 10 1, a condenser with glass plates charged say to 1000 volts, has ten times as much stored electrical energy as the same condenser charged to the same voltage but with air substituted for the glass

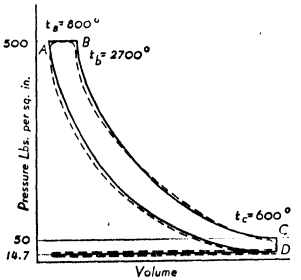
With non-polar dielectrics the dielectric constant k depends, for a given substance, up on the density ρ (and hence upon the temperature), increasing as ρ increases in accordance with a formula due to Clausius and Mosotti

$$k = \frac{2a\rho + 1}{1 - a\rho};$$

in which a is a constant for the given dielectric For different substances it depends upon a property of the molecule known as its "polarizability," which is the increase of electric moment produced in the molecule by unit electric field intensity. (See also **Electric Insulation.**) (L D W)

DIESEL CYCLE. Although modified from the inventor's original conception, the modern Diesel cycle retains the most important feature, namely that of

compression of air to the ignition temperature, followed by timed introduction of fuel. This cycle is shown in the accompanying diagram. The solid line indicates



Showing the departure of the actual cycle from the theoretical, or air standard cycle.

a theoretical cycle, the dotted line shows how the actual cycle may depart from the theoretical. Typical temperatures are also indicated. Beginning with point *D* on the cycle, imagine that a cylinder filled with air is closed at the end by a tightly fitting piston. The piston is moved to compress the air without addition or loss of heat through the cylinder walls. As the air is decreased in volume, the pressure rises adiabatically, and it arrives at the condition corresponding to point *A*. The piston is then reversed in direction, and starts to move so as to increase the volume of the air. The air is very hot due to its **adiabatic** compression. In fact, it is well above ordinary ignition temperatures of petroleum products. As the piston starts to move, carrying the cycle from point *A*, fuel is injected or sprayed into the cylinder just rapidly enough so that its combustion will keep the pressure up while the volume is being increased, at least up to point *B*. At *B* when the outward stroke is partially completed, the fuel is cut off, and the products of combustion expand adiabatically from *B* to *C*, giving work to the piston as they do. At *C* the exhaust valve opens, and the pressure drops to *D*. The line extending horizontally from *D* represents the theoretical exhaust and suction stroke. Adiabatic expansion and compression are not possible in a cylinder which must be well cooled in order to maintain a lubricating oil film. Therefore an actual cycle will not be expected to follow the adiabatic. Another difference between actual and theoretical cases is the composition of the gas within the cylinder. Theoretical studies are made assuming pure air in the cylinder. Actually there is a little burned gas present during the compression, and a great deal of it during the expansion strokes. However, by assuming no friction loss, adiabatic compression and expansion, and air, only, in the cylinder, an expression may be derived for the efficiency of the cycle *ABCD*. See **Air Standard Efficiency.** (F.T.M.)

DIESEL ENGINE. In a patent dated 1892, Dr. Rudolf Diesel, a German engineer, described an engine to operate on the **Carnot cycle.** Coal dust was the fuel, and it was to be fed rapidly enough so that isothermal expansion would result. After fuel cut-off, an adiabatic expansion would continue, followed by a compression made isothermal by the injection of water into the cylinder. An adiabatic compression then brought the cycle back to its beginning. A further claim of the patent covered the use of liquid fuels and the spray valve. Early attempts to build this engine resulted in the adoption of a modified cycle which, after much experimentation, was built into a successful working engine. Since then the Diesel has slowly but surely established for itself a secure position as a prime mover.

The reasons for continued growth of Diesel engine power are to be found in the advantages of the Diesel over other prime movers for certain classes of service which abound in this country, and to the comparative low cost of high-grade petroleum fuel.

The Diesel applications at present may be divided into **mobile** and *stationary*. Marine and locomotive service absorbs a large proportion of the annual output of engine builders. Stationary Diesels are to be found in all kinds of factories, especially small factories. A great many of them are used for pumping oil in pipe lines, and from wells, and for pumping water both for drainage and irrigation. They are also in service in mines for pumping, for compressing air, and for electrical service.

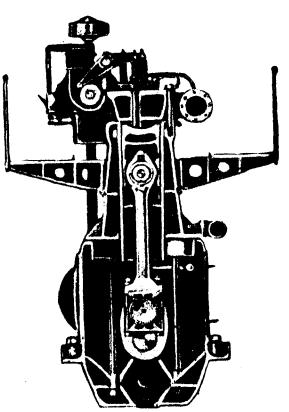
The Diesel is an excellent prime mover for electrical generation in capacities of from 100 to 5000 horsepower. As such, it is widely used by private industry, hotels, utility companies, and municipalities, especially in the water and light plants of the latter.

The advantages of the Diesel engine are:

1. Low fuel cost.
2. No long warming-up period.
3. No standby losses.
4. Uniformly high efficiency of all sizes.
5. Simple plant layout.
6. No large water supply.

The Diesel can extract more work out of each heat unit than any other engine in the world. For that reason it becomes an attractive prime mover wherever first cost is written off slowly enough so that operating costs are influential.

Where fuel prices favor oil, where prices of all fuels are extraordinarily high, where water supply is either of poor quality or inadequate, where loads are relatively small and reliable transmission line service is not available at competitive rates, and where industrial power rates are too high, the Diesel will continue in popularity as an efficient, small capacity, reliable prime mover.



Section through power cylinder—Worthington Diesel Engine.

The ordinary Diesel engine is a heavily built engine having a piston which reciprocates in a cylinder. A connecting rod is either pinned directly into a trunk type piston, or to a cross-head to which the piston is connected by a piston rod. The connecting rod bears on a crank, which has bearings in the main frame. Added to these parts are the auxiliaries such as valves and valve gear, fuel injection systems, water circulation systems, starting systems, etc. The Diesel is more heavily built

than the gasoline engine, and is a relatively slow-moving machine. Rotative speeds are commonly 100 to 400 revolutions per minute. The fuel ordinarily employed is a product from crude petroleum. The low cost of good-grade petroleum fuel in the United States has, to the present time, precluded the general use of any other type of Diesel fuel. Fuel oil is the residue left when the distillation has removed the gasoline, kerosene, and light distillates from the crude. The heavier residues are also removed from the better grades of fuel oil. This fuel is pumped into the cylinder during the first part of the power stroke, correctly gauged so that its combustion tends exactly to offset the drop of pressure which would otherwise be experienced. During combustion of the fuel in the Diesel engine the pressure remains approximately constant. After a small portion of the power stroke is completed, the fuel is cut off, and the products of combustion do work on the piston expansively.

The principal and important difference between the oil and the gasoline engine resides in the method of ignition. Compression of the air trapped in the cylinder of a Diesel engine is employed as its means of ignition. The compression is carried to much higher pressures in the Diesel than in the Otto cycles; consequently, the temperature at the end of compression is higher in the Diesel cycle. In fact, compression is carried high enough so that the temperature of the compressed gas exceeds the ignition temperature of the fuel. This is compression ignition. It may require the volume after compression to be only one-fourteenth of that before compression, whereas it is only a fifth or a sixth in the gasoline engine. It is not possible to use compression ignition in the ordinary Otto cycle engine, because an inflammable charge is compressed, and the compression to the ignition temperature would cause spontaneous, uncontrolled, unregulated ignition. However, the charge compressed in the Diesel is fresh air—incombustible. This air is compressed until its pressure is over 500 pounds per square inch, and its temperature around 800° F. Then the oil is injected into the hot compressed air whose temperature is sufficiently high to cause immediate ignition of the spray.

The Diesel engine is built in both **two-cycle** and **four-cycle** types. The fuel is injected in one of two ways, either by being blown in and atomized by a high pressure air jet (air injection), or sprayed in through a fine nozzle tip under the influence of an extremely high oil pressure created by pumps (solid injection). Thus there are four possible combinations, but the types in general use are either the two-cycle solid injection, or the four-cycle air injection. Governing is accomplished by control of the fuel oil pump, more or less oil being delivered per stroke, depending on the load. For electrical generation even the multicylinder engines must be equipped with a heavy flywheel to prevent cyclic variation of speed.

All engines require a starting air system. In addition, the air-injection types require an injection air system and some airless-injection types have a scavenging air system. Both injection and scavenging air pumps are integral with the engine.

The temperatures existing in the stationary Diesel engine would soon break down the film of lubricating oil on the cylinder liners and otherwise put the engine out of service by warping of valves, pistons, etc., were the engine not cooled by circulating water through jackets surrounding the heated parts.

The heart of a Diesel engine is the combustion chamber end of its cylinder. The shape of the cylinder head and face of the piston, and the design of the nozzle and the injection system must be carefully considered. To obtain the complete combustion necessary to good efficiency, a fuel must be thoroughly mixed with the air charge, so that all particles of it will be burned. There must be good penetration of the oil spray into the highly compressed dense air, and there must be turbulence to insure mixing of the oil spray with the air. These two important characteristics are secured by special design, both of the cylinder head and the spray valve.

In the two-cycle engine there is no valve gear. The absence of this feature is, indeed, the virtue of the two-cycle principle. In the four-cycle engine the exhaust and inlet valves are mechanically operated from a camshaft. Since the Diesel engine is commonly rather large, the valves are correspondingly large in girth, and are operated from a massive camshaft. The illustration shows a cross-section taken through a four-cycle air injection Diesel engine. In it will be seen the camshaft bearing directly on the valve rocker arm (a very common arrangement in Diesel practice). The piston is of the trunk type with a piston head designed to promote turbulence. The injection air is obtained from an air compressor having the cylinder mounted integrally with the engine, and the piston driven from the engine crankshaft. The air compressor delivers air at about 800 pounds per square inch for blowing the oil into the cylinder.

While the Diesel engine is basically a slow-moving type, careful design has enabled manufacturers to build Diesels for much higher speed service. Diesels for 750 revolutions per minute are not uncommon, and a much higher rotative speed than this was achieved in the case of the Diesel aeronautical engine. (F.T.M.)

DIFFERENCE EQUATIONS. A difference equation may be described as an **equation** connecting values of an unknown **function** at two or more equally spaced values of the independent variable, as, for example, $u(x+h)-u(x)=2x+1$, or $u(x+2h)+2xu(x+h)-u(x)=x^2$.

A linear difference equation is one in which the unknown function $u(x)$ occurs linearly and the coefficients are functions of the independent variable only. A homogeneous difference equation contains no term independent of the unknown function u. (L.L.S.)

DIFFERENTIAL. The differential drive is an important element in the automobile. As a four-wheel vehicle rounds a corner, the outer wheels travel a greater distance than the inner. The wheels on a wagon are mounted on a dead axle, so that they turn independently of each other. On a live axle some device which will permit them to revolve at different speeds to compensate for the difference in travel when rounding a curve is necessary. The ordinary automobile differential is illustrated in Figure 1. The driveshaft has mounted on it pinion B, which drives gear C. If it were not for the necessity of rounding curves, gear C could be rigidly fixed to the live axle KK. The differential action is obtained as follows: Gear C is not keyed to the axle. The spider E is rigidly fastened to the gear and has mounted on it, free to turn, the bevel gear G. Gear G meshes with gears H_1 and H, each of which is keyed to a half of the axle. When traveling straight ahead, gears G, H_1, and H revolve with the spider, but do not have any motion relative to each other. When rounding a curve, one wheel must travel faster than the other. The

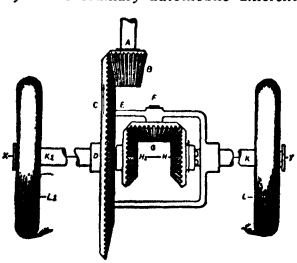


Figure 1. Bevel gear differential.

difference in rotation of the axle is compensated for by rotation of the differential gear G on its pin F Any accelerated motion of one wheel is offset by a retarded motion of the other

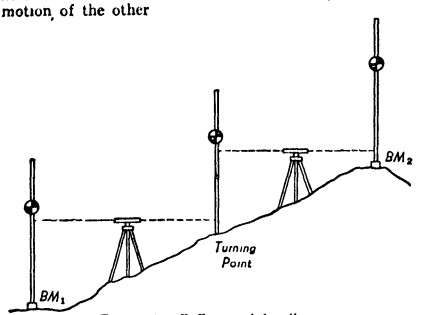


Figure 2 Differential levelling

Differential leveling is a system of surveying whereby the difference in elevation of two remote points is obtained through the use of the surveyor's **level** and **level rod** A chain or tape is not needed The procedure in differential leveling is illustrated in Figure 2 BM_1 represents a known **bench mark** The elevation of BM_2 is to be found The rod is held on BM_1 and the level set up so as to take a back sight on the rod The rodman then advances to a turning point chosen by the instrument operator, and the telescope is swung around for a foresight reading on the rod The levelman then advances the instrument to a new position, from which he takes a back sight on the rod, which is still at the turning point This procedure is continued until the rodman reaches the site of BM_2 The back sight reading, added to the elevation of BM_1, gives the elevation of the level at the first station The fore sight reading, subtracted from the instrument elevation, gives the elevation of the turning point In this way, by additions and subtractions of back sight and fore sight readings, the total difference of elevation between BM_1 and BM_2 is determined.

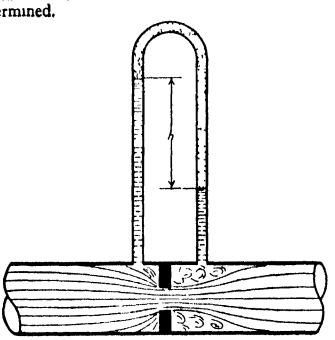


Figure 3. Differential gage.

The differential gauge is a U-tube so arranged as to measure small differences of pressure Such a tube is shown in Figure 3, where a fluid flowing across an orifice creates a certain difference of pressure which is to be measured The gauge liquid must be lighter than the liquid whose pressure is being measured, and be nonmiscible with it If the densities of the heavier and lighter liquids are d_1 and d, respectively, the difference of pressure measured by the gauge is $H(d_1 - d)$. A light oil is used when measuring small differences of pressure of flowing water

The term differential is also used in connection with the **chain. block.** (F T M)

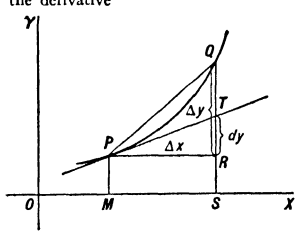
DIFFERENTIAL EQUATIONS. An equation which involves **derivatives** (or **differentials**) is called a differential equation

If **partial derivatives** occur in the equation, it is called a partial differential equation, if not, it is called an **ordinary differential equation** (L L S)

DIFFERENTIALS. A differential is a fundamental mathematical concept closely associated with the idea of the rate of change of a function

For a **function** of one variable, the differential is defined as follows Let $y = f(x)$ be a given function, assign an arbitrary increment Δx to x, then the function y takes an increment Δy given by $\Delta y = f'(x)\ \Delta x + \Delta x$, where $f'(x)$ is the **derivative** of y and ϵ is a variable which approaches 0 as $\Delta x \to 0$ Then the first term $f'(x)\ \Delta x$ is called the differential of $y = f(x)$, and is denoted by dy or $df(x)$ The differential of the **independent variable** x is the same as Δx, i e $dx = \Delta x$, but dy is not equal to Δy, where y is the function We may regard dy or $f'(x)\Delta x$ as an approximate value of Δy

Since $dy = f'(x)dx$, it follows that $f'(x) = dy/dx$, so that the derivative may be regarded as the quotient of dy by dx, which justifies the notation dy/dx commonly used for the derivative



In the accompanying figure, PT is the tangent to the curve $y = f(x)$ at the point P Then $PR = \Delta x$, $RQ = \Delta y$, and $RT = dy$

Since dy is an approximation to Δy, if x has a small error Δx, then Δy will be the corresponding error in y, and dy may be taken as the approximate small error in y

The differential of a function of several variables is defined as follows Let $u = f(x,y)$ be a function of two variables, and let x and y take arbitrary increments Δx and Δy, then the function u takes an increment Δu given by

$$\Delta u = \frac{\partial u}{\partial x}\ \Delta x + \frac{\partial u}{\partial y}\ \Delta y + \epsilon_1\ \Delta x + \epsilon_2\ \Delta y,$$

where ϵ_1 and ϵ_2 approach 0 as $\Delta x \to 0$ and $\Delta y \to 0$ Similarly for a function of three or more variables The total differential of the function $u = f(x, y)$ is defined as the principal part of the total increment Δu

$$du = \frac{\partial u}{\partial x} \cdot \Delta x + \frac{\partial u}{\partial y}\ \Delta y.$$

It follows that $\Delta x = dx$ and $\Delta y = dy$ for the independent variables Hence

$$du = \frac{\partial u}{\partial x}\ dx + \frac{\partial u}{\partial y} \cdot dy$$

Similarly for functions of three or more variables

For the calculation of small errors in a function of several variables $u = f(x, y)$, we can use du as an approximation to Δu, so that if $\Delta x = dx$ and $\Delta y = dy$ are small errors in the independent variables, then $du = \frac{\partial u}{\partial x}\ dx + \frac{\partial u}{\partial y}\ dy$ is the approximate small error in u (L L S)

DIFFERENTIATION. In geology, differentiation refers to the general process of formation of different types of igneous rocks from a common parent magma

In mathematics, the use of the term differentiation is discussed in the articles on **Derivative of the Function of a Variable;** and **Differentiation, Technique of Mathematical**

In biology, differentiation is the development of the varied structures within living units through which special functions are performed Differentiation is expressed within the cell in its various parts and in one-celled organisms further differentiation gives rise to the **organelles** which carry on locomotion, digestion, and other functions In the complex body during its development this process results in the appearance of the different kinds of cells, tissues, and organs which ultimately compose the individual (A W L, R M F)

DIFFERENTIATION, TECHNIQUE OF (MATHEMATICAL) General **differentiation** rules, and differentiation rules for **alegbraic functions:**

1 The **derivative** of a **constant** is zero. $\frac{d}{dx}(c) = 0$

2 The derivative of an algebraic sum of any number of functions is equal to the algebraic sum of their derivatives

$$\frac{d}{dx}(u + v + w) = \frac{du}{dx} + \frac{dv}{dx} + \frac{dw}{dx}$$

3 The derivative of a constant times a function is equal to the constant times the derivative of the function.

$$\frac{d}{dx}(cu) = c\,\frac{du}{dx}$$

4 The derivative of the product of two functions is equal to the first factor times the derivative of the second plus the second factor times the derivative of the first

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$$

5 The derivative of the quotient of two functions is equal to the denominator times the derivative of the numerator minus the numerator times the derivative of the denominator, all divided by the square of the denominator

$$\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{v\dfrac{du}{dx} - u\dfrac{dv}{dx}}{v^2}.$$

6 The derivative of a constant **power** of a function is equal to the **exponent** times the function with its exponent diminished by one times the derivative of the function.

$$\frac{d}{dx}(u^n) = nu^{n-1}\frac{du}{dx}.$$

7 The derivative of a function of a function is expressed by If y is a function of z and z is a function of x, then

$$\frac{dy}{dx} = \frac{dy}{dz}\,\frac{dz}{dx}.$$

8 If $x = \phi(y)$ is the **inverse function** to $y = f(x)$, then the derivatives of these two functions are **reciprocals** of each other $\frac{dx}{dy} = 1/\frac{dy}{dx}$.

9 The derivative of the **exponential function** is given by:

$$\frac{d}{dx}(a^u) = a^u \log_e a\,\frac{du}{dx}\ (a \text{ constant}),$$

$$\frac{d}{dx}(e^u) = e^u\frac{du}{dx},\quad \frac{d}{dx}(e^x) = e^x.$$

10 The derivative of the **logarithmic function** is given by.

$$\frac{d}{dx}(\log_a u) = \frac{1}{u}\cdot\log_a e\cdot\frac{du}{dx},$$

$$\frac{d}{dx}(\log_e u) = \frac{1}{u}\,\frac{du}{dx},$$

$$\frac{d}{dx}(\log_{10} u) = \frac{M}{u}\,\frac{du}{dx},\quad \text{where } M = \log_{10} e,$$

$$\frac{d}{dx}(\log_e x) = \frac{1}{x},\quad \frac{d}{dx}(\log_{10} x) = \frac{M}{x}.$$

11 The derivatives of the **trigonometric functions** are given by

$$\frac{d}{dx}(\sin u) = \cos u\,\frac{du}{dx},\qquad \frac{d}{dx}(\cos u) = -\sin u\cdot\frac{du}{dx},$$

$$\frac{d}{dx}(\tan u) = \sec^2 u\,\frac{du}{dx},\qquad \frac{d}{dx}(\cot u) = -\csc^2 u\,\frac{du}{dx},$$

$$\frac{d}{dx}(\sec u) = \sec u\tan u\,\frac{du}{dx},\quad \frac{d}{dx}(\csc u) = -\csc u\cot u\,\frac{du}{dx}.$$

12 The derivatives of the **inverse trigonometric functions** are given by

$$\frac{d}{dx}(\sin^{-1} u) = \frac{1}{\sqrt{1-u^2}}\cdot\frac{du}{dx},$$

$$\frac{d}{dx}(\cos^{-1} u) = -\frac{1}{\sqrt{1-u^2}}\,\frac{du}{dx},$$

$$\frac{d}{dx}(\tan^{-1} u) = \frac{1}{1+u^2}\,\frac{du}{dx},$$

$$\frac{d}{dx}(\cot^{-1} u) = -\frac{1}{1+u^2}\,\frac{du}{dx},$$

$$\frac{d}{dx}(\sec^{-1} u) = \frac{1}{u\sqrt{u^2-1}}\,\frac{du}{dx},$$

$$\frac{d}{dx}(\csc^{-1} u) = -\frac{1}{u\sqrt{u^2-1}}\cdot\frac{du}{dx}.$$

13 For the differentiation of an **implicit function** in two variables, say $F(x, y) = 0$ differentiate each term of the equation $F(x, y) = 0$ with respect to x, regarding y as a function of x, solve the resulting equation for $\frac{dy}{dx}$ In general, the derivative $\frac{dy}{dx}$ will involve both x and y

In terms of partial derivatives, this rule amounts to

$$\frac{dy}{dx} = -\frac{\partial F}{\partial x}\Big/\frac{\partial F}{\partial y}.$$

14 If y is given as a function of x by means of **parametric equations.** $x = \phi(t)$, $y = \psi(t)$, then the derivative of y is given by

$$\frac{dy}{dx} = \frac{dy}{dt}\Big/\frac{dx}{dt} = \phi'(t)\,/\,\psi'(t) \qquad \text{(L L S)}$$

DIFFERENTIATION UNDER THE INTEGRAL SIGN. For the **differentiation** of a **definite integral** of a **function** $f(x,\alpha)$ containing a parameter α, when the limits of the integral are constants a and b, we have the formula

$$\frac{d}{d\alpha}\int_a^b f(x,\alpha)dx = \int_a^b \frac{\partial f}{\partial \alpha}\cdot dx,$$

and when the limits of the integral are functions of α u and v, we have the formula

$$\frac{d}{d\alpha}\int_u^v f(x,\alpha)dx = \int_u^v \frac{\partial f}{\partial \alpha}dx + f(v,\alpha)\frac{dv}{d\alpha} - f(u,\alpha)\frac{du}{d\alpha}.$$

(L L S)

DIFFRACTION. A class of phenomena arising from the interruption of a wave-train, as of light, by one or more opaque obstacles For example, if light from a point source passes the edge of a postcard and falls upon

a white screen, the shadow of the edge is not sharply defined, but deepens to darkness gradually on one side, and is bordered by very narrow alternate bright and dark **interference** fringes (diffraction bands) on the other

The flux density at any point P in an uninterrupted wave field is either constant or varies progressively with the position of P But if the waves have to pass obstacles before reaching the point P, there not only will be shadows, but also the flux density at P will be subject to interference effects due to phase differences in the waves reaching it from different parts of the advancing wave front (See **Huygen's Principle**) The **diffraction grating** and the **zone plate** are dependent upon well-recognized diffraction principles

The image of a minute opaque speck under magnification against a bright background is surrounded by concentric diffraction rings The image of a bright object, such as a star, as formed in the focal plane of a converging lens, is also surrounded by diffraction rings If two such images are close together the fringe systems will overlap and no matter how much magnification is applied it will never be possible to obtain clear, well-separated, images of the points The angular diameters of the diffraction rings depend in the case of the opaque objects upon the sizes of the specks, the smaller the specks the larger the rings In the case of the star images the larger the diameter of the lens forming the image, the smaller the diameter of the diffraction fringes The resolving power of an optical instrument may be defined as a measure of the sharpness with which small images very closely together may be distinguished Hence diffraction limits the resolving power of optical instruments In the case of astronomical **telescopes** the larger the object glass, the greater will be the resolving power of the telescope (L D W)

DIFFRACTION GRATING. A series of very fine, closely spaced parallel slits, or of very narrow, parallel reflecting surfaces, which, when light is incident upon it at a definite angle, produces a succession of spectra The complete optical theory is somewhat complicated, but the action of a plane transmission grating may be explained approximately as follows

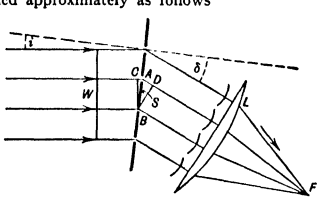


Diagram showing diffraction by a plane grating

A plane, monochromatic light wave W, incident at angle i (see figure), reaches the slits at different times A lens L receives the waves emerging from any two adjacent slots, A and B (among many others), after they have traveled paths differing by $CA + AD$, that is, by $S \sin i + S \sin \delta$, in which $S = AB$ If the lens is so placed that this path difference is a whole number of wave lengths, $n\lambda$, the successive wave-trains will reach it in the same phase, so that when they are brought to the focus F, they will be in synchronism and will produce a bright image of the distant source Therefore any angle δ for which this result is possible is subject to the condition

$$S \sin i + S \sin \delta = n\lambda,$$

or

$$\sin \delta = \frac{n\lambda}{S} - \sin i$$

Bright images will be produced for those angles δ which correspond to $n = 1,2,3,4, \ldots$, the numbers denote the "orders" of the images It is easily shown that for any order the total deviation $(i + \delta)$ is least when $\delta = i$ and therefore when $\sin \delta = \frac{n\lambda}{2S}$ If the incident light is composed of various wave lengths, the corresponding images of any order will appear at different points, since δ varies with λ, and the result is a **spectrum** In short, the grating acts as a **dispersion** piece, and as such is of great value in **spectroscopes.**

For high dispersion the slits must be very fine and very close together (S small), and for high resolving power (sharpness of spectral lines) the total number of slits must be large Gratings having several thousand slits to the inch of width are common They may be made by ruling fine scratches with a diamond point on glass, or, with reflecting gratings, on polished metal If the rulings are not spaced with absolute regularity, false lines, called "ghosts," appear in the spectrum

Rowland was the first to rule reflection gratings on concave metal surfaces Such gratings eliminate the necessity of the spectroscope collimator or focusing lenses, as they take light direct from the spectroscope slit and form the spectral-line images like a concave mirror. The **echelon** is another special type of grating (L D W)

DIFFUSER. A diffuser is a passage so shaped that it will change the characteristics of a fluid flow from a certain pressure and velocity to a lower velocity and a higher pressure The diffusion must be carried out in a well-streamlined passage having smooth interior surfaces, and sides not diverging at so great an angle as to cause the fluid to leave the sides of the diffusing chamber By reducing the velocity through increasing the cross-sectional area of flow, the pressure may be built up as the velocity head is diminished Diffusers are applied to centrifugal **fans, centrifugal pumps,** jet pumps, **wind tunnels,** and other equipment where it is required to conserve energy by efficiently converting velocity head into pressure (F T M)

DIFFUSION OF FLUIDS The **molecules** of a gas or of a liquid wander about ceaselessly, colliding frequently and exchanging kinetic energy, but maintaining a certain aimless progress If an enclosure contains two gases, the lighter initially above and the heavier below, the gases at once begin to mingle because of their molecular motion The same is true of a dense solution (as of sugar) and pure water, both the sugar and the water molecules wander across the boundary, so that in the course of time the whole body of liquid attains nearly uniform concentration The process whereby this is effected is called diffusion In the case of fluids of different color, its progress may be easily watched

The rates at which different gases diffuse at a given temperature are inversely proportional to the square roots of their molecular weights Thus, hydrogen diffuses four times as fast as oxygen This follows, according to the **kinetic theory,** from the fact that the molecules of various kinds have the same mean kinetic energy and hence their mean square speeds are in the inverse ratio of their masses In the case of a solution of non-uniform concentration, the diffusion of the solute from the more to the less concentrated regions takes place in accordance with Fick's law, expressed by the equation

$$\frac{dm}{dt} = -DS\frac{dc}{dx}$$

This gives the mass of solute diffused per unit time through a cross-section S, in terms of the concentration gradient dc/dx in the direction x perpendicular to the cross-section D is a constant for the given solute and solvent at a given temperature, and is called the diffusion coefficient For any one pair of substances, D is found to be proportional to the absolute temperature It should be stated that these laws apply only to non-electrolytic solutions.

Both gases and solutions exhibit selective diffusion through suitable porous partitions or membranes. Partitions may be used which will allow the smaller but not the larger molecules to pass through There results an increase of pressure on the side where the larger molecules are The phenomenon is called osmosis, and the osmotic pressures thus developed play an important part in many physiological processes (L D W)

DIFFUSION PUMP. Air Pumps.

DIGESTER. In the process of paper making, the wood is first reduced to chips, which are then reduced to a pulp by cooking with a solvent in a digester In the two principal methods of chemical pulp manufacture, either soda or sulfite liquor is mixed with the chips in the digester tank in definite proportions The whole is heated for several hours by high pressure steam During this process the wood chips are disintegrated, freeing the cellulose for further use in the papermaking process (F T M)

DIGESTION. The process of mechanical treatment and chemical transformation by which food is prepared for absorption by the body

The **foods** of animals consist of the complex organic materials, **proteins, carbohydrates,** and **fats** Proteins are abundant in lean meat and in some plant products, including beans Carbohydrates include starches and sugars and fats include both the animal fats and vegetable oils such as occur abundantly in nuts With the exception of a few simple sugars (grape sugar) none of these materials can be absorbed into the animal body without first being transformed into simpler compounds

In the **digestive system** the foods are mixed with secretions containing **enzymes** which bring about the chemical changes The mixing is accomplished by mechanical processes dependent upon muscular action Some animals chew their food to break it up into smaller particles and others grind it in a special region of the tubular tract Once the food enters the tubular alimentary tract of the more complex animals such as man, it is propelled and mixed by peristalsis

The enzymes in the digestive secretions change the food by hydrolysis, a process in which molecules of food and water together are split into molecules of simpler composition Ultimately proteins are broken up into amino acids, the carbohydrates into simple sugars, and the fats into fatty acids and glycerol These end-products are absorbed into the tissues of the body and there used to synthesize the necessary proteins, carbohydrates, and fats, differing chemically from those originally taken in as food (A W L)

DIGESTIVE SYSTEM The organic system which receives food and prepares it for absorption

One-celled animals and **sponges** take food into the cell to be transformed by a process of intracellular digestion While this process persists to a limited extent in **coelenterates,** flatworms, and mollusks (**Mollusca**), these and all other animals also have some form of digestive system or alimentary tract in which food is retained for extracellular digestion preceding absorption Secretions are discharged into this tract by the cells of its lining and are mixed with the food The cavity is lined with endodermal tissue, in many cases supplemented by ectodermal ingrowths at both ends

The simplest form of digestive system is the **enteric cavity** of coelenterate **polyps** It is little more than a sac with one opening through which food enters and undigested wastes are discharged In the flatworms a similar condition prevails, but in both the **jellyfishes** and in some flatworms the cavity is complex, extending throughout the body in a system of canals or branches which distribute the food as well as absorb it From the roundworms through the remainder of the animal kingdom the system is tubular, opening at one end by the mouth and at the other by the anus.

In the tubular digestive tract specialization of digestion reaches a maximum Here food passes successively through different regions instead of being mixed indiscriminately, hence each region may subject it to special treatment The chief regions are those which aid in securing food, simple passages, storage reservoirs, grinding structures, and digestive regions which include chambers and tubular regions. In addition glandular derivatives of the lining are so highly developed that they become separate organs associated with the tubular tract by slender ducts

Some of the worms have a very simple tract with a muscular **pharynx** which aids in securing food and a long simple intestine, in which it is digested Other animals, including the leeches, insects, and birds, have a crop in which food is stored prior to digestion The **mastax** of rotifers and the **gizzard** of birds are examples of grinding structures

The mammalian alimentary tract is a good example of regional specialization The oral cavity with its teeth provides for chewing and some digestion, the **pharynx** and **oesophagus** furnish a passage to the **stomach,** where food is stored and slightly digested, the small **intestine** completes digestion and absorbs the end-products, the large intestine absorbs water, and the rectum stores the remaining wastes for periodical discharge by way of the anus Glands associated with this tract are the **salivary glands,** the **liver,** and the **pancreas.** (A W L)

DIGITALIS. Digitalis purpurea.

DIGITALIS PURPUREA. Digitalis **Foxglove** Scrophulariaceae The foxglove is a biennial often grown as an ornamental plant The first year of growth produces only the long basal leaves, while in the second year the erect leafy stem two to five feet tall is developed The flowers are borne in a **raceme** which through the bending of the **peduncles** or individual flower **stalks** becomes one-sided The purple flowers have a five-parted **calyx**, a tubular bell-shaped **corolla** obscurely five-lobed, five **stamens** and a single **pistil.** They are pollinated mainly by bees The fruit is a two-celled capsule

The drug digitalin is prepared mostly from digitalis leaves of the second year's growth These are rather coarse ovate leaves covered with glandular hairs Decoctions of the leaves have been used in Europe for many years

Digitalin is one of the most valued **drugs** in medicine and is used in certain kinds of **heart** disease It can be given by mouth, rectum or hypodermically. The chief effects it has on the heart are the regulation of its rate, rhythm, tone, contraction, and conduction of impulses

As a crop plant, digitalis is grown in England, Germany, and in the United States, especially in Michigan Propagation is by seeds, which are sown under glass and later transplanted (R M W, R S M)

DIGITATE DRAINAGE. The term applied to the finger-like pattern of stream valleys Such a stream pattern usually develops only when the underlying formations are relatively horizontal or if folded, faulted, or **metamorphosed,** are relatively of equal hardness and solubility (R M F)

DIHEDRAL. The dihedral of an airplane measures the amount of tilt of the wings upward from a normal horizontal axis. Though the right and left wing of an airplane may, to the casual observer, appear to be rigged in a straight line, actually there is a slight angle between them This is for the purpose of procuring lateral stability. The low wing monoplane is inherently less stable than the high wing monoplane or the biplane, and one will note that its wings are set at a very pronounced angle. Dihedral is measured in degrees from

the normal horizontal axis to the plane of the wing It is ordinarily from one to four degrees in magnitude (F T M.)

DIHEDRAL ANGLE. A dihedral angle is formed by two intersecting planes, it is measured by the corresponding plane angle formed by drawing a plane perpendicular to the intersection of the planes (L L S)

DIKE (DYKE). A tabular, intrusive mass of **igneous** rock which cuts across other igneous rock bodies, such as batholiths, or cuts across the **bedding** (stratification) of lavas or **sedimentary** formations Not to be confused, in the chemical and mineralogical sense, with **veins**; or, in the structural sense, with **sills.** (R M F.)

DILL. Carrot Family.

DILUTION. The reduction of sewage waste to a liquid requires its oxidation Dilution of the sewage using a large amount of water having in it dissolved oxygen is a means of accomplishing this end Dilution refers, in sanitary engineering, to this particular phase of sewage disposal The amount of dilution necessary in any particular case depends on the oxygen demand of the sewage and the oxygen content of the diluting stream over and above its other oxygen requirements, such as for fish-life Knowing these dilution factors, it is possible to determine the maximum volume of sewage which can be accommodated in any particular stream without raising objectionable conditions (F T M)

DILUVIUM. Derived from the Latin **diluo**, to wash apart, through **diluvialis**, flood A relatively obsolete geologic term formerly applied to certain water-laid deposits within or bordering the glaciation regions of Europe and North America Most of the sediments which were previously thought to have been the result of the "flood," and which are now known to be stratified **drift**, were called diluvium In Germany, the term corresponds to our **Pleistocene** (R M F)

DIMENSION FORMULAE Physical Magnitudes and Physical Equations.

DIMORPHISM The occurrence of individuals of two forms in the same species

In its broadest application dimorphism includes the alternation of forms such as the **polyp** and **medusa** of the **coelenterates.** It is commonly used to indicate less fundamental differences due to the conditions attending the development of essentially similar individuals Thus some of our **butterflies** differ noticeably in the generation developed during the summer and that which emerges in the spring after passing the winter in an immature stage This condition is seasonal dimorphism, as also is the occurrence of wet- and dry-season forms in some tropical species Conspicuous difference between the sexes other than reproductive adaptations is sexual dimorphism This term is also sometimes applied to the occurrence of two forms in a single sex, like the black and yellow females of the common yellow swallowtail butterfly (A W I)

DINGO. Mammalia, Carnivora A wild **dog**, *Canis dingo*, found in forested areas of Australia It is probably descended from dogs introduced long ago

The dingo is a serious enemy of sheep and has been killed in large numbers for its depredations (A W L)

DINOFLAGELLIDA. An order of one-celled animals Chiefly marine species, whose body is surrounded by an envelop of **cellulose**, often beautifully figured. **Mastigophora** (A W L)

DINOSAURS. Fossil reptiles.

DIOECIOUS. With separate sexes Organs of only one sex developed in each individual.

There are many species of plants in which the flowers are unisexual, that is, have either stamens or pistils, but not both If these two types of flowers occur on different plants, the plants are said to be dioecious The willow is such a plant (R M W)

DIOPSIDE. The mineral diopside is a **monoclinic pyroxene** corresponding to the chemical formula $CaMg(SiO_3)_2$, **calcium magnesium silicate** Its crystals, like other pyroxenes, tend to be short stout prisms of square or octagonal cross-section Compact, granular, lamellar and fibrous varieties are often found The prismatic cleavage is characteristic, cleavage planes intersecting at angles of 87° and 93° A basal parting is often noted, but should not be confused with the cleavage The hardness of diopside is 5 to 6, specific gravity, 3 2–3 3, uneven fracture tending toward conchoidal, luster, vitreous to dull, sometimes pearly on the base, color, light or dark greens, but may be colorless, gray, yellow or blue, although the latter color is rare Diopside is a primary mineral in rocks like diorites, gabbros and the like, but is also found in schists, and, as the result of contact metamorphism, in such rocks as crystalline limestones and dolomites Diopside is found in association with **vesuvianite, garnet, spinel, scapolite, tremolite, tourmaline** and similar minerals It is a rather widespread mineral, important localities being found in the following European countries Finland, Sweden, Switzerland, Italy, it is found in eastern Siberia near Lake Baikal In Canada diopside localities are in Lanark and Hastings Counties, Province of Ontario, and in the United States in Lewis and St Lawrence Counties, New York, and in Maine

Two varieties of diopside, **malacolite** and alalite, both of a leaf green color, have been somewhat used as gem stones The word diopside is derived from the Greek meaning double and appearance, referring to its double refraction Malacolite is also from the Greek, meaning soft, because of being softer than feldspar found with it

Alalite is from the Ala Valley, in the Italian Piedmont (E S C S)

DIOPTASE. The mineral dioptase is a rather rare **copper silicate** corresponding to the formula H_2CuSiO_4 occurring in prismatic crystals of the **hexagonal** system, tri-rhombohedral in form It may be found in crystalline aggregates or simply massive Dioptase displays a conchoidal to uneven fracture, hardness, 5, specific gravity, 3 28–3 35, luster, vitreous, color, a beautiful emerald green It has been found in Russia, French Congo, Belgian Congo, South West Africa, Chile, and in the United States in Arizona The name is derived from the Greek words meaning through and to see, because cleavage was observed by looking through the crystals (E S C S)

DIORITE. Diorite is a deep-seated **igneous rock** composed dominantly of **sodiaplagioclase feldspar** with **hornblende, biotite,** and (or) **augite Orthoclase** may be present in small amounts, also **quartz** Any considerable proportion of the latter mineral produces a quartz-diorite With increasing amount of orthoclase, we have granodiorite, which is generally understood to be a rock intermediate in character between quartz-diorite and granite If quartz is absent and there are essentially equal amounts of orthoclase and plagioclase the rock is then known as a monzonite from the type locality, Monzoni, in the Tyrol There are quartz monzonites and, where the deficiency of silica is great enough, nephelite monzonites. Rocks of the latter sort have been reported from Madagascar A variety of quartz, diorite containing both hornblende and biotite is called tonalite from the Tonale Alps, although the rock found there is more nearly a granodiorite The word diorite is derived from the Greek meaning distinctive or defining, in contrast to the deceptive dolerites. The diorites are of widespread occurrence (E S C S)

DIOSPYROS EBENUM. Ebony. Ebonaceae. The ebony tree is a native of India and Ceylon. It is a large tree with entire leathery leaves and axillary flowers. The wood of the tree is divided sharply into a soft white sapwood of little value and a hard very dark heartwood. The latter is much used for inlay work, for black piano keys, for musical instruments, and for handles of various instruments. Many other species of *Diospyros* have dark woods used as a substitute for true ebony. The wood of several other trees, especially that of the pear tree, are frequently stained to imitate ebony.

Other species of *Diospyros* are esteemed for their fruits. Especially so are *Diospyros virginiana*, the American persimmon, and *D. Kaki*, the Japanese persimmon. *Diospyros virginiana* is a large American tree, 60–100 feet high, with rather thick ovate-oblong leaves and pale yellow axillary flowers. The fruit is a large globular berry an inch or more in diameter, orange-yellow in color, and very astringent until fully ripe. The astringent quality is due to the presence of much soluble **tannin**, which is gradually formed into an insoluble compound as the fruit ripens, so that the mouth-puckering quality is lost. Frost action has been considered by many to be the cause of the change in the fruit. The American persimmon is hardy as far north as Rhode Island. The Japanese persimmon is a smaller tree, seldom growing more than 40 feet tall, and is less hardy. Its fruits are larger than those of the American tree, and of reddish color. Both trees have a hard dark wood. (R.M.W.)

DIOTOCARDIA. An order of mollusks, mostly marine species. **Gasteropoda.** (A.W.L.)

DIP. Anticline.

DIP FAULT. Fault.

DIPHENYL. Hydrocarbons.

DIPHTHERIA. An acute infectious disease caused by the diphtheria bacillus. (In some forms it is popularly called membranous croup.) It produces a marked inflammatory reaction of the throat and air passages with production of a membrane on the involved surfaces. The constitutional symptoms are caused by the toxins liberated by the diphtheria organisms.

Susceptibility to diphtheria varies. It is most marked in young children. As they grow older, a certain number develop some degree of natural immunity. An artificial immunity is very generally given now by the injection of toxin-antitoxin—or more recently by the use of Toxoid. Even those who have been actively exposed to infection can be protected if antitoxin is given immediately.

A very valuable indication as to the body's immunity to diphtheria is the Schick Test. This test has shown that from 85% to 95% of all children are susceptible to this disease at the end of the first year of life unless artificially immunized.

Diphtheria is spread by direct contact with infected nose and throat discharges. After infection takes place the disease takes from two to five days to develop. It is characterized by the production of a typical membrane on the affected portions. In most cases the membrane is sharply defined. It is difficult to remove, and leaves a raw bleeding surface on which a new membrane soon forms. In moderately severe cases the fever and constitutional symptoms continue for five or six days, after which recovery takes place if no complication develops. In septic diphtheria the patient is profoundly ill, the temperature is higher and recovery is slower. The mortality is higher in this form. In the hemorrhagic form the toxemia is very severe, and hemorrhages occur beneath the skin. Death frequently takes place within a week.

The most frequent complications of diphtheria are bronchopneumonia, hemorrhage from the nose and throat, **nephritis**, heart complications, and **paralysis**. The paralysis may involve different groups of muscles and is caused by the diphtheria toxins circulating throughout the system.

The greatest advance in the treatment of diphtheria has been the discovery of antitoxin (in 1891 by von Behring and Wernicke). Before this was made, the mortality was about 35% as compared to the present rate of about 5%. It is the only effective treatment, and if given during the first twenty-four hours of the disease nearly every patient can be saved. As late as the third or fourth day striking improvement may be observed. After that its value diminishes rapidly. Within twenty-four hours after giving the antitoxin the patient shows signs of recovery—the membrane stops spreading and the tissues of the throat stop swelling.

Certain cases of laryngeal diphtheria develop obstruction to breathing and require intubation—that is, the insertion of a tube through the mouth past the obstruction in the air passages. This procedure is used but seldom since the development of antitoxin. (R.S.M.)

DIPLEURULA. A bilaterally symmetrical **larva** of the **echinoderms**. It is formed from the **gastrula** by the breaking through of a depression to form the mouth and by the assumption of a form peculiar to the several classes, usually with projecting lobes. The cilia of the outer surface become arranged in a band in most classes. The **auricularia**, **bipinnaria**, and **pluteus** are forms of dipleurula larvae. (A.W.L.)

DIPLOBLASTIC. Derived from two embryonic germ layers. The first step in the formation of tissues in the developing multicellular animal is the formation of two layers, one covering the outside of the body and the other lining a cavity within it. These are the ectoderm and endoderm, respectively. The bodies of **sponges**, **coelenterates**, and possibly **ctenophores** develop by the further differentiation of these two layers alone. (A.W.L.)

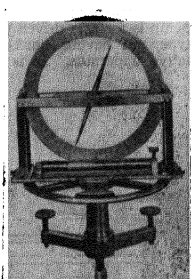
DIPLOPODA. The millipedes. A class of the phylum **Arthropoda.**

Millipede.

Millipedes are wormlike animals with a head and segmented body. Each segment bears two pairs of legs, excepting the first and last few. The head bears a pair of antennae and in some species a pair of eyes. Most millipedes have a cylindrical body.

These animals live in moist places, usually among rubbish on the surface of the ground, and eat decaying organic matter or plant tissues. Some attack roots and are therefore of economic importance.

The class is divided into two orders, Pselaphognatha and Chilognatha. All common species belong to the latter. (A.W.L.)



Photograph of dip needle or magnetic inclinometer.

DIPLOSOME. See **cell.** A centrosome with two centrioles.

DIP NEEDLE. More properly called an inclinometer. The instrument consists essentially of a magnetic needle poised to swing on a horizontal pivot and thus to indicate the "dip" or inclination of the earth's magnetic field. (See **Terrestrial Magnetism.**) The zero diam-

eter of the vertical graduated circle should be carefully leveled and adjusted to the magnetic meridian. In order to correct for errors of level, balance, magnetization, and eccentricity, the circle should be reversed north to south, the needle axis should be reversed in its bearings, the magnetization should be reversed, and for each of these positions both ends of the needle should be read on the circle. A complete observation is thus the mean of sixteen circle readings. (L.D.W.)

DIPNOI, DIPNEUSTI. The lungfishes. An order of the class **Pisces** made up of a few species found in Australia, Africa, and South America. They have an air sac opening from the **pharynx** which serves as a lung. These fishes live in marshes and intermittent streams. When the water becomes stagnant they thrive by breathing air at the surface and when it dries up completely they form cells in the mud at the bottom with a vent leading to the surface and lie dormant until the pond is renewed. (See also **Fossil Fishes.**) (A.W.L.)

DIP OF HORIZON. Horizon.

DIPPER. Aves, Passeriformes. The water **ouzel.**

DIPSOMANIA. A chronically disturbed state of the mind or personality which causes an individual to have constant recourse to alcohol. It is almost always a conscious or unconscious attempt to obtain forgetfulness or escape from the realities or failures of life. (R.S.M.)

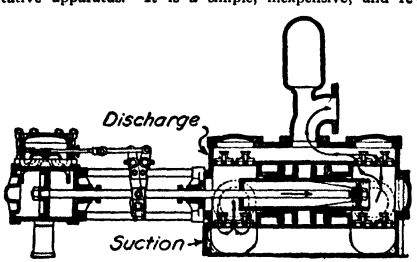
DIPTERA. Flies, mosquitoes, midges, gnats and other **insects.** An order characterized by sucking and sometimes piercing mouths and the presence of a single pair of wings. The hind wings are represented by the halteres, slender clubbed appendages, often inconspicuous. A few species lack wings. The metamorphosis is complete and the larvae of many species are known as maggots.

This is one of the largest orders of insects, with about 50,000 described species, and in variety of adaptations it is exceeded by no other. Some species suck the juices of plants, some eat the tissues during larval life, some visit flowers for nectar, some suck blood, some are parasitic inside or outside the bodies of warm-blooded animals, and many are parasitic on other insects or are predacious. Many are scavengers, living on decaying organic matter or on the wastes of animals.

Species of economic importance include some of the plant feeders, such as the **Hessian fly**, the blood-sucking **horse flies** and **mosquitoes**, and the parasitic **bot flies.** (A.W.L.)

DIPTERUS. Fossil fishes.

DIRECT ACTING PUMP. The direct acting pump is a steam-driven **pump** of the piston and cylinder type, not having crankshafts, flywheels, or similar rotative apparatus. It is a simple, inexpensive, and reliable piece of equipment—but inefficient as a pumping unit. However, as the heat of the exhaust steam can often be recovered in feed water the low thermal efficiency is not of much importance. In construction it consists of steam and water cylinders the pistons of which are rigidly connected by a pump rod. The steam piston must have a larger diameter than the water piston when the pump is used in boiler feed service. If p is the boiler gauge pressure, p_h the static plus friction head on the water end, p_f the friction drop in the steam pipe, $A_w p_t$, the pounds excess push required to overcome pump friction, water inertia, etc., A_w, D_w, A_s, D_s area and diameter of steam and water pistons:



Direct acting pump.

$$\frac{D_s}{D_w} = \sqrt{\frac{p + p_h + p_f}{p - p_f}}$$ (all p's being expressed in lbs./sq. in.)

p_t involves the design and operating characteristics of the pump. In order to insure ample operating pressure D_s/D_w is made large enough to include considerable margin of reserve, being about 1.6 for ordinary boiler feed service and 2.5 for low-pressure feed service. Control of capacity is exercised through speed variation by throttling the steam line (i.e., adding a throttle pressure drop to p_f). In practice, units are rated at maximum piston speeds of 100 feet per minute, but should actually be operated at between 25 and 40 strokes per minute. The pulsation of delivery is absorbed by an air compression chamber placed in the discharge line.

The direct-acting steam pump consumes from 100 to 300 pounds of steam per horsepower hour. Thermal efficiency is so low as to have no comparative meaning and in its place is substituted pump duty; that is, the foot pounds work done in the pump cylinders per million B.T.U. chargeable to the steam end. The high steam consumption is caused by non-expansive use of the steam. Were the steam expanded the pump would stall before reaching the end of its stroke unless the ratio D_s/D_w were extremely large and a flywheel provided to steady the speed. (F.T.M.)

DIRECT CURRENT CIRCUITS. Unidirectional current is produced from batteries, from dynamo machinery equipped with **brushes,** or by means of **rectifiers.** The great disadvantage of direct current is the fact that until recently it has not been commercially expedient to transform it from low voltage to the high voltage necessary for long-distance transmission of electrical power. Difficulties of **commutation** prevent generation at high voltages. Recently the use of vacuum tubes, such as the thyratron tube, has opened up new transmission possibilities for direct current.

In lighting and heating apparatus there is not much difference between direct and alternating current. Direct current motors are more expensive than alternating current of equivalent power rating, but they have better operating characteristics and simpler speed control. Inductance and capacitance are factors unknown to direct current transmission.

The basis for most direct current circuit calculations is **Ohm's Law.** Ohm's Law is stated:

$$E = IR \text{ volts}$$

E is the voltage drop across the resistance of R ohms when I amperes flow. If conductors are connected in series, the overall resistance of the circuit is the sum of the resistances of the separate conductors. If, however, they are connected in parallel, the reciprocal of overall resistances is obtained by summing the reciprocals of the individual resistances. Therefore, adding more wires in series increases the overall resistances of the conductors, but decreases it if they are connected in parallel. In any complex direct current network, it will always be true that first, the sum of currents flowing to a joint will equal the sum of currents flowing away from that joint; second, the algebraic sum of the impressed voltage on any circuit will be equaled by the sum of the resistance voltage drops on that same circuit. The electrical power flowing in a direct current circuit is found by multiplying the voltage by the current, the unit of power being watts. Heat which is generated by elec-

trical current flowing through a resistance of R ohms for T seconds is

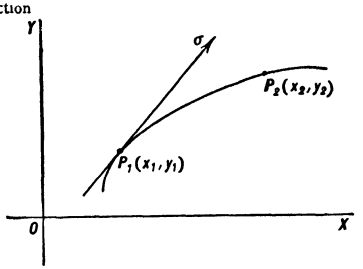
$$\text{Heat} = I^2RT \text{ watt-seconds}$$

The watt-second is a unit of electrical energy so small that 1055 watt-seconds are required to equal a British Thermal Unit See **Electric Circuits.** (F T M)

DIRECT MOTION. Planetary motion.

DIRECTION COSINES OF A LINE IN SPACE. Let a set of **rectangular coordinate** axes in space be chosen, and let l be any line in space Through the origin O of the coordinate system draw a line l' parallel to the given line l Let α, β, γ be the angles which line l' makes with the X-, Y-, Z-axes respectively Then these angles α, β, γ are called the direction angles of the given line l, and cos α, cos β, cos γ are called the direction cosines of the line l (L L S)

DIRECTIONAL DERIVATIVES A directional derivative is an important mathematical concept which expresses the rate of change of a function in any given direction



Let $u(x,y)$ be a **continuous function** in a region S of the plane, let $P_1(x_1,y_1)$ be a fixed point in S and let C be a curve passing through P_1 Take another point P_2 on C, and let $\Delta u = u(x_2, y_2) - u(x_1, y_1)$ Let ΔS be the arc P_1P_2 of the curve C, and form the ratio $\frac{\Delta u}{\Delta s}$

Let the point P_2 approach the point P_1 along curve C, so that $\Delta S \to 0$, then the limit is called the directional

$$\lim_{\Delta s \to 0} \frac{\Delta u}{\Delta s}$$

derivative of u at the point P_1 along the curve C If σ is the direction of the **tangent** to C at P_1, then the above limit may also be called the directional derivative of u at P_1 in the direction σ The usual notation for this directional derivative is either $\frac{\partial u}{\partial s}$ or $\frac{du}{ds}$.

This directional derivative may be evaluated in terms of **partial derivatives** by the following formula.

$$\frac{\partial u}{\partial s} = \frac{\partial u}{\partial x} \cos \alpha + \frac{\partial u}{\partial y} \sin \alpha,$$

where α is the inclination angle (with the X-axis) of the direction σ in which the derivative is taken

The directional derivative of a function $u(x,y,z)$ of three variables in any direction in space may be defined in a similar way For such a derivative we have the following formula

$$\frac{\partial u}{\partial s} = \frac{\partial u}{\partial x} \cos \alpha + \frac{\partial u}{\partial y} \cos \beta + \frac{\partial u}{\partial z} \cos \gamma,$$

where α, β, γ are the **direction angles** of the direction σ in which the derivative is taken

The directional derivative of a function $f(x, y, z)$ at a given point in the direction of the normal to the surface $f(x, y, z) = c$ (a constant) through this point is called the normal derivative of f, and is denoted by $\frac{\partial f}{\partial n}$ or $\frac{du}{dn}$ It is the greatest value of the directional derivative in any direction (L L S)

DIRECTRIX OF A CONIC. Conic Sections.

DIRIGIBLE. Airship.

DISACCHARIDES. Carbohydrates.

DISCONFORMITY. The geological meaning of this term is treated under **Unconformity**

DISCONTINUITY OF A FUNCTION. Continuous Function.

DISCRIMINANT OF A QUADRATIC EQUATION. Quadratic Equations in One Unknown.

DISEASES OF PLANTS. Plants are attacked by a great many diseases A plant disease may be defined as any variation from a normal condition, either in structure or function Disease may be due to an unfavorable environment, one lacking in water or in the mineral requirements of the plant, or to attacks by various organisms Among the many agents which cause diseases in plants are **bacteria** and **fungi**, and many animals, as well as the **viruses** The results of infection are many and varied Often the afflicted plant is stunted, its leaves become wrinkled and irregular, and the normal green color spotted or mottled with white or yellow patches Parts may die and drop off Again, various abnormalities, such as **galls** and **witches' brooms**, may be formed

If the disease is caused by a fungus or a bacterium, the disease-causing organism must gain entrance into the plant There are many ways in which this may occur The older stems of higher plants are covered by a thick layer of cells, the walls of which become suberized (See **Suberin**) The leaves and young stems are protected by a thinner epidermal layer of cells, the outer surface of which is often further protected by a layer of cutin In the epidermis of the leaf, however, there are many minute openings or **stomata** through which gases pass In the outer layer of stems there are lenticels, masses of loosely packed cells which permit a ready movement of gases from the outer air into the stem Through these openings disease-causing organisms may enter the plant A fungous **spore**, falling onto a leaf, germinates if moisture is available, and pushes out a slender tube or hypha which grows through a **stoma** into the body of the leaf There conditions are more favorable, and the fungus grows rapidly, spreading through the leaf

But entrance to the plant is more frequently through accidental openings A branch is broken off, or bruised Sucking insects or other organisms make a puncture through the outer layers In any case, a favorable condition is then established for the rapid growth of the disease-producing organism Careless pruning often provides the means of entrance for disease

In many cases the growth of the parasite causing the disease is very slow Years may elapse before the real damage appears On the other hand, in some diseases the infection spreads rapidly and soon shows its presence The spores or cells which cause disease are formed in immense numbers They are of small size and easily carried about by wind or by water, and deposited everywhere Only chance brings them to a suitable host Insects also carry disease-producing organisms from one plant to another In this stage these organisms are extremely resistant to adverse conditions around them and usually able to live unharmed for long periods of time When conditions around them become favorable, infection quickly follows One of the most important requirements is moisture When moisture is abundant, therefore, epidemic outbreaks of the diseases may occur

There are many ways of combating these various dis-

eases First among these is prevention. Since mechanical injury offers a means of entrance, it should be avoided as much as possible When such injury is necessary, as in pruning, care should be taken to cover the cut surfaces with protective substances Another means of combating disease is by spraying, spreading over the plant a film of substance which is toxic to the disease-causing organisms Not only may most insects be controlled by this means, but also the growth of many fungi may be inhibited Bordeaux mixture, sulfur dust, and many different chemical mixtures are much used in controlling fungous pests Once a plant has become infected it becomes necessary to remove the infected part and destroy it, or to destroy the entire plant, to prevent the disease from spreading to other plants

In recent years a new method of combating disease has been utilized This is based on the observation that many plants, even of susceptible species, become immune If the plant is a perennial and the disease attacks only one part, it is possible to graft resistant forms onto the plant An example of this treatment is found in the European grape The roots of the European grape are attacked by the **Phylloxera** insect, and succumb rapidly This pest threatened to wipe out the grape industry of Europe The American grape resists the insects, so that by grafting European grape stocks onto American roots, the disease was controlled and the industry saved Another method is to breed immune strains by selecting resistant plants and crossing them with plants of desirable quality, but poor resistance By such means a new form may be developed which combines the resistant quality of one plant with the superior or desired qualities of the other Nature itself seems to develop such resistant varieties Often one may use such naturally immune plants directly

Among the commoner diseases of plants are fire-blight, also called pear blight, caused by *Bacillus amylovorus*, a bacterium which attacks the **cambium** and bark The disease is spread by insects It causes the leaves, blossoms and young twigs to wilt and turn dark-colored as though damaged by fire Citrus canker, caused by *Pseudomonas citri*, is another bacterial disease It attacks various citrus plants, causing brown spots to appear on leaves, young shoots and on the fruit Apple scab is a widespread disease of the apple trees The organism causing the disease is an **ascomycete**, *Venturia inaequalis*, introduced into this country from Europe The fungus grows on the leaves and fruit, forming small grayish spots which become scab-like The fungous hyphae grow in the tissues just beneath the epidermis, spreading slowly The parasite survives the winter on fallen leaves or on the young twigs Another common and widespread disease is black knot of plum trees It is caused by an **ascomycete**, *Plowrightia morbosa*, which attacks the **cambium**, **phloem** and cortical tissues of young twigs The presence of the fungous **mycelium** stimulates the tissues of the plum to increased growth, forming conspicuous black warty growths These may develop on one side of the stem only, in which case the branch continues to grow and fruit, or the warty growth may completely surround the stem, causing its death Ergot, caused by an **ascomycete**, *Claviceps purpurea*, is a disease of rye and other grasses The fungus grows in the young ovary, forming a dense mass of **mycelium** which replaces the ovary tissues and causes a pronounced hypertrophy of the ovary Later the fungus forms hard black horn-like bodies which project from the **glumes** of the **floret** These black bodies are called sclerotia, or ergot spurs It is through them that the fungus survives the winter In the spring the sclerotium develops a brownish outgrowth with an enlarged tip In this tip flask-shaped cavities called perithecia are formed In them the asci each containing eight ascospores are found From these ascospores conidia are cut off These conidia may infect developing rye ovaries Ergot spurs are very poisonous, causing serious trouble when eaten by cattle The animals suffer from grave digestive disturbances, and, in severe cases, serious impairment of the nervous system and a sloughing off of hoofs, and loss of teeth and hair Bread made from ergot infested rye causes similar effects in human beings Ergot is used medicinally

Other important plant diseases are caused by **rusts** and **smuts** (R M W)

DISINFECTANT. Any agent, physical or chemical, that destroys infective organisms (R S M)

DISLOCATION. The displacement of any part from the normal This term is used especially in reference to the **joints** of the body In a compound dislocation a joint is penetrated by a wound In a fracture dislocation, there is a fracture existing with the dislocation A traumatic dislocation is one that is caused by violence or trauma (R S M)

DISORIENTATION A confused state of mind in which the normal relationship of identity, time and place is lost (R S M)

DISPERSION. The selective deviation of an emission in accordance with some variable characteristic, such as the refraction of light at different angles for different frequencies When an emission is so dispersed, the result is a **spectrum**

The dispersion of light may be accomplished through **refraction** by a **prism**, **diffraction** by a grating, or other means Refractive dispersion is due to the fact that the velocity of light in a given medium, and hence the **refractive index**, vary with the frequency In any case, if the deviation Δ produced by the dispersing apparatus is expressible as a function of the wave length λ, then the measure of the dispersion may be taken as $D = \frac{d\Delta}{d\lambda}$. For example, for a plane **diffraction grating** at normal incidence, the deviation in the first order is given by $\sin \Delta = \lambda/s$, in which s is the grating space, from which it follows that the dispersion is $D = (s^2 - \lambda^2)^{-\frac{1}{2}}$

Refractive dispersion is not so simply expressed For a single refraction at angle of incidence i and with refractive index n, it may be shown that the dispersion $d\Delta/d\lambda$ is equal to

$$D = \frac{\sin i}{n\sqrt{n^2 - \sin^2 i}} \cdot \frac{dn}{d\lambda}$$

Various attempts have been made to express n as a function of λ, for example, by the empirical dispersion formula of Cauchy

$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \quad ,$$

or by that of Sellmeier (See **Anomalous Dispersion**)

$$n = 1 + \frac{A\lambda^2}{\lambda^2 - \lambda_1^2} + \frac{B\lambda^2}{\lambda^2 - \lambda_2^2} +$$

Different media are commonly compared through some arbitrarily defined "dispersive power", such as $(n_F - n_C)/(n_D - 1)$, in which the n-terms are subscripted to indicate the refractive indices for the *F*, *C*, and *D* **Fraunhofer lines.** (L D W)

DISPLACEMENT. Displacement in a piston and cylinder mechanism is the volume swept out by the piston face It is assumed that the face of the piston is coplanar Given the bore and stroke as D and L, the number of cylinders n, the displacement is

$$\frac{\pi D^2 L n}{4}.$$

The portion of a ship which is immersed displaces a certain weight of water According to Archimedes' principle, a body immersed in water is buoyed up by a force equal to the weight of water displaced by the body Hence the displacement of a ship in tons of water is

equal to the weight of the ship and of its contents For electric displacement, see **Dielectrics.** (F T M)

DISPLACEMENT CURRENT. Electric Currents.

DISPLACEMENT LAW. Wien's Law.

DISSEMINATION OF SEEDS. Fruit, Seed.

DISSEPIMENT. A partition or septum

DISSOCIATION. For electrolytic dissociation see **Electrochemistry** and **Reactions Involving Recombination of Ions;** for thermal dissociation see **Equilibrium; Association and Polymerization.**

DISSOLVING. The limiting amount of a gas or solid dissolving in a liquid at a given temperature and pressure is termed the solubility (See **Solutions and Solubility**) The method of attaining the limit is to expose the liquid, which is generally water, to the gas or solid for a sufficient length of time, until no more of the gas or solid dissolves at the given temperature and pressure In order to make the time as short as possible, vigorous mixing of the solution is demanded and a relatively large surface of contact between the gas or the solid and the solution

These ends are accomplished in the case of a gas by the use of the principle of countercurrent flow, by which the gas is passed first through the almost saturated solution, consecutively thereafter through less and less saturated solution, and finally through the pure solvent The gas is commonly introduced at the bottom of a tower into the top of which the solvent is fed The tower may be charged with inert material or contain bubbling plates to furnish the desired large surfaces of contact and the mixing **Ammonia, hydrogen chloride, sulfur dioxide, carbon dioxide** are common soluble gases which are subjected to such a process The process of dissolving one gas from a gas mixture is often called scrubbing The liquid or solution used in scrubbing may be one with which the gas reacts chemically

The solution of a solid is accomplished by allowing the liquid or solution to pass over a sufficient surface of the solid, or the solid is suspended in the upper part of the liquid, in which case the solution as formed being itself denser than the liquid, descends and allows fresh contact

An interesting application of dissolving on a large scale is that in which the sulfite liquor is prepared for cooking wood chips to pulp for **paper** A tower, sometimes about 100 feet in height, is charged with lumps of **limestone** (calcium carbonate) Water is run into the top of the tower, flows down over the limestone, meets sulfur dioxide which enters at the bottom, and the resulting solution of **sulfurous acid** dissolves the limestone in the lower portion Carbon dioxide gas passes out at the top of the tower, and the cooking solution, consisting of **calcium** hydrogen sulfite and sulfurous acid, is recovered at the bottom

The heat change accompanying solution is characteristic of the substances Specific examples are given in the following table For solubility of the gases listed see **Solutions and Solubility.**

Gas		Upon Dissolving	Heat Evolved in Gram-calories
Ammonia	17	grams in 200 × 18 grams water	8,460
Hydrogen chloride	36 5	" " 200 × 18 " "	17,440
Sulfur dioxide	64	" " 300 × 18 " "	8,550
Carbon dioxide	44	" " 300 × 18 " "	4,760
Solid			
Sodium hydroxide	40	" " 200 × 18 " "	9,040
Sodium chloride	58 5	" " 100 × 18 " "	−1,180
Sodium nitrate	85	" " 200 × 18 " "	−5,030
Sodium sulfate decahydrate	322	" " 400 × 18 " "	−18,760

Heat is evolved upon solution of all gases Heat is absorbed upon the solution of the majority of solids (The heat of solution in an almost saturated solution is negative in the case of solids whose solubility increases with increases of temperature) (R K S)

DISTILLATION, EVAPORATION, AND DRYING Distillation, evaporation, drying, sublimation are processes that involve the vapor pressure The **vapor pressure** of a given pure substance is a constant varying with temperature In a solution of two or more liquids, the vapor pressure of each concentration ratio is definite Many systems have been studied For the separation of two liquids in solution, use is made of the fact that the ratio of the two substances in the vapor and liquid phases is usually different

System Ethyl Alcohol-Water
Total Pressure, 760 mm

Mol Percent in Liquid Phase		Temperature of Volatilization, °C	Mol Percent of Ethyl Alcohol in Vapor (and, therefore, in condensate)
Ethyl Alcohol	Water		
0	100	100	0
1 90	98 10	95 5	17 00
7 21	92 79	89 0	38 91
12 38	87 62	85 3	47 04
26 08	73 92	82 3	55 80
39 65	60 35	80 7	61 22
51 98	48 02	79 7	65 99
67 63	32 37	78 7	73 85
89 43	10 57	78 15*	89 43

* Minimum boiling-point mixture

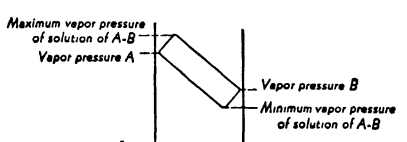


Figure 1 Diagram showing vapor pressure relations of a solution of two liquids

Figure 2. Diagram showing boiling point relations of ethyl alcohol-water solutions

EFFECT OF CHANGE OF PRESSURE ON BOILING POINT AND COMPOSITION OF DISTILLATE OF CONSTANT MINIMUM BOILING POINT MIXTURE OF ETHYL ALCOHOL-WATER

Constant Minimum Boiling Point Mixture, °C	Pressure, mm	Mol Percent of Ethyl Alcohol
78 15	760	89 43
62 8	400	91 4
87 8	1100	89 3

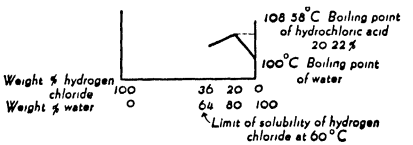


Figure 3 Diagram showing boiling point relations of hydrochloric acid solutions

Constant minimum boiling point mixtures are also known of the systems **ethyl alcohol-carbon tetrachloride**, ethyl alcohol-**carbon disulfide**, ethyl alcohol-**chloroform**, isopropyl **alcohol**-water, isopropyl alcohol-chloroform, **acetone**-methyl **alcohol**, etc

SYSTEM HYDROGEN CHLORIDE-WATER
Total Pressure, 760 mm

Constant Maximum Boiling Point Mixture, °C	Pressure, mm	Density at 25° C	Weight Percent of Hydrochloric Acid
108 584	760	1 0959	20 222
107 859	740	1 0962	20 268
106 424	700	1 0966	20 360
110 007	800	1 0955	20 155

Constant maximum boiling point mixtures are also known of the systems **hydrobromic acid-water, hydriodic acid-water, hydrofluoric acid-water, nitric acid-water, sulfuric acid-water, formic acid-water, acetone-chloroform,** etc

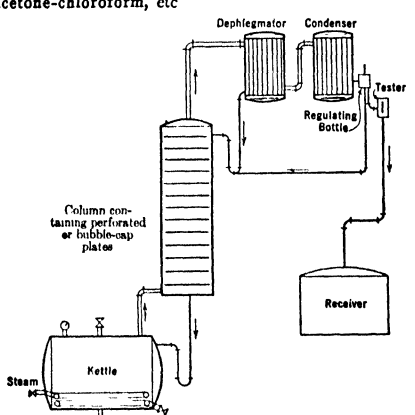


Figure 4 Intermittent still used in the distillation and separation of liquid mixtures

Plain Distillation is conducted in an apparatus consisting of three essential parts connected in series, namely, (1) the still or retort, (2) the condenser, (3) the receiver The material is heated in the still or retort, its vapor passes into the condenser in which the vapor is cooled, and the liquid condensate is collected in the receiver Modifications of this set-up are introduced affecting (1) the pressure in the apparatus and (2) the degree of refluxing to which the vapor is subjected

The system may be closed to the atmosphere and the pressure within increased or diminished as desired, resulting in pressure or vacuum distillation respectively

The system may be subjected to refluxing by the introduction of a fractionating column between the still and condenser In such a column the ascending vapor is caused to bubble through the descending liquid Assuming that the rate of flow is constant, the upward rate of flow of the vapor, V, in mols per second, minus the downward rate of flow of liquid, L, in mols per second, equals the condensed output, C, from the top of the column, in mols per second, and $\frac{L}{V}$ is called the reflux ratio Fractional distillation is practiced on a large scale in the production of **alcohols, benzene hydrocarbons,** and **petroleum** fractions

When a substance such as **aniline** has a high boiling point but an appreciable vapor pressure at 100° C and is practically insoluble in water, use is frequently made of steam to distil the substance The total or atmospheric pressure equals the sum of the partial pressure of the substance, somewhat below 100° C, and of the partial pressure of water vapor at that temperature The distillate contains the substance and water approximately in the weight ratio. the product of the vapor pressure

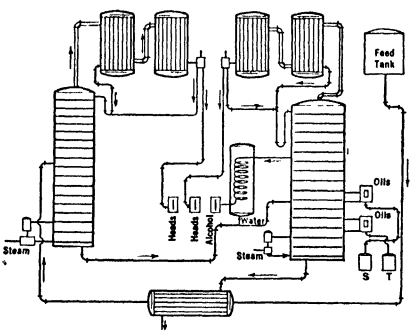
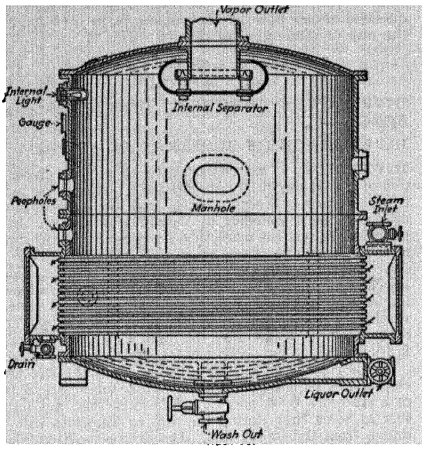


Figure 5 Continuous still used in the distillation and separation of liquid mixtures

of the substance and its molecular weight *to* the product of the vapor pressure of water (733 mm at 99° C, 707 mm. at 98° C) and 18 (the molecular weight of water)

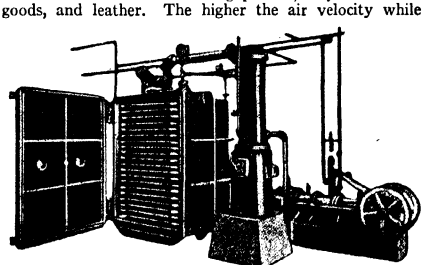
Evaporation is in principle the same operation as plain distillation, with the modifications in practice that (1) the vapor may or may not be recovered, (2) the residue in the evaporator may or may not contain solids, and (3) vacuum evaporation is frequently used in a single compartment or in multiple stages with each successive stage operated at an increasing vacuum utilizing the heat of condensation of the vapor from the preceding stage In multiple stage evaporators there is a saving in the cost of heat and an increased expenditure for apparatus Vacuum evaporation is frequently utilized to lower the temperature to which a substance is subjected and thus avoid decomposition by passing a current of warm dry air over the substance Water vapor passes from the place of higher concentration, that

is, the substance, to the place of lower concentration, that is, the air, and is thus removed from the substance. If oxygen of the air reacts with the substance, an inert gas such as nitrogen may be substituted for air.



Zaremba horizontal tube evaporator.

The effect of air velocity, air **humidity**, temperature, and dimensions of the solid being dried have been studied in a quantitative manner for a number of materials, such as wood in the seasoning process, clay in ceramic goods, and leather. The higher the air velocity while



Vacuum shelf drier installation (open) with surface condenser (center) and dry vacuum pump (right).

the material is wet the more rapid the drying, but this effect diminishes as the material dries, due to the preponderance of the capillarity effect in transfer of water from the interior, through the interstices of the material to the air. Driers for solids are of several types. The principal types are: (1) pan driers, (2) cabinet or tunnel driers, (3) rotary driers. (R.K.S.)

DISTORTION. In the field of communication engineering, there arises a problem in distortion not directly connected with actual material substance. Communication by speech in both wired and wireless systems is subject to speech distortion. This may be produced at the transmitting end through imperfections in the transmitter, or it may occur somewhere along the line of communication. The common **transmitter** of the telephone gives some distortion, which, however, does not normally interfere with intelligibility. Transmission of speeches and music in radio is quite another matter, and dynamic microphones have been developed to replace the distortion-producing carbon-granule types of earlier days.

Distortion occurring in the operation of communication systems, including radio network program circuits, may arise, *first*, from frequency distortion. The defect causing this is the variation of transmitting efficiency at different frequencies. This distortion is one of amplitude. *Second*, if there are **impedances** in the circuit the magnitude of which varies with the current or voltage, harmonic distortion will follow; that is, if the transmitter should deliver to the line a voltage free of harmonics, the output would be found to contain some harmonics. The *third* type of distortion is that in which the velocity of transmission along a wire varies with the frequency of the wave front. This is called phase distortion, and while it does not greatly affect speech or music transmission, it is said to be troublesome in television.

Optical distortion results from imperfection of lens or mirror surfaces, and is recognized by lack of propagation between corresponding dimensions of object and image. (F.T.M.)

DISTRIBUTION. The portions of the earth's surface occupied by different kinds of animals are determined by the relation of environmental conditions and inherited adaptations and result in a spatial arrangement of living forms known as distribution.

In vertical or altitudinal distribution animals may be surrounded either by water or by air, and may either rest on the solid surface, float in the surrounding medium, or move actively through this medium. Those which rest on the solid support constitute the faunal group known as the benthos, those which float are the plankton, and those which move actively through air or water are the nekton. Since animals can float permanently in water but not in air, and since the aerial nekton are commonly known as flying animals, these terms are largely restricted to aquatic species.

Horizontal distribution relates the animals to geographic divisions. The earth has been divided into a number of zoogeographical regions characterized by some uniformity of the included species. These are as follows: The palaearctic region includes Europe, Iceland, Northern Africa and Arabia, and Asia north of the Himalayan mountains. The nearctic region includes North America, Greenland, and part of Mexico. The neotropical region includes most of Mexico, the West Indies, and South America. The Ethiopian region includes Africa and Arabia south of 20° N. Lat., and sometimes Madagascar, although this island is also held to be a distinct region. The oriental region includes India and China south of the Himalayas, the Malay peninsula, Celebes, Java, Ceylon, Sumatra, and smaller adjoining islands. The Australian region includes Australia, New Guinea, New Zealand, and the remaining Pacific islands with the exception of the Hawaiian group, which constitute a small separate region. See also **Gaussian Distribution.** (A.W.L.)

DISTRIBUTIVE LAW OF ALGEBRA. **Multiplication.**

DISTRIBUTOR. This is a rotary electrical switch used to distribute electric current from one source to a number of separate circuits. A common example is the distributor of the automobile engine **ignition system.** High tension ignition current suitable for use by spark plugs is delivered to the distributor at its revolving switch arm. Around the periphery of the travel of this distributor arm are mounted contact points which are connected to the various circuits to which the current is to be distributed. On the multi-cylinder gasoline engine, each circuit leads to a separate spark plug, and there are as many contact points as there are spark plugs. The rotation of the distributor arm brings it successively opposite the contact points. There may be actual contact between the distributor arm and the contact points, or the current may be required to jump a small gap between them. Its voltage must be high

enough to do this The contact points are mounted in a case of insulating material, such as bakelite The distributor arm is mounted on a rotating shaft driven from the crankshaft In the four-cycle engine this shaft revolves at one-half crankshaft speed. It revolves at crankshaft speed in the two-cycle engine (F T M)

DITHIONIC ACID AND DITHIONATES. Dithionic acid ("hyposulfuric acid" $H_2S_2O_6$) is a colorless solution, formed by reaction of **barium** dithionate solution and dilute **sulfuric acid,** and filtering off barium sulfate The resulting solution may be evaporated in vacuum to specific gravity 1 35 beyond which point decomposition occurs, with resulting formation of sulfuric acid and **sulfur dioxide.** Dithionic acid does not react in the cold with **chlorine, sulfur, nitric acid, permanganate** or **hypochlorite,** but **sodium** peroxide oxidizes it to **sulfate.**

Sodium dithionate ($Na_2S_2O_6$) is made by reaction (1) of barium dithionate and sodium sulfate, and filtering off barium sulfate, (2) of dithionic acid and sodium hydroxide, (3) of **sodium** sulfite solution and **iodine,** some sulfate being formed

When **sulfurous acid** is allowed to come in contact with suspensions of **manganese** dioxide, **ferric** hydroxide, **cobaltic** hydroxide, but not barium peroxide, or sodium sulfite and lead dioxide, in the cold, the corresponding dithionate is formed, and this may be conveniently converted into barium dithionate by reaction with barium hydroxide, and filtering The solution of barium dithionate is then evaporated to **crystallization** (R K S)

DIURETIC. Any **drug** or substance which causes the **kidneys** to secrete more **urine** (R S M)

DIVER. Aves, Gaviiformes Large diving birds (**Aves**) with strong pointed beaks and webbed feet, found throughout the northern part of the world The **loons.** The most common species is the great northern diver (A W I)

DIVERGENCE OF A VECTOR FUNCTION The divergence of a vector function is a certain type form of mathematical expression which occurs very frequently in discussions of mathematical physics

Let **v** be a **vector function** of position, with rectangular components v_1, v_2, and v_3 (in magnitude) The **scalar** expression

$$\nabla \cdot \mathbf{v} = \frac{\partial v_1}{\partial x} + \frac{\partial v_2}{\partial y} + \frac{\partial v_3}{\partial z}$$

is called the divergence of **v**, and is denoted by div **v**.

A fundamental property of the divergence is the so-called **divergence theorem.**

If **r** is a variable vector of the form $\mathbf{r} = x\hat{i} + y\hat{j} + z\hat{k}$, and if **a** is a constant vector, then

$$\operatorname{div} \mathbf{r} = \nabla \cdot \mathbf{r} = 3,$$
$$\operatorname{div} (\mathbf{r} \times \mathbf{a}) = \nabla \cdot (\mathbf{r} \times \mathbf{a}) = 0,$$
$$\operatorname{div} (r\mathbf{a}) = \nabla \cdot (r\mathbf{a}) = \frac{\mathbf{r} \cdot \mathbf{a}}{r}.$$

If **u** and **v** are vector functions of position and u is a scalar function of position, then

$$\operatorname{div} (\mathbf{u} + \mathbf{v}) = \nabla \cdot (\mathbf{u} + \mathbf{v}) = \nabla \cdot \mathbf{u} + \nabla \cdot \mathbf{v} = \operatorname{div} \mathbf{u} + \operatorname{div} \mathbf{v},$$
$$\operatorname{div} (u\mathbf{v}) = \nabla \cdot (u\mathbf{v}) = (\nabla u) \cdot \mathbf{v} + u(\nabla \cdot \mathbf{v}),$$
$$\operatorname{div} (\mathbf{u} \times \mathbf{v}) = \nabla \cdot (\mathbf{u} \times \mathbf{v}) = \mathbf{v} \cdot (\nabla \times \mathbf{u}) - \mathbf{u} \cdot (\nabla \times \mathbf{v}),$$
$$\operatorname{div} (\operatorname{grad} u) = \nabla \cdot (\nabla u) = \nabla^2 u \quad \text{(Laplacian of } u\text{)}$$

An alternative definition of the divergence is the following.

Let **v** be a vector function of position, let δ be a small region of space and also its volume, surrounding a point P, and let **w** be the bounding closed surface of δ and let $d\sigma$ be a surface element on **w**, let **n** be an outward drawn normal unit vector to any point on **w** The outward flux through the element $d\sigma$ is $\mathbf{n} \cdot \mathbf{v}\, d\sigma$ The total flux outward through **w** is the integral of this expression, and represents the net quantity of outward flow from δ per unit time The limit approached by the quotient of net flow by the volume δ, as $\delta \to 0$, gives the rate of diminution of density This is

$$\operatorname{div} \mathbf{v} = V \cdot \mathbf{v} = \lim_{\delta \to 0} \frac{1}{\delta} \int\int_{\omega} \mathbf{n} \cdot \mathbf{v}\, d\sigma \qquad \text{(L L S)}$$

DIVERGENCE THEOREM. Green's Theorem in Space

DIVERGENCY OF SERIES. Infinite Series

DIVERSITY That characteristic of public consumption of a good specifically produced and marketed for public use, known as diversity, arises from the diversification of use of the commodity by individual customers In a public utility system marketing a commodity which may be stored, diversification is not of as much importance as in services such as transportation and electric power, where warehousing the salable commodity is either impossible or impractical Thus, in a water or gas system, a certain amount of storage may be interposed between supply and demand which would effect the result that only a diversification of usage can achieve in the electric service system

In the case of an electric utility system, the fact that customer A requires 5 kilowatts during some part of the day, customer B, 8, and C, 7 kilowatts, does not mean that at some time during the day 20 kilowatts will be drawn from the supply line The diversity of usage between customers would so stagger their periods of maximum demand that the feeder capacity could be considerably less than the sum of the individual maximum demands Taking into account a certain amount of diversity between feeders themselves, and between substations supplying these feeders, the maximum demanded load of a power plant is likely to be only a small fraction of the sum of the individual customer's peak loads Diversity factor is the ratio between individual maximum demands of parts of a system and their combined simultaneous maximum demand It is defined as the maximum simultaneous demand of a system or part of a system, divided by the sum of the individual maximum demands of the subdivision, taken as they may occur A low diversity factor is a desirable loading condition (F T M)

DIVERSITY FACTOR. Diversity.

DIVI-DIVI. Tannins.

DIVISION. Division is the **inverse operation** to **multiplication** The result of dividing one number by another is called their quotient The quotient a/b of two numbers a and b is that number c such that $b \cdot c = a$ (provided $b \neq 0$) It follows that $(a/b) \cdot b = a$ and $(a \cdot b)/b = a$ That is, division undoes the effect of multiplication

The reciprocal of a number a is the quotient of 1 by that number, namely $1/a$ The reciprocal of a **fraction** is that fraction inverted

The quotient of two numbers of like sign is positive, that of two numbers of unlike sign is negative, the **absolute value** being the quotient of the absolute values of the numbers

To find the quotient of two **polynomials,** arrange each in descending powers of some common letter involved Divide the first term of the dividend by the first term of the divisor, the result is the first term of the quotient Then multiply the whole divisor by the first term of the quotient and subtract the product from the dividend Consider the remainder thus obtained as a new dividend and repeat the operation Continue in this manner until a remainder is obtained which is either, zero or an expression whose first term does not contain the first term of the divisor as a factor (L L S)

DOBSON FLY. Corydalis.

DOCTRINE OF SIGNATURES. This curious belief came into existence during the Middle Ages According to its proponents, every plant was created for a purpose, and, more than that, was marked so that its purpose could be known The most able interpreters of this doctrine were those gifted with an imagination capable of discovering the signature

If the shape of the leaf suggested that of the human heart or liver, then obviously that plant, or its leaves, was meant to be used to cure diseases of the heart or the liver A little plant, which has small white flowers with a conspicuous dark spot in the center, is known as Eyebright It was quite clear that this plant was marked as a plant which should be used to treat eye trouble Common walnuts were seen to resemble a skull—the meat within was very like the human brain in appearance Surely here was a remedy for any trouble which originated in the brain A certain **lichen,** *Usnea barbata,* commonly known as Old Man's beard, grows on dead branches of trees, from which it hangs in slender branching threads A decoction of this lichen was therefore used to promote growth of the hair

Sometimes the marks or signs were extremely obscure One lichen, for example, commonly grows on barren rock surfaces This lichen, *Parmelia saxatilis,* will also grow on old bones, including skulls, if the latter happen to be in a favorable spot Surely anything growing on a skull is valuable, so here is a plant which is a cure for epilepsy and also a healing salve for wounds (R M W)

DODO. Aves, Columbiformes A large clumsy flightless bird, *Didus ineptus,* once common on the island of Mauritius but now extinct (A W L)

DOG Mammalia, Carnivora A member of certain species of the dog family, Canidae, characterized by the slender build, long legs, elongate muzzle, and blunt claws which cannot be retracted

The family is represented in all continents but the wild species are known as dogs only in the case of a few which inhabit Asia, Africa, and South America, including the raccoon dog and the Siberian wild dog The species that bear special names are the **wolves, coyote, kaberu, jackals, dingo, foxes** and **fennecs**

The name is best known as applied to the domestic dog, *Canis familiaris,* one of the most highly diversified of animals as a result of long selection and controlled breeding (A W L)

DOGFISH Pisces 1 Plagiostomi Several species of small **sharks,** all marine 2 Holostei The **bowfin,** also called the fresh-water dogfish (A W L)

DOLERITE. The term dolerite, derived from the Greek meaning deceitful, was originally applied to all dark, heavy, fine-grained **igneous rocks** of doubtful character It is now used to indicate gabbroid or basaltic types occurring as dikes or sills whose mineralogical composition is **plagioclase, feldspar, hornblende** or **pyroxene** or both, **olivine** and perhaps **biotite, magnetite** or **ilmenite** and pyrite. Included in the dolerites are the diabases, which display plagioclase laths in a somewhat radial arrangement, and from this circumstance we have the textural term diabasic which is synonymous with ophitic

Both terms dolerite and diabase have been used interchangeably but the suggestion of Kemp that diabasic refers to rocks in which the feldspar is in excess and the augite occupies the interstices between the feldspar laths is one which should receive more attention (E S C S)

DOLICHOCEPHALIC VS. BRACHIOCEPHALIC. Paleontology of Man.

DOLOMITE. The mineral dolomite, the **carbonate** of **calcium** and **magnesium** corresponds to the formula $CaMg(CO_3)_2$ and closely resembles **calcite.** Its crystals, **rhombohedral** in habit, fall in the **hexagonal** system Like calcite it may be massive or granular, some marbles being dolomite rather than calcite It displays a perfect cleavage paralled to the rhombohedron, sub-conchoidal fracture, brittle, hardness, 3 5–4, specific gravity, 2 8–2 9, luster vitreous to pearly, color varies widely, white, reds, greens, black, browns, yellows or colorless, transparent to translucent Unlike calcite, dolomite dissolves very slowly if at all in dilute cold hydrochloric acid, powdered dolomite will dissolve in warm acid This is the common test for the two minerals Much dolomite occurs as stratified rocks where it is believed to have been formed by a secondary process, probably by the action of waters charged with magnesium compounds Dolomite also is found as a vein mineral, as is calcite **Iron** or **manganese,** rarely **zinc** or **cobalt** may replace some of the magnesium **Ankerite** is the name given to a mineral whose composition is essentially a calcium-magnesium-iron carbonate Among the many noted localities for dolomite may be mentioned the following Saxony, Switzerland, Italy, France, Spain, Brazil, Mexico and in the United States at Roxbury, Vermont, Lockport, New York, Phoenixville, Pennsylvania, Alexander County, North Carolina, Hancock County, Illinois, and the Joplin District, Missouri It was named for Deodat de Dolomieu who first described its characteristics (E S C S)

DOLOMITIC LIMESTONE or **DOLOMITE.** Many of the **carbonate** rocks consist largely of the mineral dolomite, the double carbonate of **calcium** and **magnesium,** thus differing from ordinary **limestone** which is essentially carbonate of calcium Such rocks are called dolomites It should be noted, however, that the term dolomite is sometimes loosely used to mean a magnesian limestone The term dolomite is properly restricted to the rock made up of the double carbonate, $CaMg(CO_3)_2$ Dolomite occurs in bedded deposits probably as a chemical precipitate either as the result of inorganic or organic agencies, or in certain cases because of leaching out of the calcium with the accompanying concentration of the magnesium, or from the carbonates of decomposed shells of marine animals The replacement of calcium carbonate by dolomite is also of importance Dolomite is used to some extent as a building stone, as a refractory and in the production of heat insulating materials (E S C S)

DOLPHIN. 1 Pisces, Teleostei Marine game fishes (**Pisces**), *Coryphaena,* with a deep head, short snout, and long tapering body They look like the mammalian dolphins in general form 2 Mammalia, Odontoceti Small toothed **whales,** attaining a length of about eight feet There are many species of several characteristic forms One of the more peculiar is the narwhal, *Monodon monoceros,* which has a single spirally twisted ivory tusk Several species of dolphins live in large rivers of the Old and New World tropics, among them the Gangetic dolphin or susu of India and the Amazonian dolphin, *Inia geoffroyensis,* also called the inia or bouto, of South America (A W L)

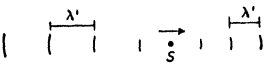
DOME. As used by the geologists this term has several meanings. Principally applied to mounds of viscous lava which are squeezed out of volcanoes and solidify without forming lava flows When portions of the older lavas or ashes are pushed up by the pressure of later lavas the resulting structure is called a volcanic dome (R M F)

DOMESTIC CHEMISTRY. Chemistry.

DOMESTIC HEATING. Heating.

DOMITE. The term proposed by Von Buch for the **trachyte** lavas of the famous volcanic Puy de Dôme district of France More specifically, trachytes which contain appreciable amounts of **oligoclase,** and **hematite.** (R M F)

DOPPLER EFFECTS. The effects upon the apparent frequency of a wave train produced (1) by motion of the source toward or away from the stationary observer, and (2) by motion of the observer toward or from the stationary source, the motion in each case being with reference to the (supposedly stationary) medium.



Doppler effect of motion of source λ' is the altered wave length

(1) It is easy to see that when the source moves, the waves are crowded together on the side toward which it moves, and are more widely separated on the opposite side, thus producing, respectively, an apparent increase and an apparent decrease in frequency If the speed of the waves is V and that of the source is u, and if the true frequency is ν, the apparent frequency is

$$\nu' = \frac{V}{V+u}\nu, \qquad (1)$$

u being + or − according as the distance is increasing or decreasing Thus if a whistle of actual frequency 250 per second is moving away from the listener with a speed of 11 feet per second, and the speed of sound is 1100 feet per second, the apparent pitch is lowered to $\frac{1100}{1111} \times 250$ per second = 247 52 per second (This effect is often observed with the bell or the whistle of a passing locomotive)

(2) If the observer is moving with speed u, which is + or − according as his distance from the stationary source is increasing or decreasing, the apparent frequency is given by

$$\nu'' = \frac{V-u}{V}\nu \qquad (2)$$

Then if the listener moves away from the whistle at 11 feet per second, the pitch is lowered to $\frac{1089}{1100} \times 250$ per second = 247 50 per second The two effects are thus very nearly but not quite equal, frequently both are operative at once

The Doppler effects are of great importance in the case of light (for which it is quite impossible to distinguish between them) The slight abnormality (Doppler shift) in the positions of the spectrum lines from a star, for example, affords a fairly accurate value of the relative speed with which the star and the earth are approaching or receding from each other (the **radial velocity**) Many **double stars** (**spectroscopic binaries**) are recognized as such only by the doubling of their spectrum lines due to the components moving in opposite directions The spectrum lines of gases are often broadened because of the various speeds of the molecules (L D W)

DORAB. Pisces, Teleostei A slender marine fish (**Pisces**) of the Oriental region, of large size and vicious habits (A W L)

DORMOUSE. Mammalia, Rodentia Small arboreal **rodents** of the Palaearctic and Ethiopian regions They are somewhat like squirrels in appearance, with long hairy or bushy tails Also called sleepers The common dormouse is *Muscardinus avellanarius* (A W L)

DORSAL LAMINA. In the **tunicates**, a ciliated ridge along the middle line of the dorsal wall of the **pharynx.** (A W L)

DORY, JOHN DORY. Pisces, Teleostei Marine fishes (**Pisces**) of ugly form and world-wide distribution The John dory, *Zeus faber*, is a species of the northern hemisphere which is valued as food Family Cyttidae (A W L)

DOT PRODUCT OF TWO VECTORS. Scalar Product of Two Vectors.

DOTTEREL. Aves, Charadriiformes *Eudromias* Several Old World species of birds (**Aves**) related to the plovers (A W L)

DOUBLE INTEGRAL. A double integral is a fundamental mathematical concept extensively used in **Calculus** for the treatment of geometric and physical problems, particularly those dealing with plane figures.

Let $f(x,y)$ be a **continuous function** in a region S of the XY-plane Let the region S be divided in any manner into n sub-regions $\Delta S_1, \Delta S_2, \cdots, \Delta S_n$, denote any one of these sub-regions by ΔS_k Let (x_k,y_k) by any point within or on the boundary of ΔS_k Then form the sum

$$\sum_{k=1}^{n} f(x_k,y_k)\ \Delta S_k = f(x_1,y_1)\Delta S_1 + \qquad + f(x_n,y_n)\,\Delta S_n.$$

Let $n \to \infty$ and at the same time let the greatest diameter of each sub-region $\Delta S_k \to 0$ Then the **limit** of this sum is defined as the double integral of $f(x,y)$ extended over the region S, and we write

$$\lim_{\Delta S_k \to 0} \sum_{k=1}^{n} f(x_k,y_k)\Delta S_k = \iint_S f(x,y)\,dS$$

A double integral may be interpreted geometrically as follows If $z = f(x,y)$ is interpreted as the equation of a **surface,** the double integral $\iint_S f(x,y)\,dS$ represents the volume bounded by this surface, the XY-plane and a right **cylinder** standing on the region S and perpendicular to the XY-plane

Let $f(x,y)$ be continuous in a region S of the XY-plane bounded by the lines $x = a$, $y = b$, the X-axis and a curve $y = \phi(x)$, in **rectangular coordinates.** The integral

$$\int_a^b \left(\int_0^{\phi(x)} f(x,y)\,dy \right) dx,$$

which is called an iterated, or repeated, double integral, is defined as follows hold x constant and integrate $f(x,y)$ with respect to y, substitute the limits $\phi(x)$ and 0 for y and subtract, then integrate this function of x with respect to x from a to b

This iterated integral is sometimes written

$$\int_a^b \int_0^{\phi(x)} f(x,y)\,dy\,dx, \quad \text{or} \quad \int_a^b dx \int_0^{\phi(x)} f(x,y)\,dy,$$

and occasionally as

$$\int_a^b \int_0^{\phi(x)} f(x,y)\,dx\,dy$$

The fundamental theorem on double integrals is the following Let S be a region bounded by the lines $x = a$, $x = b$, the X-axis, and a curve $y = \phi(x)$ Then the following double integral and iterated integral are equal

$$\iint_S f(x,y)\,dS = \int_a^b \left(\int_0^{\phi(x)} f(x,y)\,dy \right) dx,$$

i e , the double integral may be evaluated by the iterated integral (using successive integrations)

In terms of **polar coordinates,** a double integral $\iint_S f(r,\theta)\,dS$ may be evaluated by an iterated integral of the form

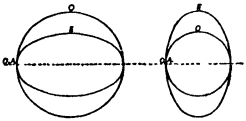
$$\int_\alpha^\beta \left(\int_{r_1(\theta)}^{r_2(\theta)} f(r,\theta) r\,d\theta \right) dr.$$

(L L S)

DOUBLE REFRACTION. If a crystal of calcite (calcium carbonate, a common mineral) is held between the eye and a pinhole in a card, two bright dots are seen If the crystal is rotated around the line of sight, one dot travels in a circle around the other, which remains fixed Evidently there are two refracted rays,

with the light normally incident on the natural crystal face, they make (within the crystal) an angle of about 6° 9′ The two refracted rays reveal a difference in **refractive index.** The one which remains fixed as the crystal revolves, called the ordinary ray, corresponds to a greater index than does the other, called the extraordinary ray For sodium light the two indices of calcite are, respectively, 1 658 and 1 486 A simple test shows that the two rays consist of plane-**polarized light,** one vibrating at right angles to the other By cutting the calcite into plates making various angles with the natural faces, a divergence as high as 6° 16′ may be obtained for normal incidence, but it is generally less For one direction (and, for calcite, only one) there is no divergence at all, the light is then said to be traveling along the optic axis of the crystal Quartz also exhibits double refraction (though with much less divergence), but in this case the extraordinary ray corresponds to the greater refractive index (ordinary, 1 544, extraordinary, 1 553, for sodium light)

These phenomena were explained by Huygens (1678) as due to the fact that the ordinary wave has a spherical wave front, traveling with the same speed in all directions, just as if the medium were isotropic, while the extraordinary wave has either a maximum or a minimum speed along the optic axis, so that its wave front is either an oblate (doorknob-shaped) or a prolate (football-shaped) spheroid, externally or internally tangent to the spherical ordinary wave front at the two points on the axis (See figure) Along the "equators" of the two wave fronts the difference in speed is greatest Here the extraordinary vibration is parallel to the axis, the ordinary vibration perpendicular to the axis, and the two vibration components, proceeding together, experience a progressively greater difference of phase A "quarter-wave plate" is a layer cut just thick enough for this phase difference to be one-fourth of a cycle



Many crystals have two optic axes In this case the double wave surface is a much more complicated system in which there are four points of intersection, corresponding to the two axes Its section in the X-Z plane is a circle inside an ellipse and not touching it, in the Y-Z plane, an ellipse within a circle, and in the X-Y plane, which contains the axes, an ellipse intersecting a circle at four points Crystals of mica, borax, and topaz are biaxial See also **Electric and Magnetic Double Refraction,** and **Photoelasticity.** (L D W)

DOUBLE STAR (c f **Binary** star) There are numerous cases where two stars are so nearly in the same direction, as seen from the earth that they appear as single stars to the unaided eye but may be separated into two components by the use of a telescope Such a pair of stars is referred to as a double star Double stars may be either one of two kinds In cases where the two stars are only apparently close to each other (i e, lie in approximately the same direction from the earth, but are separated by a great distance in the radial direction) the pair is known as an optical double In the great majority of cases, however, the stars are actually close enough together to exert strong **gravitational** attractions on each other and are in **orbital** motion relative to each other Such physically connected stars form what is known as a **binary star.** Optical doubles may be distinguished from binaries by observing the pair in a telescope over a period of years In case the distance between them changes progressively over a long period of time while the position angle (c f **filar micrometer**) remains constant it may be safely assumed that the motion is due to **proper motion** alone and that an optical **double** is **under observation.** Position angle changes progressively and distance oscillates between a maximum and minimum in the case of a binary

The first recorded discovery of a double star was by Riccioli in 1650 when Zeta Ursae Majoris was announced to be a double star Since that time the search for double stars has been carried on very thoroughly and every star, down to the 10th **magnitude** has been carefully examined Dr R G Aitken, who has completed one of the most comprehensive surveys of variable stars thus far attempted, makes the following statement "At least one in every eighteen, on the average, of the stars in the northern half of the sky which are as bright as 9 0 magnitude is a close double star visible with the thirty-six inch refractor" (W K G.)

DOUC. Langur.

DOUGLAS FIR Conifers.

DOUROUCOLI Monkey.

DOVE. Pigeon.

DOVEKIE. Aves, Charadriiformes The black guillemot, *Uria grylla,* a marine bird (**Aves**) of the north Atlantic Sometimes incorrectly applied to the little auk Also spelled dovekee and dovekey (A W L)

DOWN WASH. The action of an **airfoil** upon air in relative motion is to impart a downward component of velocity to that air Air flowing from the trailing edge of an airplane wing has this vertical component which inclines the airstream relative to the tail surfaces This is known as down wash, and must be taken into account in the design and setting of the horizontal tail surfaces, which are necessary for longitudinal stability The angle between the direction of motion of the plane and the direction of the airstream meeting the tail surfaces is known as the angle of down wash It varies directly with the coefficient of **lift.** (F T M)

DRAFT. Draft of a ship or boat is its depth of flotation It is also the minimum depth of water in which navigation is possible

As applied to a gaseous system, draft is a pressure-differential that operates to move the gases **Combustion** requires oxygen—and therefore air To move this air through the fuel bed and to produce a flow of the gaseous products of combustion out of the furnace, then through the boiler, economizer, etc, requires a difference of pressure equal to that necessary to accelerate the gases to their final velocity, plus friction head losses This difference of pressure is called draft whether measured above or below atmospheric pressure The range of pressures required is most easily measured by manometers reading in inches of water

A manometer measures pressures in terms of a displaced column of water The pressure may be obtained from the manometer reading by employing the factor relating a head of water to the pressure produced at its base It requires 2 31 feet of water to result in a pressure of 1 pound per square inch The ordinary draft gauge is a variation of the U tube manometer

Requisite draft can be obtained by use of **chimneys, fans,** steam or air **jets,** or combinations of these The chimney is probably the most common, but the least understood of any of them At one time the chimney was universally used as the sole means for producing a draft and even in these days of advanced designs it is relied on entirely in numberless small plants and partially in most of the large ones The reason the chimney can produce a draft lies in its confinement of a column of hot gases The density of these gases is much less than the outside air, consequently they are displaced upwards in the stack by the greater weight of the cold air entering under the fuel bed

In making a pattern which is to be molded in sand, a certain small taper is necessary where the pattern is of a shape as to be rather deeply imbedded in the **sand.**

When the pattern is rapped or jarred loose from the sand, a slight taper, called, in foundry practice, draft, allows the pattern to pull free during its removal from the mold, without disturbing the side walls. (F T M)

DRAFT FAN. The mechanically driven draft **fan** is widely employed to supplement or supersede **chimney** action in the production of draft For the most part, the service of the draft fan is that of moving air required for combustion of a fuel

Draft fans are designated from the character of their blading, as *paddle-wheel* (or *plate*), *multivane*, or *screw propeller types* The paddle-wheel type is a low-speed machine, generally suitable for engine drive It is simple in construction, does not easily foul (and when fouled its operation is not seriously hampered), and wearing parts are readily replaced It is used to produce **drafts** up to 2 inches of water The multivane fan is essentially a high-speed machine Balance is important, but the multivane fan responds to scientific design with large capacity, high draft, good efficiency performance The screw propeller fan is good for small blowers on account of its compactness, high speed, and direct connection to a single stage auxiliary steam turbine

The centrifugal fan compresses the air or gas but slightly In modern fan theory the work of compression is neglected and the action is assumed to be similar to a reversed hydraulic turbine or a centrifugal pump

Given the weight of gas flowing per minute and the draft, expressed feet of air

$$\text{Air horsepower} = \frac{WD}{33{,}000}$$

Given the cubic feet per minute delivered, and the draft expressed as pounds per square foot

$$\text{Air horsepower} = \frac{PV}{33{,}000}$$

$$\text{Mechanical efficiency} = \frac{\text{air horsepower}}{\text{driving horsepower}}$$

This will ordinarily be in the range 50–80% for well designed plate and multivane fans

The draft varies as the square of the speed Volume delivered varies directly with speed, therefore driving power varies with the cube of speed

In the earlier days of mechanical draft the fan drive was nearly always steam engine The use of the engine at present is mainly confined to the industrial plant The electric motor has replaced the engine in practically every public service plant on account of the general use by these of regenerative feed-water heating and the economizer Steam engine exhaust has no feed heating value in such plants, consequently steam engine drive becomes expensive Furthermore, the electric drive has positive advantages of its own, principally based on compactness, absence of vibration, flexibility, and centralization of control Where exhaust steam finds a place in the heat balance, **steam turbine** drive is used, especially with large capacity fans. (F T M)

DRAFT TUBE. **Hydraulic turbines** frequently discharge the water with considerably more velocity than would be economical from the efficiency viewpoint, were it not possible to recover a great deal of that energy by the proper use of a diffusing chamber at the outlet The diffusing chamber or tube is known as the draft tube, and there are a variety of types However, the main objective is to convert the velocity head residing in the water leaving the turbine into pressure head If this can be done efficiently, the turbine can be set somewhat below normal tailwater level

The greater the **specific speed** of a turbine runner the higher will be the velocity of the water discharged into the draft tube, and the more important the recovery of this velocity by draft tube design The draft tube is to take the water from the turbine at a point where the pressure is considerably less than atmospheric, and, by efficiently reducing the velocity, convert it into pressure head so that it can emerge smoothly into the tailrace at atmospheric pressure By "efficiently" is meant without shock or whirl loss Not all the velocity head can be recovered, for the water must be given to the tailrace at normal tailrace velocity to prevent its backing up into the turbine Also, whatever friction loss occurs in the draft tube adds to this reduction of useful head. (F T M)

DRAG. (See **Aerodynamics.**) An object subjected to an airstream is acted on by a resultant air pressure Drag is the component of air reaction which is parallel to the airstream Its origin lies in profile impact of molecules of air against the face of the object, the skin friction of the molecules of air as they slide along the object, and the vortices and eddying air currents set up in an otherwise undisturbed airstream by the presence of the object Drag is that quantity which imposes limitations upon the top speed of vehicles, missiles, and so forth As it is proportional to the square of the velocity, its magnitude mounts rapidly as velocities are increased

There are two kinds of drag,—drag on surfaces which obtain a useful reaction from the airstream as well as a drag, and drag upon surfaces whose only reaction is the drag A wing has both drag and lift Drag is the price paid for lift, and is so accepted A strut, or wire, or wheel, creates no lift, and the drag is wholly undesirable A drag of this type is called parasite drag Careful streamlining and reduction of parts exposed to the airstream are the means of reducing parasite drag The drag of a wing may be divided into profile drag and induced drag The former comes from the impact of the molecules against the upstream face of the wing, the second is directly due to the production of lift, and is called induced drag See **airfoil** Profile drag depends on the shape of the airfoil Induced drag depends upon the lift and the **aspect ratio** of a wing During a test, profile and induced drag are not separable Parasite drag depends upon the surface roughness and shape of the object

Experiments in the **wind tunnel** show that factors affecting reaction of air on airfoils are

1 The relative velocity of the air and airfoil
2 Extent of the surface area
3 Density of the air
4 The angle of inclination of the airfoil to the airstream

All this may be stated somewhat as follows

$$R \sim \alpha d S V^2$$

R is wind reaction, α is the **angle of attack** of the wing, d is the density of the air, S the surface area, V the air velocity

If a proper constant K be inserted, the similarity can be made into an equality K may also be made to include the effect of angle of attack and air density The equation is then simplified to

$$R = KSV^2$$

This reaction is neither perpendicular nor parallel to the wind stream It is convenient to divide it into its components of lift and drag Letting K_L and K_D be the corresponding coefficients,

$$\text{Lift } L = K_L S V^2,$$
$$\text{Drag } D = K_D S V^2$$

There will be a different value of K for each angle of attack

The defect of this equation is that K is not dimensionless, as a true coefficient should be, also, the formula is not flexible with respect to air density If it were rewritten

$$R = C_\rho S V^2,$$

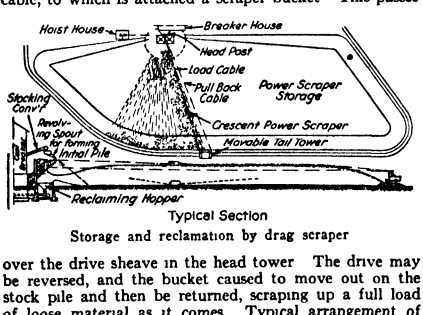
in which ρ equals mass density of air, C would be dimensionless The equation is usually written thus for drag,

$$D = C_d \frac{\rho}{2} SV^2,$$

because $\frac{\rho V^2}{2}$ is the pressure necessary to give air of density ρ a velocity of V This is called the dynamic pressure The drag is $C_d qS$, where q stands for dynamic pressure The drag coefficient C_d varies with angle of attack, but it is dimensionless The wind tunnel test is used to establish the law of variation, and the results are plotted as a drag curve, with the coefficient of drag as the ordinate, and either coefficient of lift, or angle of attack as the abscissa (F T M)

DRAG LINE. The drag line excavator consists of a turntable on wheels or caterpillar treads, which supports the excavating machinery A long **boom** is pivoted at its lower end to the turntable, and guyed at its outer end by a rope **sheave.** Extra long booms are characteristic of the drag line excavator because the loading of the bucket is by scraping action in contrast to the shoveling action of a grab bucket By the use of the boom, to which is attached the scraper, with the intermediary of a block and tackle, the operator can place the scraper bucket at a distance of 25 to 100 feet from the position of the excavator The scraper has attached to it a drag line which is wrapped around a powered drum in the cab As this drag line is reeled in, it drags the scraper bucket and fills it, after which it is hoisted and dumped wherever wished The drag line excavator has been built in very large capacities, and is especially suitable for such work as levee building, **borrow pit** work, etc

The drag line scraper is a means for stocking out bulk material to storage and reclaiming the same It is comparatively low in first cost, and adaptable to a storage lot of irregular area A head post and machinery house is located at the point from which stocking out begins, and to which reclamation moves A movable tail tower may be operated at different points along the edge of the storage lot farthest from the head post Between the tail tower and head post is an endless wire cable, to which is attached a scraper bucket This passes



Storage and reclamation by drag scraper

over the drive sheave in the head tower The drive may be reversed, and the bucket caused to move out on the stock pile and then be returned, scraping up a full load of loose material as it comes Typical arrangement of the drag scraper is shown in the accompanying figure (F T M)

DRAGONET. Pisces, Teleostei. *Callionymus* Brightly colored marine shore fishes (**Pisces**), limited to the Palaearctic region with the exception of a few tropical species in the Pacific Ocean (A W L)

DRAGON FLY. Insecta, Odonata. Large insects of powerful flight which eat other insects caught in the air The immature insect is aquatic and predacious The order is composed of dragon flies and damsel flies only All have four slender net-veined wings and long slender bodies but the dragon flies have fore and hind wings of slightly different shape and hold them extended when at rest Also called Devil's darning needles (A W L)

DRAGON'S BLOOD. Resins.

DRAIN. In medicine, this term refers to any appliance placed in a wound to provide for escape of discharge or drainage A common drain for small infections is a small piece of rubber or gauze In abdominal cases, where drainage is required, the cigarette drain is most commonly used This is made up of several layers of gauze surrounded by a sleeve of thin rubber sheeting A Penrose drain is a thin tube of rubber sheeting without any gauze filling Soft rubber tubing of all sizes is also commonly used (R S M)

DRAINAGE. The removal of water from any particular locality constitutes the action of drainage Natural drainage is embodied in the rivulets, streams, and rivers to which surface and subsurface water is drained. Artificial drainage is used for a wide variety of purposes Drainage in pipes is very common, especially in removing the water-floated wastes from human habitations The drainage from sinks, lavatories, baths, and toilets constitutes a special phase of plumbing All such drainage is accommodated in pipes The principal drainage arteries for such a system are cast iron pipes with bell and spigot joints which are made water tight by calking Secondary drains are usually 1¼ inch or 1½ inch screwed iron pipe

Artificial drainage of surface waters for the purpose of drying, or partly drying, a certain area of land, or for the purpose of intercepting water on its natural way toward a particular tract, can be accomplished by the use of ditches which are pitched in the direction in which the water is to be removed Swampy, marshy land is often drained by this method

Subsurface drainage systems are used where a ditch would be undesirable, as on a playing field The subsurface drain can be a French drain or a pipe drain A French drain is a deep ditch filled to a short distance below the surface with loose rock, the larger rock being at the bottom Due to the larger friction loss in a drain of this type, it must be laid to a steeper gradient than that used in the pipe drain In a subsurface pipe drain terra cotta drain tile is laid end to end with slightly open joints A fill of loose materials, such as crushed stone or gravel, is laid around the open joints so that water which enters this porous area will seep through the open joints into the pipe drain (F T M)

DRAVITE. Tourmaline.

DRAWING. One use of the word drawing is in reference to an operation performed on metal The metal is originally in the form either of sheets, solid blanks, or pierced billets These are pulled in suitable dies into many different shapes, such as hollow cylinders, cup like parts, or solid parts of various shapes Pipe, wire, various structural shapes, are often formed by drawing Drawing tends to reduce the thickness of the metal and to harden it, especially cold drawing (F T M)

DREDGE. An excavating machine for use in river, harbor, or drainage work, is a dredge A characteristic application of the dredge is in submarine excavation Dredges are usually floated on watertight hulls There are several types, which may be classified according to the way they excavate The dipper dredge, which is the more common type, is very similar to a locomotive crane, except that it is mounted on a floating hull Its digging equipment consists of a dipper or grab bucket, which is able to dip as deep as 50 feet below the water surface This type of dredge may be used in dredging channels or in cutting a wide drainage ditch provided the ditch is large enough to float the dredge This dredge will dig its own water-way through land, and is particularly useful for drainage work A dredge where the

excavating is done by a number of buckets placed on an endless chain is known as an elevator dredge. A bucket chain is able to elevate the spoil considerably higher than other types It is frequently used to raise sand and gravel from a stream bed

The hydraulic dredge digs by suction of the spoil material from the bottom A large pipe is lowered to the area to be dredged A water pump attached to the upper end creates a powerful flow of water through the pipe which picks up and carries the loose material near the mouth of the pipe Large, specially-designed centrifugal pumps create the flow Dredges are usually steam driven The larger sizes contain living quarters for the crew (F T M)

DREIKANTER. Literally a three-sided or three-faceted pebble A term, of German origin, signifying a pebble that has been sculptured or faceted by natural sandblasting Such pebbles are usually considered to be proof of the semi-arid or even desert condition under which they have been formed, but they may also be formed in pluvial climates provided that the **regolith** is composed of porous and shifting sands such as compose glacial sand plains and coastal beaches. They are also called gibbers or glyptoliths (R M F)

DREWITE. A term proposed by R M Field in 1918 for pure **calcium** carbonate muds of organic chemical origin Drewite probably forms the bulk of the fine grained unfossiliferous **limestone** from the **pre-Cambrian** to the present (R M F)

DRIFT. In mechanics a drift is a hand tool somewhat resembling a punch, but used to drive pins in or out of deep holes The drift is made slightly smaller than the diameter of the hole

In structural engineering the term drift pin refers to a tapered steel pin which is used during the fabrication of a member to hold the individual parts together before the fitting-up bolts (bolts which are necessary to draw the parts together subsequent to riveting) are inserted in the **rivet** holes Drift pins are also used together with bolts in steel erection to fasten the members to the **gusset plates** or other connections before the field rivets are driven.

In geology, the use of the term drift came about in the following way Before Louis Agassiz propounded his theory that extensive deposits of sand, gravel, boulder clays, etc, of Northern Europe and North America were the result of the action of great continental ice sheets, it had been suggested that during some period when the land had stood at a lower level, ice bergs were swept from the north over the continents and, melting, dropped their loads of detritus Thus some of the material which we now know to be of glacial origin was called drift, because it was believed to have been "drifted" to its place through the agency of ice This was the theory of Sir Charles Lyell as a substitute for the still older theory of the diluvialists who believed that these glacial deposits were positive evidence of the "deluge" Geologists have retained the term drift to designate all unconsolidated sediments which are determined to be of glacial origin, and still further divide drift into stratified drift and unstratified drift or till For "ether drift," see **Ether** and **Michelson-Morley Experiment.** (F T M, R M F)

DRILL. For the use of this term in zoology, see **baboon.** In mechanics a drill is a tool for boring holes It is distinguished from the boring machine in that a boring machine revolves the work against a fixed cutting tool, as in a **lathe,** whereas the work is held fixed for drilling, and the drill revolved The common drill for boring metals is the steel twist drill, having a spiral fluted cutting surface, and a round shank which is held by the **chuck** of the drilling machine The work is suitably clamped or held to the table of the machine, and the revolving drill forced against it under pressure. The twist drill is slightly larger at the point than at the shank, to prevent binding in the hole The cutting edges of the flutes are eased off on their backs for the same reason Steel twist drills are sized by **gauge numbers** and by diameters. In small sizes they are designated by number corresponding to the steel wire gauge These gauge numbers extend from one through eighty, and the drills have corresponding diameters varying from 0 2280 to 0 0135 of an inch Larger sizes of drills are designated by their diameters, beginning at 1/16 inch and advancing by sixty-fourths of an inch Up to about three inches, these may be had in either the straight or tapered shanks, but in the larger sizes the tapered shank is standard

Tools for boring other materials than metal are sometimes called drills For example, a tool for drilling rock or concrete is known as the star drill, but its cutting action resembles that of a chisel more than an ordinary twist drill. Tools for boring wood are known as bits, and although somewhat similar to the ordinary twist drill, there are some significant differences For instance, they are terminated at the tip by a small screw or worm, which advances the bit into the material Instead of being fluted, they are constructed on the order of a spiral web (F T M)

DROMEDARY. Mammalia, Artiodactyla An Arabian **camel** of a breed used for riding Incorrectly applied to the Bactrian camel (A W L)

DRONGO Aves, Passeriformes The king crows of southern Asia and Africa Birds (**Aves**) of several species, mostly black, forming a family not closely related to the true crows (A W L)

DROPSY. Accumulation of fluid in the tissues or cavities of the body It is more correctly called **edema.** The common causes of this condition are **heart** and **kidney** disease (R S M)

DROSOPHILA. Insecta, Diptera The name of a genus of fruit flies or pomace flies Because of the extensive use of these insects, and especially *Drosophila melanogaster,* in the study of heredity the name of the genus has become more commonly used than the vernacular names See **Heredity**

These flies are small and usually light colored insects which frequent decaying or fermenting fruit They are attracted by vinegar, cider, and fruit wastes even when fresh and so are often common about the house during the canning season The **larvae** live in the fermenting material (A W L)

DRUGS. A wide variety of sources has been tapped to furnish materials to combat disease and its effects, and to promote health Many of the products of vegetable, animal and mineral origin in use were recognized many centuries ago as possessing therapeutic value Great improvements have been made in this field in recent decades The desired products have been obtained in greater purity and of greater efficacy. In many cases individual or group substances have been isolated and synthesized The role played by particular drugs in promoting recovery or improvement of health has been studied Many drugs are used, not for their function in combating directly the causative agent of a disease but for their indirect action (1) upon its toxic products, (2) by inducing a **biochemical** reaction, which causes the body organism to produce substances to combat the disease organisms or their toxic products, (3) by inducing physiological reactions which enable the patient to resist those reactions caused by the disease

Vegetable drugs may occur in all parts of plants, but are particularly abundant in such storage regions as seeds, roots and bark Many used by man are found in the leaves, and a few in the flowers Their function in the plant is a debated one, perhaps they are by-

products of the plant's metabolism, or they may be energy-yielding reserves stored until needed. The poisonous nature of many of them suggests the thought that they may be designed for protection against attacks by insects and other animals Drug substances in the plant fall into several classes One of these contains the alkaloids, nitrogenous organic substances which react with acids Many of these alkaloids are powerful poisons; all of them are toxic to animals In another group of drug substances are the glucosides, complex organic substances which, when acted upon by certain **enzymes**, break down into **sugars** plus other compounds Glucosides contain no nitrogen Other medicinal substances are found in **resins**, **tannins**, **gums**, and **oils**

In former times the number of plants used medicinally was very great The medicinal value of many of them was determined largely by the curious and interesting "**Doctrine of Signatures**" Quite probably the value of many others was discovered entirely by accident Many were known by primitive man and the knowledge of their value handed down from generation to generation In modern times the number of plants used medicinally has diminished greatly, partly because men learned how absurd was the reason for their use and how slight their value, and partly because other drugs, many of them prepared synthetically, replaced the natural products But many continue to be of great benefit to man

Every part of the world yields drug plants In a very few instances, these plants are cultivated Mostly, however, the plants are gathered wild Usually all that is necessary to prepare the crude drug for market is to gather and dry the plants They are then shipped to the wholesale buyers If the plant itself is to be used as a drug, it is now thoroughly cleaned and then ground More frequently the preparation is an elaborate process calculated to free the pure drug from the tissue in which it occurs

Common vegetable drugs are **belladonna**, **ipecac**, **quinine**, **coca**, **digitalis**, **strychnine**, **opium**, **castor oil**, **camphor**, and **menthol**

The narcotics include very valuable drugs which, taken in moderate doses, properly prescribed, relieve pain and produce sleep, but in large doses cause stupor, or coma, and commonly convulsions Among the habit-forming drugs are **opium** and its derivatives, **coca**, and hashish from **hemp**

The pioneer workers in pharmacology acquired considerable empirical information about methods of extraction of drugs from natural materials by water, hot water, alcohol and other solvents, and combinations of solvents In the more purely scientific field, some outstanding discoveries are the **hypnotic**, chloral hydrate (1867), the **antipyretic**, acetanilide (1885), the **antisyphilitic**, salvarsan (1910), the **thyroid** principle, thyroxin, and insulin (used in **diabetes**)

Refinements in the technique of biological assay have contributed largely to the progress in the study of **vitamins**, **enzymes**, and **hormones** By means of the methods that have been developed in this branch of science the effects of complex mixtures of substances are measured by their physiological reaction on test animals In this way the direction of physiological research is controlled, even though the chemical nature of the substance under examination is entirely unknown

Some substances that are mentioned elsewhere may be classified as drugs, since they are of the greatest importance in treating disease and promoting health These are (1) the serums and **vaccines** usually produced in animals, directly or indirectly, by biochemical reactions of **bacteria** In some cases the bacteria produce an attenuated strain which is utilized Vaccines are used to induce a mild attack of the disease or a related disease By this means protective substances are formed in the system of the patient The protective substances are added directly to the system in other cases (2) The glandular products, of which **adrenalin**, the active principle of the **suprarenal gland**, and **thyroxin**, the active principle of the **thyroid gland**, have attracted widespread attention, have been studied physiologically on test animals, and on man, and both have been synthesized (3) The **vitamins** have been shown to be necessary for the normal functioning of the organism as well as necessary for the avoidance and cure of certain deficiency diseases

Representative drugs may be classified upon the basis of physiological function as follows·

1 *Antiseptics* Sodium hypochlorite, iodine, alcohol, silver nitrate, tannic acid, picric acid, potassium permanganate, iodoform, chloramine T, dichloramine T, hydrogen peroxide, 4-hexylresorcinol (urinary disinfectant), phenol, mercuric chloride solution (very poisonous), boric acid, argyrol (colloidal silver), menthol, phenyl salicylate (salol), triphenylmethane dyes, both basic (very poisonous) and acidic, flavine dyes (proflavin, acriflavin, rivanol —active in the presence of proteins)

2 *Anesthetics* (a) General ether, chloroform, nitrous oxide, ethylene, cyclopropane, avertin, alcohol (b) Local. cocaine, novocaine, stovaine, production of cold by evaporation of ethyl chloride

3 *Soporifics, hypnotics* Bromides of sodium, potassium, ammonium, calcium, lithium, chloral hydrate, sulfonal, trional, tetronal, ethyl carbamate, hedronal, barbital (Veronal), phenobarbital (Luminal), diallybarbituric acid, allylisopropylbarbituric acid, and other barbituric acid compounds

4 *Antipyretics, analgesics* Acetanilide, acetphenetidin (Phenacetin), acetyl salicylic acid (Aspirin), antipyrine, pyramidon, Atophan, Novatophan

5 *Purgatives, laxatives, cathartics* Citrates, tartrates, acetates, phosphates, sulfates of magnesium, sodium, potassium, phenolphthalein, castor oil, croton oil, cascara, rhubarb, aloin, podophyllin, and other plant principles.

6 *Circulatory depressants and stimulants* (a) Depressants glyceryl trinitrate, erythritol tetranitrate, mannitol hexanitrate, isoamyl nitrite, sodium nitrite, benzyl nitrite, aconite, veratrine (b) Stimulants digitalis, digitoxin, digitalin (not digitonin), caffeine, adrenalin, ammonia, camphor, cocaine

7 *Parasympathetic nerve paralysers and stimulants.* (a) Paralyzers atropine, homatropine (b) Stimulants. pilocarpin, physostigmine, histamine

8 *Mydriatics and myotics* (a) Mydriatics (causing dilation of the pupil) belladonna, atropine, strychnine, scopolamine (hyoscine) (b) Myoptics (causing contractions of the pupil) pilocarpine, eserine

9 *Diuretics* Caffeine, theobromine, theophyline (theocin), hexamethylenetetramine

10 *Emmenagogues* Ergot, apiol, rue, tansy

11 *Emetics* Ipecac, potassium antimony tartrate (tartar emetic), apomorphine, mustard

12 *Expectorants* Ammonium chloride, ammonium anisate, woodtar creosote, eucalyptus, terebene

13 *Astringents* Tannic acid, alum

14 *Counterirritants* Mustard, capsicum, turpentine, chloroform, cantharides

15 *Antiarthritics* Lithium citrate, cinchophen, salicylates and iodides of sodium, potassium, ammonium, calcium, strontium, lithium

16 *Alteratives* Iodides of sodium or potassium, colchicum, taraxacum

17 *Antacids* Sodium bicarbonate, magnesium hydroxide and oxide, bismuth basic carbonate

18 *Tonics, bitters.* Cinchona, nux vomica, ferric citrate, sodium hypophosphite, glycerophosphates of sodium, potassium

19 *Narcotics* Morphine, codeine, heroin, scopolamine (hyoscine)

20 *Demulcents* Glycerol, olive oil, gelatin.

21 *Drugs for specific diseases* For counteracting (a) malaria· quinine, (b) syphilis· arsphenamine (Salvarsan, Ehrlich 606), neoarsphenamine (Neosalvarsan), (c) leprosy: esters and sodium salt of chaulmoogric acid,

(d) sleeping sickness: tryptane blue (Bayer 205), (e) acute rheumatic fever: salicylic acid compounds.

22. *Enzymes.* Pepsin, pancreatin.

23. *Hormones.* Adrenalin (active principle of the suprarenal gland), thyroxin (active principle of the thyroid gland). Insulin (active principle of the pancreas). Pituitary extract (active principle of posterior lobe of pituitary gland).

24. *Vitamins.* See **Vitamins.** (R.K.S., R.M.W.)

DRUM. Pisces, Teleostei. Fishes (**Pisces**) of numerous species, mostly marine, constituting the family Sciaenidae. The **sheephead** is a North American fresh water species of some food value. (A.W.L.)

DRUMLIN. A drumlin is a hill composed of glacial material of unstratified and heterogeneous character usually about 100 feet in height and one-quarter to one-half mile in length, oval in shape, and with its long axis parallel with the general direction of ice movement. Sometimes a mass of bed rock seems to have been the anchor about which the glacial till was deposited. Drumlins are known, however, which contain no bed rock core. Drumloid-shaped hills similar to the smaller glaciated rock features called roche moutonnée are sometimes called rock drumlins. (R.M.F.)

DRUPE. **Fruit.**

DRUSE. A cavity, usually in a **sedimentary** rock, the walls of which are encrusted with minerals which have been derived, through underground solutions, from the rocks in which the cavities were formed, by **solution.** (R.M.F.)

DRYING. **Distillation, Evaporation and Drying.**

DRYOPITHECUS. **Paleontology of man.**

DUANE AND HUNT'S LAW. The quantum-energy law for the generation of x-rays. When a cathode particle in an x-ray tube strikes the target, its energy may all be transformed into heat; or it may excite an atom of the metal to emit a quantum of x-radiation. (See **X-rays and Quantum Theory.**) If all the cathode particles have the same energy Ve (voltage times electronic charge), some may give rise to low-frequency quanta and have energy left to heat the target, others may excite quanta of higher frequency and have less energy to spare. But no quantum can be emitted of frequency and energy higher than that corresponding to the original energy of the electrons. This is Duane and Hunt's law. It is expressed by the so-called Planck-Einstein equation. If the highest frequency emitted is ν_{max}, and h is Planck's constant, the equation may be written $h\nu_{max} = Ve$. It follows that for a given voltage V, the **x-ray spectrum** must terminate abruptly at the frequency Ve/h. (L.D.W.)

DUCK. Aves, Anseriformes. Swimming birds (**Aves**) of moderately large size with heavy bodies, short legs, webbed feet, and broad flattened beaks with sieve plates at the sides. In common usage the term includes the closely related **teals, sheldrakes,** and **mergansers.** With the exception of the mergansers, which have narrow beaks with serrate edges and live chiefly on fish, the ducks eat rice and other plant products, with some insects and other small animals. They are among the leading game birds and many wild species have very palatable flesh. Many species have been domesticated and interbred with the common domestic duck.

Among species which have received special names are the **gadwall, widgeon, mallard, shoveler, pintail, buffle-head, scoter,** and **canvas-back.** (A.W.L.)

DUCKBILL. Mammalia, Monotremata. *Ornithorhynchus.* A primitive egg-laying mammal of Australia, also called the platypus and the duck-mole. It is about eighteen inches long and has close fur somewhat like that of the moles. The muzzle is broad, flat, and naked, resembling the beak of a duck but not horny. The feet are broad and webbed. Duck-moles are found in the streams of southern and eastern Australia. They nest in burrows in the banks and deposit two small eggs at a time. The young are nourished with milk secreted by the mother. (A.W.L.)

Duckbill or Platypus. (Courtesy of *N. Y. Zool. Soc.*)

DUCT. In physiology, a tube-like structure providing for the passage of secretions or excretions from any bodily organ. (R.S.M.)

DUCTILITY. **Metals, Physical Properties of.**

DUCTLESS GLAND. **Endocrine gland.**

DUCTUS COMMUNIS. A passage connecting the ducts of all female organs of reproduction with the genital **atrium** in the flatworms. (A.W.L.)

DUGONG. Mammalia, Sirenia. A marine **mammal,** *Halicore,* found along the shores in the Oriental region. Related to the American manatee. It has a blunt muzzle, a broad horizontal tail, and pectoral flippers. These animals eat seaweed and are caught for their flesh and oil. (A.W.L.)

DUIKERBOK. Mammalia, Artiodactyla. Small South African **antelopes.** Daintily built, with large ears and in the male short straight horns. (A.W.L.)

DULONG AND PETIT'S LAW OF SPECIFIC HEATS. It has long been known that the atomic heats of the great majority of elements have nearly the same value at room temperature; in fact, the thermal capacity of a gram atom of most elements is not far from 6 calories per degree. Dulong and Petit expressed this by stating that the specific heats of elements are in inverse proportion to their atomic weights.

That this should be the case for gases, easily follows from the **kinetic theory** and the principle of **equipartition of energy.** For example, if the same mean energy per molecule is necessary to raise the temperature of oxygen and of hydrogen 1°, the same is true per atom, and weights of these gases having the same number of atoms will have equal thermal capacities.

For solids the matter is not quite so simple, and the more exacting theories of Einstein, Debye, and others show that the atomic heat should be expected to vary with the temperature. According to Debye, there is a certain characteristic temperature for each crystalline solid at which its atomic heat should equal 5.67 calories per degree. Einstein's theory expresses this temperature as $h\nu_m/k$, in which h is **Planck's constant,** k is **Boltzmann's constant,** and ν_m is a frequency characteristic of the atom in question vibrating in the crystal lattice (See **Chemical Composition**). (L.D.W.)

DUNE. Dunes are elliptical or crescent shaped mounds of sand which may reach a height of a hundred or more feet. The windward slopes of dunes are gentle, the lee sides steep, if crescentic in shape the convex side faces the direction from which the wind is blowing. The crescentic shaped dunes are called barchans. Sand blown up the windward side drops down the lee slope causing the dunes to migrate slowly. Dunes are common and characteristic phenomena of lake and sea beaches, semi-arid regions, and particularly deserts, but also may develop on any dry, sandy soil in a relatively

humid region where there is a lack of vegetation Ancient geologic formations which may have originated

Types of sand dunes (after Walther and Cornish).

as dunes may be discovered by their peculiar type of **cross-bedding**, and by the peculiar texture of the sand. (R M F)

DUNITE. Peridotite.

DUNLIN. Aves, Charadriiformes *Tringa* A common European shore bird, a **sandpiper** Also called the ox bird (A W I)

DUNNOCK. Aves, Passeriformes The European hedge sparrow, *Prunella modularis* (A W L)

DUODENUM. That portion of the intestinal tract immediately beyond the stomach It begins at the **pylorus** and extends to the beginning of the **jejunum** Horseshoe shaped, it forms a curve around the head of the pancreas The secretions of the duodenum are alkaline Into it empty the bile duct from the liver and two ducts from the pancreas It is here that digestion of food really begins

The duodenum is a common site for ulceration (R S M)

DUPLEX PUMP. The kind of **direct acting pump** most often found has two steam cylinders arranged side by side The water cylinders are also two in number, arranged side by side The duplex pump is in reality a twin cylinder **pump** It has two steam pistons, two water pistons, and two piston rods The special advantage of the twin arrangement comes from the convenience of valve operation in a twin-cylindered direct acting pump The steam valve of one of the cylinders is caused to reciprocate properly in its valve chest with a motion derived from the travel of the piston rod of the other

The mechanism is quite simple A collar block attached to the piston rod operates an oscillating type lever to one end of which is attached the steam valve The motion of that piston rod moves the valve in the other cylinder, which then executes a pumping stroke as the steam enters and pushes against the piston As that piston rod moves, it similarly operates the valve in the first steam cylinder, causing it to effect a pumping stroke Thus in a duplex pump the valve action on one cylinder is derived from the stroke of the other, and pumping strokes are consummated alternately, first in one cylinder, then in the other (F T M)

DURAIN. The term proposed by Marie Stopes in 1919 for an ingredient of bituminous **coal**, occurring in bands In thin, translucent sections durain is seen to be composed of reddish **spores** in a gray, granular **matrix** (R M F)

DURALUMIN. **Alloys.**

DURCHMUSTERUNGEN. **Bonner Durchmusterung.**

DURIRON. **Alloys.**

DYADS. **Dyadics.**

DYADICS. Two **vectors** placed in juxtaposition neither with a dot nor a cross $\times$ between them constitutes a dyad, as for example **ab**

Any polynomial of dyads, as $\mathbf{a}_1\mathbf{b}_1 + \mathbf{a}_2\mathbf{b}_2 + \quad + \mathbf{a}_n\mathbf{b}_n$, is called a dyadic

A dyadic is sometimes regarded as a **tensor** of the second rank

The first vector of a dyad is called its antecedent and the second its consequent The antecedents and consequents of a dyadic are respectively the antecedents and consequents of its constituent dyads

In general, a dyadic is usually denoted by bold-face capital Greek letters, as Φ

If the order of the vectors in each dyad of a dyadic Φ is reversed, the resulting dyadic is called the conjugate of Φ

Two dot products of a dyadic $\Phi = \mathbf{A}_1\mathbf{B}_1 + \quad \mathbf{A}_n\mathbf{B}_n$ by a vector $\mathbf{v}$ are defined thus

$$\Phi \cdot \mathbf{v} = \mathbf{A}_1(\mathbf{B}_1 \cdot \mathbf{v}) + \mathbf{A}_2(\mathbf{B}_2 \cdot \mathbf{v}) + \cdots \mathbf{A}_n(\mathbf{B}_n \cdot \mathbf{v}),$$
$$\mathbf{v} \cdot \Phi = (\mathbf{v} \cdot \mathbf{A}_1)\mathbf{B}_1 + (\mathbf{v} \cdot \mathbf{A}_2)\mathbf{B}_2 + \quad \cdots + (\mathbf{v} \cdot \mathbf{A}_n)\mathbf{B}_n,$$

both being vectors In $\Phi \cdot \mathbf{v}$, the dyadic Φ is said to act as pre-factor, in the other case, as post-factor

A dyadic acting as pre-factor or post-factor upon any vector produces a **linear vector function** of this vector

Any dyadic $\Phi = \mathbf{A}_1\mathbf{B}_1 + \cdots + \mathbf{A}_n\mathbf{B}_n$ can be reduced to the trinomial form $\mathbf{a}_1\mathbf{b}_1 + \mathbf{a}_2\mathbf{b}_2 + \mathbf{a}_3\mathbf{b}_3$, where $\mathbf{a}_1$, $\mathbf{a}_2$, $\mathbf{a}_3$ are chosen arbitrarily

Any dyadic Φ can be expressed in the form

$$\Phi = a_{11}\hat{\mathbf{i}}\hat{\mathbf{i}} + a_{12}\hat{\mathbf{i}}\hat{\mathbf{j}} + a_{13}\hat{\mathbf{i}}\hat{\mathbf{k}}$$
$$+ a_{21}\hat{\mathbf{j}}\hat{\mathbf{i}} + a_{22}\hat{\mathbf{j}}\hat{\mathbf{j}} + a_{23}\hat{\mathbf{j}}\hat{\mathbf{k}}$$
$$+ a_{31}\hat{\mathbf{k}}\hat{\mathbf{i}} + a_{32}\hat{\mathbf{k}}\hat{\mathbf{j}} + a_{33}\hat{\mathbf{k}}\hat{\mathbf{k}}.$$

This is called the nonion form of the dyadic

A dyadic which is identical with its conjugate is called a symmetric dyadic, for it, we have $a_{ij} = a_{ji}$, i e , $a_{12} = a_{21}$, $a_{13} = a_{31}$, $a_{23} = a_{32}$

A dyadic is called anti-symmetric or skew-symmetric when it is equal to the negative of its conjugate, then $a_{ij} = -a_{ji}$, i e , $a_{11} = a_{22} = a_{33} = 0$, $a_{12} = -a_{21}$, $a_{23} = -a_{32}$, $a_{31} = -a_{13}$

If Φ is symmetric, and $\mathbf{v}$ is any vector, then $\Phi \cdot \mathbf{v} = \mathbf{v} \cdot \Phi$

A dyadic which, acting as pre-factor or post-factor upon a vector, produces the vector itself, is called an idemfactor or unit dyadic Its standard form is

$$\mathbf{I} = \hat{\mathbf{i}}\hat{\mathbf{i}} + \hat{\mathbf{j}}\hat{\mathbf{j}} + \hat{\mathbf{k}}\hat{\mathbf{k}}$$

Any dyadic can be resolved into a sum of a symmetric part and a skew-symmetric part

Any symmetric complete dyadic Φ can be reduced to the normal form

$$\Phi = a\hat{\mathbf{i}}\hat{\mathbf{i}} + b\hat{\mathbf{j}}\hat{\mathbf{j}} + c\hat{\mathbf{k}}\hat{\mathbf{k}},$$

where the coefficients a, b, c are positive or negative (scalar) constants, by a transformation of axes (L L S)

DYES AND DYEING TEXTILE FIBERS. With few exceptions the dyestuffs in use for dyeing textiles, coloring foods, as chemical indicators, biological stains, antiseptics, and photographic sensitizers, are made industrially from the benzenoid **hydrocarbons, benzene, toluene, naphthalene, anthracene** These hydrocarbons are colorless substances when observed in natural light They show, however, slight absorption of light of wave length outside the range of easy visibility to the naked eye, at the extreme edge of the spectrum Such simple derivatives of these hydrocarbons as pure **phenol, hydroquinone**, the naphthols, anthranol, chlorobenzene, dichlorobenzene, benzenesulfonic acid, **aniline** and hydrazobenzene are likewise colorless to the naked eye, and some show slight absorption of light beyond the visible spectrum

But nitrobenzene is of a pale yellow color, and azoxybenzene pale yellow Thus, these two substances show some absorption of light in the visible spectrum Finally, benzoquinone and azobenzene are highly colored substances, thus showing marked absorption in the visible spectrum Quinones are the only carbon-hydrogen-oxygen compounds that as a class possess marked color Azo-nitrogen compounds possess marked color Some nitro-compounds are decidedly colored, others slightly, some scarcely The following table is intended to make these results graphic

TABLE SHOWING HIGHLY COLORED DERIVATIVES OF BENZENOID HYDROCARBONS

Note Highly colored substances (not dyes) are underlined once, dyes twice

HYDROCARBON	SELECTED DERIVATIVES OF HYDROCARBONS				
Benzene	Phenol Dihydroxybenzenes (1, 2, 1, 3, 1, 4) Aniline Benzidine Chlorobenzene Dichlorobenzene Benzene sulfonic acid	Benzoquinone Hydrazobenzene	Azobenzene Aminoazobenzene Hydroxyazobenzene	Azoxybenzene	Nitrobenzene 4-Nitrophenol Sodium-4-nitrophenolate 2,4,6-Trinitrophenol 2,4,6-Trinitroaniline
Toluene	Cresols Orcinol Toluidine Tolidine Chlorotoluenes Toluene sulfonic acids	Toluquinone Hydrazotoluene	Azotoluene		Nitrotoluenes 2,4,6-Trinitrotoluene
Naphthalene	Naphthols Dihydroxynaphthalenes Naphthylamines Chloronaphthalenes Naphthalene sulfonic acids	Naphthoquinone			Nitronaphthalenes
Anthracene	Anthrols and Anthranol Dihydroxyanthracenes Anthramine	Anthraquinone 1,2-Dihydroxyanthraquinone (alizarin)			

The groups which distinguish these and other highly colored organic substances—chromogenes—are called chromophors (color producers)

CHROMOGENE	CHROMOPHOR GROUP
Quinones	
Azo-compounds ...	—N · N—
Nitro-compounds	$-NO_2$

Chromogenes, although highly colored, are not dyes Colored substances, in order to be classed as dyes, must be capable of permanent attachment to some other substance, such as cotton and linen, wool and silk, rayon, in such a way as to withstand the action of water and soap Dyes for ordinary use should also be fast to sunlight

Chromogenes are converted into dyes by the introduction of a secondary group, called an auxochrome (color fixing) group, such as (1) amino group (—NH_2, also for example, —N$\langle^{H}_{CH_3}$, —N$\langle^{CH_3}_{CH_3}$, >NH), (2) hydroxyl group (—OH), (3) carboxyl group (—COOH) Picric acid (2,4,6-trinitrophenol) is a dye, while TNT (2,4,6-trinitrotoluene) is not a dye, although highly colored Para-aminoazobenzene (C_6H_5—N N—$C_6H_4(NH_2)(4)$) and para-hydroxyazobenzene (C_6H_5—N N—$C_6H_4(OH)(4)$) are dyes, while azobenzene (C_6H_5—N N—C_6H_5) and para-para-prime-azotoluene ($(4)(CH_3)C_6H_4$—N N—$C_6H_4(CH_3)(4)$) are not dyes although highly colored Alizarin (1,2-dihydroxyanthraquinone) is a dye, while anthraquinone, like naphthoquinone and benzoquinone, is not a dye although highly colored

Auxochromes increase the solubility of the dye over that of the chromogens, and the presence of the sulfonic acid group is of great importance in this respect (See **Thioalcohols**) Dyes must usually possess a basic, or acidic nature Basic dyes contain the amino auxochrome (forming salts, e g, hydrochlorides), feebly acid dyes the hydroxyl chromophore, and acid dyes the sulfonic acid (more commonly) or carboxyl (less commonly) auxochrome (forming salts, e g, sodium salt) The solubility of acid dyes is frequently attained by the use of the sodium salt

The effect of increasing the weight of the dye molecule by addition of methyl (—CH_3), ethyl (—C_2H_5),

amino ($-NH_2$) groups is to darken the color For example, aminoazobenzene is pale yellow, diaminoazobenzene orange, and triaminoazobenzene brown

As to the basic or acidic nature of the fibers to be dyed, wool and silk are proteins (See **Aminoacids**) and behave as acids towards bases, and as bases towards acids (that is, they are amphoteric) and are readily dyed directly by dyes of a basic or acidic nature Cotton and linen, on the other hand, are cellulose (See **Carbohydrates**) and noted for their chemical inertness These are scarcely affected by basic or acidic dyes Rayons of cellulose are similar to cotton and linen in respect to dyeing, and rayons of cellulose acetate require special dyes

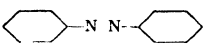
The cellulose fibers are dyed directly by some dyes such as benzidines, primulines (both are amino dyes), curcumines (hydroxy dyes), by the use of **sodium** chloride or sodium sulfate solution But generally these fibers are dyed by the use of mordants In this process dyestuffs containing either hydroxyl (—OH) or carboxyl (—COOH) groups in their composition are used with a solution of **chromium, aluminum, iron, tin** or **copper** salt Other dyes are used as mordant dyes, and other mordanting materials, for example, **tannic acid,** are used with basic dyes With these salts the mordant dyes form a colored insoluble substance called a lake, which is permanently fixed in the fiber under the conditions of dyeing The color is dependent upon the mordant used for a particular dye **Cellulose** acetate fibers are dyed by ionamines, which are insoluble azo or anthraquinone dyes, temporarily converted into soluble derivatives by the introduction of the group $-CH_2SO_3Na$, and later split off in the dyeing process leaving the insoluble dye on the fiber Insoluble azo or anthraquinone dyes are also maintained in suspension in the dye bath by means of sulfonated castor oil These dyes do not adhere to cotton, linen, or viscose, and therefore permit the operation of selective dyeing when other fibers are used with cellulose acetate

In vat dye processes an insoluble dye is converted into a weakly acidic, alkali-soluble, colorless or leuco-compound Upon immersion of the fiber in the dye bath and removal of the immersed fiber, the dye is fixed in the fiber by **oxidation** in the air Indigo and anthraquinone dyes are typical vat dyes **Sodium** hyposulfite ($Na_2S_2O_4$) is frequently used to reduce the dye to the leuco form

Selected classes of dyes are discussed as follows

(1) Azo dyes, (2) Disazo dyes, (3) Triphenylmethane dyes, (4) Xanthene dyes, (5) Acridine dyes, (6) Thiazine dyes, (7) Alizarin and Anthraquinone dyes, (8) Indigo dyes

(1) *Azo dyes* These dyes contain one or more azo groups (—N N—)

Chromogene Azobenzene, 

Formed mainly by diazotization (See **Diazo-compounds**) of primary amines and coupling with

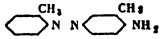
(1) An **amine,** in acid solution Reaction slow, accumulation of acid may be prevented by gradual addition of sodium carbonate

(2) A **phenol,** in alkaline solution Reaction rapid, accumulation of acid is prevented by presence of alkali

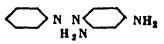
Coupling takes place at the carbon para to $-NH_2$ and —OH (—ONa) group, if the para carbon is occupied by another group, then coupling takes place at the carbon ortho to $-NH_2$ and —OH(—ONa), not at the carbon meta to $-NH_2$ and —OH but beta-naphthol and beta-naphthylamine at carbon number 1, never at 3 or 4 Aminonaphthols in (a) acid solution, at carbon ortho to $-NH_2$ group, (b) alkaline solution, at carbon ortho to —OH(ONa) group Diamines undergo only meta coupling

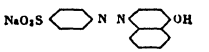
SELECTED REPRESENTATIVE DYES

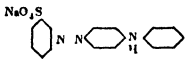
(1) Monoazo dyes

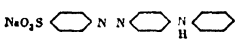
Butter Yellow 

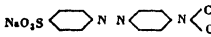
Fast Yellow

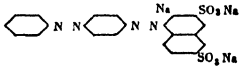
Chrysoidine 

Tropaeoline Orange I 

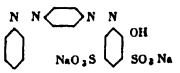
Metanil Yellow 

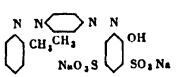
Orange IV 

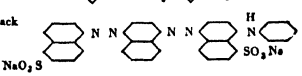
Helianthine Methyl Orange 

Ponceau 5R (red) 

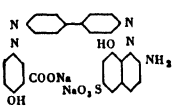
(2) Disazo dyes

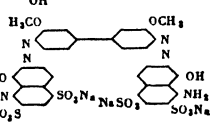
Cloth Red R 

Cloth Red D 

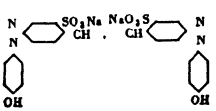
Durol Black 

Benzidines

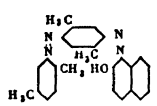
Fast Red 

Sky Blue F 

Stilbenes

Brilliant Yellow 

Xylidines

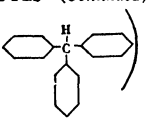
Oil Red E G. 

(Continued on next page)

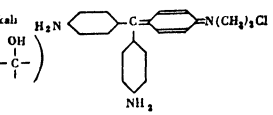
SELECTED REPRESENTATIVE DYES—(*Continued*)

(3) Triphenylmethane dyes

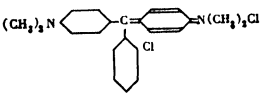
Chromogene, Triphenylmethane,



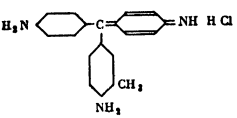
Fuchsine (red)
(colorless with alkali by formation of leuco base



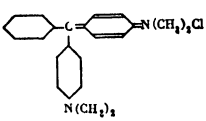
Fast green



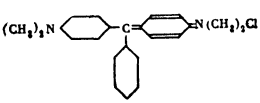
Rosaniline



Malachite green



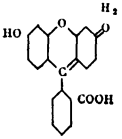
Crystal violet



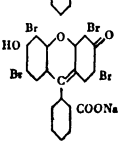
(4) Xanthene dyes
(From phthalic anhydride)

Derivatives of Xanthene

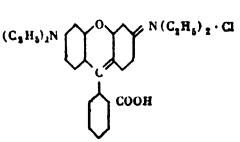
Fluorescein (green yellow)



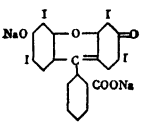
Eosine (red)



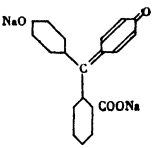
Rhodamine B (blue red)



Erythrosine 3B
(This dye is a mixture consisting chiefly of the following compound)



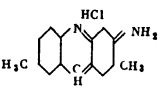
Sodium phenolphthalein (red color, not a dye)



(5) Acridine dyes

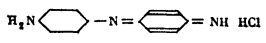
Derivatives of Acridine,

Acridine yellow



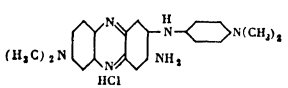
Quinoneimides

Phenylene blue (An Indamine)

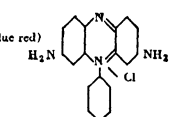


Azines

Neutral violet

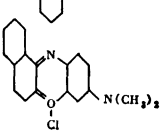


Safranine B extra (blue red)
(Phenosafranine)



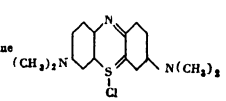
Oxazines

Meldola's blue (cotton blue R)



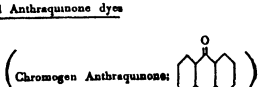
(6) Thiazine dyes

Methylene blue

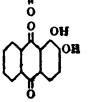


(7) Alizarin and Anthraquinone dyes

Chromogen Anthraquinone:



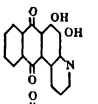
Alizarin (red)
Insoluble
Soluble by introducing $-SO_3H$ groups



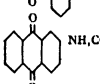
Alizarin orange.

Alizarin maroon.

Alizarin blue

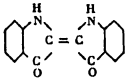


Algol yellow

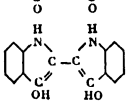


(8) INDIGO DYES

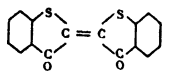
Indigo (blue) (Insoluble)

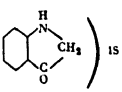


Indigo white (Soluble in alkali)



Thioindigo (bluish-red)



One of the methods for the synthesis of indigo is carried out in the following steps Aniline ($C_6H_5NH_2$) plus formaldehyde (HCHO) plus sodium cyanide (NaCN) plus sodium hydrogen sulfite ($NaHSO_3$) in water solution forms phenyl glycine ($C_6H_5NHCH_2COOH$), which is condensed by heating at 200–220° C with sodium hydroxide-potassium hydroxide mixture in the presence of sodamide ($NaNH_2$) (Sodamide removes the water formed) Indoxyl  is formed Then water is added, and air is bubbled through the solution, with resulting precipitation of indigo

Special applications of dyes have attained a position of great importance Some of these applications and the dyes used are given below Data is given for various dyes that are used for such special purposes as coloring food, chemical analysis, biological investigation, and photographic sensitizing

APPROVED FOOD COLORS

Approved Food Colors These are soluble in water and insoluble in oils, except as stated.

NAME OF DYE	COLOR OF DYE	KIND OF DYE	FORMULA
Red Shades			
Ponceau 3R	Cherry red	Monoazo	$C_{16}H_{16}N_2S_2Na_2$
Amaranth	Magenta red	Monoazo	$C_{20}H_{11}N_2O_{10}S_3Na_3$
Erythrosine	Cherry red	Sodium salt of tetraiodofluorescein	$C_{20}H_8O_5I_4Na_2$
Ponceau SX	Red	Monoazo	$C_{18}H_{14}N_2O_7S_2Na_2$
Orange Shade			
Orange I	Orange-red	Monoazo	$C_{16}H_{11}N_2O_4SNa$
Yellow Shades			
Naphthol yellow S	Yellow in acid and alkali	Nitro	$C_{10}H_4N_2O_8SNa_2$
Tartrazine	Yellow-orange	Pyrazolone	$C_{16}H_9N_4O_9S_2Na_3$
Yellow AB	Yellow, insoluble in water, soluble in oils	Monoazo	$C_{16}H_{13}N_2$
Yellow OB	Yellow, insoluble in water, soluble in oils	Monoazo	$C_{17}H_{15}N_2$
Sunset yellow FCF	Orange-yellow	Monoazo	$C_{16}H_{10}N_2O_7S_2Na_2$
Green Shades			
Guinea green B	Green	Triphenylmethane	$C_{37}H_{34}N_2O_9S_3Na$
Light green SF yellowish	Green	Triphenylmethane	$C_{37}H_{34}N_2O_9S_2Na_2$
Fast green FCF	Bluish-green	Triphenylmethane	$C_{37}H_{34}N_2O_{10}S_2Na_2$
Blue Shades			
Indigotine	Blue	Indigo	$C_{16}H_8N_2O_8S_2Na_2$
Brilliant blue FCF	Greenish-blue	Triphenylmethane	$C_{37}H_{34}O_9S_3N_2Na_2$

CHEMICAL INDICATORS.

(See **Reactions Involving Recombination of Ions.**)

	*p*H Range.
Methyl violet	0–2
	5–6
Meta-cresol purple	1 2–2 8
	7 4–9 0
Thymol blue	1 2–2 8
	8 0–9 6
Cresol red	2–3
	7 2–8 8
2,6-Dinitrophenol	2–4
Bromthymol blue	2 8–4 6
	6 0–7 6
Bromphenol blue	3 0–3 6
Methyl orange	3–4
Congo red	3–5
Ethyl orange	3 5–4 5
Bromcresol green	3 8–5 4
Methyl red	4 4–6 0
Ethyl red	4 5–6 5
Para-nitrophenol	5–6
Bromcresol purple	5 2–6 8
Alizarin	5 5–6 8
	10 1–12 1
Phenol red	6 8–8 4
Rosolic acid	6 9–8 0
Cyanin	7–8
Orange II	7 2–8 6
Cresol red	7 2–8 8
Phenolphthalein	8 3–10 0
Thymolphthalein	9 4–10 6
Sodium indigosulfonate	12–14
1,3,5-Trinitrobenzene	14–14 3

CERTIFIED BIOLOGICAL STAINS

The following dyes are certified by the Commission on Standardization of Biological Stains

Name of Stain	Application	Solubility grams per 100 ml.
Aniline blue, water soluble	Cytoplasm (acid)	
Bismarck brown Y		1 4
Brilliant cresyl blue		
Brilliant green		
Carmin	Nuclear (basic)	
Congo red	Cytoplasm (acid)	
Cresyl violet		0 4
Crystal violet		1 7 (chloride)
Eosin, bluish		39 1 (Sodium salt)
Eosin, yellowish	Cytoplasm (acid) Blood	
Ethyl eosin		0 03 1 13% sol in alcohol (95% strength)
Fast green F C F		16 0
Fuchsin, acid	Cytoplasm (acid)	
Fuchsin, basic	Nuclear (basic) Bacterial	
Hematoxylin	Nuclear (basic)	
Indigo carmine		1 7
Janus green B		5 2
Jeuner's stain		
Light green S F, yellowish	Cytoplasm (acid)	20 4
Malachite green		
Martius yellow		4 6 (Sodium salt)
Methyl green	Nuclear (basic)	
Methyl orange		0 5 0 015 (acid)
Methyl violet		2 9
Methylene azure		
Methylene blue	Nuclear (basic) Vital Blood Bacterial	3 6 (chloride)
Methylene violet		
Neutral red	Cytoplasm (acid) Vital	5 6 (chloride)
Nile blue A		
Nigrosin		
Orange G	Cytoplasm (acid)	10 9
Orange II		11 4
Phloxine		50 9 (Sodium salt)
Pyronin		9
Rose bengal		36 3
Safranin O	Nuclear (basic)	5 5
Sudan III	Fat	Insol 0 15% sol in alcohol (95% strength)
Sudan IV	Fat	Insol 0 09% sol in alcohol (95% strength)
Tetrachrome stain (MacNeal)		
Thionin	Nuclear (basic)	0 25
Toluidine blue		3 8
Wright's stain		

PHOTOGRAPHIC SENSITIZERS

Eosin, erythrosin	For yellow-green
Pinaflavole, orthochrome T	For green
Pinachrome, pinaverdol, acridine orange	For orange
Ethyl red	For orange-red
Pinacyanole (6,800), naphthocyanole (7,500)	For red of wave-length (Ångstrom units) specified
Kryptocyanine (8,000), dicyanine (9,000), neocyanine (10,000)	For infrared of wave-length (Ångstrom units) specified

Special Dyes There are special dyes for such materials as gasoline, and synthetic resins. (R K S)

DYNAMICAL PARALLAX. Dynamical parallax is an indirect method for the determination of the distances of **binary stars** In the determination of **orbits** of binary stars the semi-major axis of the relative ellipse is determined in angular units. This distance cannot be expressed in any linear units unless the distance of the system is known With this distance known the orbit may be solved, and the combined masses of the two stars determined in terms of the sun's mass as unity For the systems thus far solved it is found that the majority of the stars are between one-fifth and ten times the mass of the sun Hence, as a first order of approximation we may assume that for any binary system the combined mass will not differ greatly from twice the mass of the sun.

The rigorous expression for the so-called harmonic **Keplerian Law of Planetary Motion** we find the period or revolution of one object about the other to be dependent upon the combined masses of the objects and also their distance apart The combined mass of the earth and the sun is known, and the period of revolution of the earth about the sun is one year Hence, assuming the combined mass of the binary system to be twice that of the sun, and knowing the period of revolution of the system in years, we may find the mean distance between the components of the system in astronomical units Since from the orbit we know the distance between the components in angular units, we can immediately find the angular distance subtended by one astronomical unit at the distance of the star, or, in other words, we can find the stellar parallax of the system

The parallax thus determined is based on the assumption that the combined mass is twice that of the sun However, with the parallax thus computed and the apparent **magnitudes** of the stars known, we can then calculate the **absolute magnitude** of the system. With this absolute magnitude we go to the **mass-luminosity** relation and get a second approximation to the mass of the system With this improved mass the process is repeated and an improved value of stellar parallax obtained By a sufficient number of approximations, values of the so-called dynamical parallax may be obtained with an accuracy approaching that of the direct trigonometric determinations

Within recent years several methods have been devised for obtaining dynamical parallaxes for systems which are moving so slowly that orbit determination is impossible While such methods do not lead to results of great accuracy, nevertheless, they are valuable for statistical discussions (W K G)

DYNAMICS OF GASES. The laws pertaining to the forces of gas pressure and to the flow of gases are based ultimately upon the **kinetic theory**, but certain principles can be stated without analyzing their origin to that extent To a first approximation, the **ideal gas law**, or the **Boyle-Charles law**, represents the dynamics of gases at rest At a given temperature, the pressure of a body of gas varies inversely as its volume, and hence directly as its density (**Boyle's law**), and at a fixed volume, the pressure is a linear function of the temperature, varying at the same rate (1/273 per centigrade degree) for all gases (**Charles's law**) But dynamic processes in a gas are complicated by the fact that change in volume is in general accompanied by change in temperature, so that simple dynamics is overshadowed by **thermodynamics** It was for this reason, for example, that the correct formula for the speed of **sound** in air proved so elusive A gas is highly compressible, and this property affords ready opportunity for mechanical impulses, which would be merely transmitted by a non-compressible fluid, to be transformed

into heat, or for the gas to use its thermal energy to create impulses of its own The same circumstance complicates the effect of gravity The **atmosphere** is not an ocean of uniform density and definite depth, its pressure and density are logarithmic functions of the altitude The forces associated with moving gases form the subject-matter of **aerodynamics** See also **Thermal Convection, Winds, Pressure Gages, Air Pumps,** etc (L D W)

DYNAMICS OF ROTATION. A body is said to rotate when all of its particles move in circles about a common axis with a common **angular velocity** This motion may be either free or constrained, as illustrated, respectively, by the earth turning on its axis, and by a flywheel or a pendulum

If one twirls an umbrella about its handle, it tends to open This is because the **centrifugal forces** exert torques tending to throw the stays outward on their pivots Through any point of a rigid body there are at least three lines, mutually perpendicular, about which the body would rotate without any such centrifugal torque It may be shown that the **moment of inertia** of the body with respect to any one of these lines is either a maximum or a minimum as regards all lines through the given point They are called principal axes In general there is only one line about which a free body will rotate permanently, it is the principal axis of greatest moment of inertia through the **center of mass** A body constrained to rotate about an arbitrary axis will, when released, tend to change its motion so as to rotate about this permanent axis, but the adjustment is complicated by precession, so that the body may "wobble" like a badly thrown discus

If a free body, at rest, is given a sudden push along some line not through the center of mass, it begins to rotate about some other line beyond the center of mass and perpendicular to the applied force This line is the axis of instantaneous rotation It is only a temporary axis, the rotation being at once transferred to an axis through the center of mass The line mutually perpendicular to the instantaneous axis and to the line of the force passes through the center of mass, and its intersections with the other two lines are conjugate points, having the same relation as the center of oscillation and the center of suspension of a rigid **pendulum** If the push is given in line with the center of mass, the axis of instantaneous rotation is at infinity, and the motion is then one of pure translation

A torque applied so as to tend to change the axis about which a body is rotating results in the peculiar behavior known as **precession** The **angular momentum** of a rotating body is the product of its angular velocity by its moment of inertia about the axis of rotation The **kinetic energy** associated with rotational motion is equal, in absolute units, to one-half the product of the moment of inertia by the square of the angular velocity—a formula analogous to that for kinetic energy of linear motion (L D W)

DYNAMITE. **Explosives.**

DYNAMO. Dynamo refers to a general class of machines capable of transformation of electrical into mechanical energy, or vice versa The word is a shortened form of dynamo-electric A feature of all dynamo machines is the employment of magnetic induction in effecting the transformation The essential parts of an ordinary dynamo are the armature and the field One of these is mounted on a rotating shaft, and the other is stationary Theoretically, the dynamo is perfectly reversible, that is, it may be used either as a generator or a motor Actually, this is not always possible See, **also, generators, motors** (F T M)

DYNAMOMETER. A dynamometer is an instrument for measuring force, such as a spring balance Some writers, however, apply the term to certain devices for the measurement of mechanical power The principal classification is derived from the fact that some types of dynamometers absorb all of the power, which is converted into heat, whereas others transmit the power they receive to some other absorber of power, measuring it during the process. These are called, respectively, absorption and transmission dynamometers.

In the absorption dynamometer class there are types which convert the mechanical to heat energy through the medium of mechanical friction They are all similar to the Prony brake (See **Brake Horsepower.**) The friction surfaces are variously wooden blocks against metal drums or pulleys, bands with wooden cleats, ropes, or friction surfaced brake bands Also there are hydraulic dynamometers which absorb the power by fluid friction One common arrangement is similar to a **centrifugal pump,** except that the casing, instead of being rigidly fixed to a bed plate, is freely supported on the propeller shaft It is restrained from rotating by an attached arm The restraining moment in the brake arm is measured by platform or spring scales The energy absorbed appears as a heating of the water in the dynamometer To prevent it boiling it must be steadily renewed Thus the energy is carried off in a stream of water entering the dynamometer cool and leaving warm Air friction has also been set to use in the fan brake absorption dynamometers

One of the most convenient means for measuring power is to convert it to electrical energy (watts) In an electrical dynamometer a **generator** is slightly modified The stator is mounted, free to revolve, but restrained from revolving by a brake arm which is attached to it, and to which are fastened weighing scales The tendency of the casing to rotate with the rotor which is connected to the source of the power is opposed by the brake arm The force shown on the scales becomes a **torque** when multiplied by its lever distance from the center of rotation Since power is torque multiplied by rotative speed, the only other reading necessary from the dynamometer is the speed of the rotor shaft In all absorption dynamometers the casing is mounted free to revolve under the action of mechanical friction, fluid friction, or magnetic drag Actual rotation is prevented by the attached brake arm Power is measured as a torque operating at the rotative speed of the driven shaft

A transmission type dynamometer is illustrated by the torsion type, in which a shaft delivering power is twisted through a small angle by the torque Such a shaft may be calibrated at rest by measuring the torsional deflection obtained under known torque loadings This dynamometer has its greatest field of usefulness where the other types are impractical Measurement of power output from a large marine engine is typical (F T M)

DYNE. The c g s absolute unit of **force,** defined as the force required to give a free mass of one gram an acceleration of one centimeter per second per second Since the weight of one gram mass, or one gram of force, would give it an acceleration of about 980 centimeters per second per second, a dyne is about 1/980 of this weight, or only a little more than a milligram Nevertheless it is the fundamental dynamic unit of physics, and is the basis of the units of **energy (erg),** of **power (watt),** of **pressure (bar),** etc (L D W)

DYSENTERY. A term applied to intestinal disorders characterized by frequent watery stools containing blood and mucus, abdominal pain, tenesmus, and constitutional symptoms Dysentery may be caused by **bacteria, parasites,** and chemical irritants There are two important forms—amebic and bacillary dysentery. (R S M.)

DYSMENORRHEA. A disturbance of **menstruation** marked by pain and other constitutional symptoms. The chief causes are, local disease of the generative organs, glandular disturbances, and mechanical interference with the flow. (R.S M.)

DYSPAREUNIA. Painful or difficult **coitus.** (R.S M.)

DYSPEPSIA. This term does not represent any disease entity, but is merely a group of symptoms due to various physiological or **pathological** activities of the **gastro-intestinal** tract which may indicate some form of impairment of the normal digestive function. This term is not used medically to any extent. (R S.M.)

DYSPROSIUM. Symbol: Dy Atomic number: 66. Atomic weight: 162.46. Type of compound: Dy_2O_3, white Color of salts: Yellow. Discovered by Boisbaudran in 1886. A member of the **yttrium** sub-group of the rare earth metals. (R.K.S.)

E

e, THE NUMBER. The number e may be defined by:

$$e = \lim_{n \to \infty} \left(1 + \frac{1}{n}\right)^n,$$

or by

$$e = \lim_{x \to 0} (1 + x)^{1/x},$$

and is represented by the infinite series

$$e = 1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots + \frac{1}{n!} + \cdots$$

It has the approximate value $e \approx 2.71828$.

The number e is an **irrational number** and is also a **transcendental number**. It is used as the base of the system of natural (or Napierian) **logarithms**. (L.L.S.)

EAGLE. Aves, Falconiformes. Large birds (**Aves**) of prey with strong hooked beaks, large curved claws, and powerful flight. The American golden eagle, *Aquila chrysaetus*, is an example of the typical members of the group, which also includes the harpy eagles, hawk eagles, harrier eagles, sea eagles, and others. The bald eagle, *Haliaeetus leucocephalus*, national bird of the United States, is one of the sea eagles. (A.W.L.)

EAR. Auditory organ.

EARTH. (cf. tables of planetary data in the article on **planet**. The earth is third planet in point of distance from the sun and is unique in being the only planet which is known to carry an **atmosphere** capable of supporting human life.

The earth is approximately spherical, but due to the fact that it is rotating on an axis, the actual shape is an oblate **spheroid**. The actual shape is determined by making accurate determinations of astronomic **latitude** at a number of different stations and then determining the linear north-south distance between the two stations measured along the surface of the earth. If the earth were a perfect sphere, a degree of latitude would have the same linear length everywhere. Observations show that a degree of astronomic latitude is longer the higher the latitude on the earth. Accurate measurements indicate a difference of 26.70 miles between the equatorial and polar diameters of the earth, the polar being the shorter.

A theory that the earth is in rotation was advanced by Copernicus in the fifteenth century but it was not until the nineteenth century that any proofs independent of the motions of the heavenly bodies were available. The most familiar of these is the so-called Foucault pendulum. Tradition says that Foucault noticed that the plane in which one of the chandeliers in the cathedral in Paris was swinging gradually rotated. According to physical principles a pendulum will remain swinging in the same plane in space unless acted upon by external forces. In 1851 Foucault hung a heavy iron ball from the dome of the Pantheon in Paris by means of a fine wire, carefully isolating it from all external forces. When this ball was started swinging the plane of swing gradually deviated to the right, relative to the floor. The conclusion is that the floor of the room must be rotating while the plane of swing of the pendulum remains fixed in space. The rate of deviation will be a maximum at the poles and zero at the **equator**.

In accordance with the Copernican Theory of the structure of the universe the earth should be revolving about the sun, but a proof of this motion was not available until 1725, when Bradley demonstrated that the **aberration of light** which he had previously observed could only be explained by the revolution of the earth about the sun. There are several other proofs of the revolution of the earth, but none of them can be demonstrated without the use of refined telescopic observations. The best known of these proofs is the annual variation in the **radial velocities** of the stars and **stellar parallax**. (W.K.G.)

EARTHQUAKES. The lithosphere, or so-called crust of the earth, is continuously undergoing deformative movements which are expressed at the surface in folds, faults and volcanic activity. When the adjustments beneath the surface are sudden a vibration is expressed in the form of an earth tremor or earthquake, the result of a sudden fracture in the lithosphere.

An earth fracture is called by geologists a **fault**, and the surface along which realignment of the crustal blocks takes place is called a fault plane. The intersection of the fault plane with the surface of the earth is called the trace of the fault plane. The relative movement of the fault blocks may be vertical, horizontal or oblique. Pronounced vertical movements of the fault blocks may produce fault scarps, often the loci of intermittent earthquakes. Incipient fault scarps may be, however, obliterated or greatly reduced by erosion. Earth tremors which are too gentle to be recorded by the senses alone are called **microseisms**. Instruments for measuring earthquake waves are called **seismographs** or seismometers and the study of earthquakes is called **seismology**.

The first seismograph was used in Italy in 1841, but many different types of instruments have been invented since. In the simple type of instrument, as illustrated, a delicately balanced horizontal pendulum is attached to a mast from the heavily weighted end. An arm attached to the pendulum magnifies and records the movements of the pendulum on a revolving drum or **chronograph** which automatically registers both the time and magnitude of the shock. The resulting records are called **seismograms**. A seismoscope is an instrument which detects an earthquake but does not record it. The various types of true seismographs may be classified as horizontal, vertical, inverted, electromagnetic, and torsion.

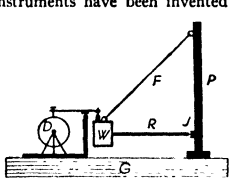


Diagram showing the principle of a seismograph. *G*, ground; *P*, post set in the ground, *W*, weight, *R*, rigid support connecting the post with a free-moving sharp point at *J*; *F*, flexible wire, *D*, recording drum revolved by clockwork, and the marker extends from *W* to *D*. When the ground shakes, the suspended weight, due to its inertia, scarcely moves, but the shaking motion is transmitted to the marker which leaves a record on the drum.

The principal machines now in use are the Milne-Shaw, McComb-Romberg, Wenner, Benioff, Wood-Anderson, Galitzin, Wiechert and Mainka. Of the American operating stations there are 46 in the United States, one in Puerto Rico, two in Alaska, and 6 in Hawaii. Many more are needed, and the same holds true of the rest of the world, especially on the oceanic islands.

The point of origin of an earthquake, at varying distances beneath the surface of the earth, is called the **centrum**. Directly above the centrum, on the surface of the earth, is the **epicentrum**, or center of the maximum shock.

The study of seismograms shows that there are three principal types of earthquake waves The compressional wave which passes through the interior of the earth, is the fastest wave, and therefore is recorded first The transverse wave which passes through the interior of the earth, and the wave which travels around the earth's surface is the slowest of all, but has the greatest amplitude

The intensity or destructive activity of an earthquake, in populated areas, is determined by the acceleration, amplitude, period of vibration, length of time of vibration, and character of the surficial materials in the region of the epicenter

Amplitudes vary from a fraction of an inch to several inches The destructive phase of earthquakes varies from 1 minute to only a few seconds It is estimated that for the whole earth, there are over 10,000 earthquakes per year, but the majority of them occur in regions of recent mountain building A major earthquake occurs, approximately, once a week The total number of all earthquakes, with definite epicenters, was 548, between 1925 and 1930, one every 14½ hours

It has been estimated that over 3 million people have been killed by earthquakes of intensities 9 and 10 from the sixth century to 1927 Tremors of the ocean bottom cause seismic seawaves, called *Tsunami* (Japanese term) Seismic seawaves have been known to rise 100 feet or more, and when such waves break upon a densely inhabited coast, they cause great destruction of life and property Approximately 224 seismic seawaves are known to have occurred, chiefly on the coasts of Japan, Dutch East Indies, Caribbean Sea, Mexico, South America, and Alaska (R M F)

EARTHWORK. This term includes work, the object of which is to alter the surface of the earth to serve some useful constructional purpose In addition to excavation, building of embankments and trimming of slopes, earthwork also includes the clearing and grubbing of rough land, grading, etc Excavation of rock and loose rock is usually considered earthwork Among the most common forms of earthwork are preparation of subgrade for railways and highways, building of embankments for hydraulic work and construction of open drainage systems In the preparation of a roadbed, the original surface of the ground is altered to the required degree by cuts and fills As far as possible, cut should equal fill, so that the material excavated may be hauled a short distance and used to fill depressions in the proposed roadway Where the amount of cut is insufficient for filling, the deficiency must be made up by hauling from **borrow pits** An excess of cut is deposited on spoil banks

To measure the amount of cut or fill in earthwork, transverse cross-sections of the cut or fill are measured at regular intervals These sections are then plotted on paper, and the area computed Sections are taken close enough so that the volume of earthwork between them is considered that of a prism of length equal to the distance between stations, and area equal to the average of the two sections This is known as the end area method A more accurate result is obtained by the use of the prismoidal formula, which states that the volume of the earth equals $1/6(a_1 + 4a_m + a_2)D$, a_1 and a_2 are the end areas, a_m is the mid-section area, D is the length of the section being measured Earthwork is usually done on a contract basis and paid for on the basis of volume excavated, or volume of fill A fill of earth usually shrinks 10% to 20% upon compacting Rock may be expected to occupy 15% to 30% greater volume after excavation than before. (F T M)

EARTHWORM. Annelida, Oligochaeta. Terrestrial segmented **worms** of many species They burrow in earth containing organic matter on which they live, coming to the surface only in damp cloudy weather and at night Their activity in loosening and mixing the soil in fields is estimated to be valuable in crop production. (A W L)

EARWIG. Dermaptera.

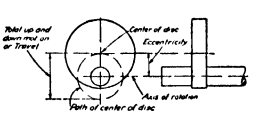
EBONY. Diospyros Ebenum.

EBULLITION. The boiling or ebullition of a liquid is due to the escape of bubbles of its vapor formed where heat is applied below the surface, as at the bottom of a kettle For the bubbles to form, the temperature must be sufficient to produce a vapor pressure equal to the hydrostatic pressure of the liquid plus the pressure of the air or the vapor above it, hence at normal atmospheric pressure the liquid must be somewhat hotter than the normal **boiling point** If the liquid contains a dissolved gas, the first bubbles to appear are composed largely of that gas, the transition from the escape of these bubbles to ebullition proper may not be marked When the liquid has begun to boil steadily, it maintains a very nearly constant temperature until it has all boiled away, no matter how rapidly the heat is applied

The formation of vapor bubbles appears to require some sort of nucleus, so that if the liquid is pure and perfectly free from suspended matter, and the vessel very smooth, the liquid may become superheated before ebullition suddenly begins If the solid surface imparting heat to the liquid is very hot, a film of vapor forms between it and the liquid and escapes quietly from under the liquid without forming bubbles This is the so-called "spheroidal state," observable when drops of water glide silently off a hot stove (L D W)

ECARDINES. Brachiopoda.

ECCENTRIC. The eccentric is a machine element employed to convert rotating to reciprocating motion Its function is similar to that of the **crank** The eccentric is used chiefly for short throws, where it would be undesirable to break the shaft, as is necessary in the case of a crank It consists of a disk mounted on a shaft in such a way that the geometric center of the disk does not coincide with the center of rotation The distance between the center of rotation and the geometric center of the eccentric is the throw This corresponds to the crank arm distance of an equivalent crank The eccentric must be used in conjunction with an eccentric strap which surrounds the eccentric, and which transmits the reciprocating motion to an eccentric rod rigidly attached The eccentric is chiefly used to drive auxiliaries such as valve gear, and where reciprocation of small magnitude is needed The **cam** and **crank** may be employed to provide similar service (F T M)

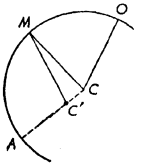


Simple eccentric

ECCENTRICITY. This term is used in astronomy with two different significances The term as descriptive of the shape of an **ellipse**, and hence as one of the elements of an **orbit**, is discussed elsewhere We shall limit this article to a brief description of the correction for eccentricity that must be applied to many types of instruments used for **angular** measurement. Instruments for this purpose usually consist of a circle graduated in angular units, with an arm, assumed to be concentric with the circle, which sweeps around the circle, carrying a **vernier**, or a measuring microscope, for the purpose of determining accurately the direction of the arm relative to the circle It is practically a mechanical impossibility to make the centers of both

the circle and also the measuring arm exactly coincident.

In the diagram we have C the center of the circle OMA, graduated from O. C' is the center of the measuring arm (commonly known as the alidade). The direction $C'M$ is the actual direction of the alidade, while OM is the direction obtained from the circle reading (i.e., the angle OCM). The difference between these two directions, the angle $C'MC$, is the eccentricity correction for the circle reading OM. This will be different for different circle readings, being zero for the circle reading OA.



Eccentricity correction for circle with alidade.

An equation may be developed which will give the eccentricity correction for any circle reading as a function of the reading and three numerical constants. To determine these constants at least three known angles must be measured with the instrument. The differences between the values obtained with the instrument and the known values of the angles are the eccentricity corrections for the circle readings. These eccentricity corrections are then used for the solution of three equations for the three constants. With the constants determined the equation, giving the eccentricity correction for any circle reading, may be written down. The results are usually tabulated, or plotted on a curve and supplied by the maker of the instrument. (W.K.G.)

ECCENTRICITY OF A CONIC. Conic Sections.

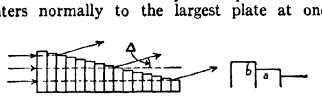
ECDYSIS. The molting or shedding of the cuticula by arthropods.

Since the cuticula of these animals is also the rigid skeletal support of the body and is inelastic, it is shed at intervals during growth and a new covering of larger dimensions is formed. In preparation for molting the insect or other arthropod becomes inactive for a time, then by crawling movements crowds forward in the old integument, which splits down the back and allows the animal to emerge. During the resting period preparation is made by the secretion of fluid from the molting glands of the cellular layer and the loosening of the under part of the cuticula. Following the shedding of the old cuticula, a new layer is secreted during a further period of inactivity. All cuticular structures are shed at ecdysis, including the terminal linings of the alimentary tract and of the air tubes if they are present.

The molting of reptiles is sometimes called ecdysis. (A.W.L.)

ECHELETTE. Echleon.

ECHELON. A highly specialized form of diffraction grating, devised by Michelson. It consists of a row of glass plates of exactly equal thickness, packed together to form a miniature stairway of equal risers. The light enters normally to the largest plate at one end



(see figure) and emerges at various deviations through the low "risers." It is easily shown that if the thickness of the plates is a, the height of the "risers" b, and the refractive index of the glass n, the equivalent path difference between successive streams for any angle of deviation Δ is $na - a\cos\Delta + b\sin\Delta$; or since Δ is in practice always small, $\cos\Delta = 1$ and $\sin\Delta = \Delta$ (in radians), giving $(n-1)a + b\Delta$. This must be equal to an integral multiple, N, of the wave length λ for any spectrum line, the deviation of which is therefore

$$\Delta = N\frac{\lambda}{b} - (n-1)\frac{a}{b}.$$

The smallest value N can have (for $\Delta = 0$) is $(n-1)\frac{a}{\lambda}$, which, since a is usually several millimeters and $(n-1)$ is 0.5 or more, is of the order of several thousand. The despersion, viz.,

$$D = \frac{d\Delta}{d\lambda} = \frac{N}{b} - \frac{a}{b}\frac{dn}{d\lambda},$$

is correspondingly large. The echelon is thus especially adapted to the study of the hyperfine structure of spectrum lines.

A kind of reflection echelon of very small steps, called an "echelette," has been ruled on metal by R. W. Wood. (L.D.W.)

ECHIDNA. Mammalia, Monotremata. The spiny ant-eaters of the Australian region. Egg-laying mammals from one foot to twenty inches in length, belonging to several species. The body is covered with hair and spines and has a slender snout, short legs, and strong claws. They are burrowing animals. There are two genera, *Tachyglossus* (*Echidna*) and *Zaglossus* (*Proechidna*). (See also **Fossil Mammals.**) (A.W.L.)

ECHINODERA. Kinorhyncha.

ECHINODERMATA. A large division of the animal kingdom including the starfishes, sea cucumbers, brittle stars, sea lilies, sea urchins, and basket stars, all marine animals.

This phylum is characterized by the following structures: 1. The adult is almost perfectly radially symmetrical, although the young are bilateral. 2. The wall of the body contains a hard skeleton in most forms, made up of calcareous bodies called ossicles. 3. The coelom is well developed. 4. A water vascular system is present, consisting of a closed series of tubes opening to the exterior at one point on the body and bearing many delicate sacs, the tube feet or tentacles, which protrude at the surface of the body. 5. There is no special excretory system.

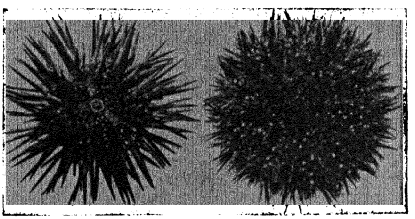
The echinoderms are divided into several classes which fall into two subphyla:

Subphylum Eleutherozoa. Without a stalk.
- Class **Asteroidea.** The starfishes.
- Class **Ophiuroidea.** The brittle stars.
- Class **Echinoidea.** The sea urchins, sand dollars, etc.
- Class **Holothuroidea.** The sea cucumbers.

Subphylum Pelmatozoa. With a stalk at least when young.
- Class **Crinoidea.** The feather stars, basket stars, and sea lilies.

(See also **Invertebrate Paleontology**). (A.W.L.)

ECHINOIDEA. The sea urchins, keyhole urchins, and sand dollars. A class of the phylum **Echinodermata.**


Echinoidea. (Courtesy *N. Y. Zoological Society.*)

The members of this class are distinguished by the following characters 1 The body is circular, varying from almost globular to thin disks 2 The tube feet are suckers 3 The surface bears long spines and pedicellariae 4 There are no radiating arms 5 The ossicles are closely associated to form a shell

Sea urchins live on organic matter of all kinds, including small animals, plant tissues, and waste matter They are of little economic importance but in some of the Mediterranean countries and to a limited extent in the Orient they are used as food

The class is divided into the following orders

Order Cidaroida Sea urchins without gills around the mouth

Order Centrechinoida Gills present around the mouth

Order Exocycloida With indications of bilateral symmetry

Many species flattened Sand dollars, etc (A W L)

ECHINORHYNCHOIDEA. Acanthocephala.

ECHIURIDA, ECHIUROIDEA. Gephyrea.

ECLAMPSIA. A toxic condition characterized by the occurrence of convulsions Eclampsia may occur in such toxic conditions as **uremia**, but the term is usually applied to the convulsive seizures seen in the latter half of pregnancy While it usually occurs before delivery it may occur following the completion of delivery It is a dangerous complication of pregnancy and frequently results in death of both mother and child Post-mortem examination shows characteristic lesions in the liver The specific cause of eclampsia is not known

Prophylactic treatment is best Hence the necessity of regular and frequent prenatal examination of the pregnant woman This includes regular urine analysis, blood-pressure determinations, weighing, etc, with immediate treatment of any of the preliminary signs of toxemia (R S M)

ECLIPSES. The term eclipse is applied to the darkening of a heavenly body due to the presence of another object There are two cases to be considered depending upon whether the object in question is self-luminous or is shining by reflected light In the case of a self-luminous object, an eclipse or **occultation** takes place when an opaque object passes between the object and the observer An object which is shining by reflected light is eclipsed when an opaque body passes between the object under consideration and its source of light Eclipses of the first type are illustrated by an eclipse of the sun where the moon passes between the sun and the observer, in the case of an occultation of a star by the **moon**, and in the cases of **eclipsing binary** stars A typical example of the second case is found in an eclipse of the moon where the earth passes between the sun and the moon

Eclipses of the sun and moon have always been regarded with much superstitious awe and we find references to them in all of the ancient literatures Because of their comparatively infrequent occurrence at any one point of the earth, records of eclipses of the sun may be used by historians to fix accurate dates for events As an example of this reference may be made to an Assyrian tablet which states "Insurrection in the city of Assur In the month of Sivan the sun was eclipsed" This undoubtedly refers to the solar eclipse of June 15, 763 B C. This is the same eclipse referred to in Amos VII, 9· "I will cause the sun to go down at noon, and I will darken the earth in the clear day"

The accompanying figure illustrates the shadow cast by the opaque body *O*, the body *S* being assumed luminous An observer in the region *A*, the umbra of the shadow, will be unable to see any portion of *S* and will be in darkness, in *B* and *C*, the penumbra, he will be able to see portions of *S*, in *B* observing the disk of *S* with a circular segment cut out, and in *C* observing *S* as an **annulus**, i e, a ring of light From a knowledge of the diameters of *S* and *O* and the distance between the two objects, the dimensions of the various parts of the shadow may be calculated

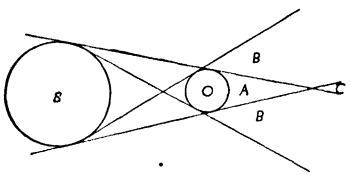


Figure 1 Eclipse of Sun or Moon.

For an eclipse of the sun we consider *S* (Figure 1) as the sun and *O* the moon Because of the fact that the **orbit** of the earth-moon system about the sun is eccentric the length of the umbra cone, *A*, varies between 236,000 miles at **aphelion** and 228,000 miles at **perihelion**, while, owing to the eccentricity of the moon's orbit, the distance of the moon from the surface of the earth varies between 217,800 miles at perigee and 247,500 miles at apogee Examination of these numbers indicates that with the earth at aphelion and the moon at perigee, the surface of the earth will be 18,200 miles inside of the apex of the umbra Under these conditions, the most favorable for an eclipse of the sun, the shadow of the moon on the earth will be a spot about 170 miles in diameter and within this area a total eclipse of the sun may be observed Surrounding the spot of totality there will be a region of about 3,000 miles radius within which the sun will be partially eclipsed With the earth at perihelion and the moon at apogee the surface of the earth will be 19,500 miles beyond the apex of the umbra cone and, while an annular eclipse may be observed, no totality is possible

As the moon revolves about the earth in its orbit the shadow sweeps along the plane of the moon's orbit with a velocity of about 2100 miles per hour to the eastward The earth is rotating at such a rate that a point on the **equator** is moving to the east with a velocity of about 1040 miles per hour Accordingly under the most favorable conditions for a solar eclipse (i e the earth at aphelion, the moon at perigee, and the eclipse taking place at noon for an observer on the equator) the shadow will pass the observer with a speed of 2100–1040 = 1060 miles per hour from west to east The spot will pass the observer in slightly less than eight minutes which is the maximum duration of totality The duration of a partial eclipse may be several hours

For an eclipse of the moon we consider *S*, Figure 1, the sun and *O* the earth From the relative dimensions and distances we find that even under the most unfavorable conditions, i e with the earth at perihelion and the moon at apogee, the shadow of the umbra cone of the earth will extend well out beyond the distance of the moon Hence an annular eclipse of the moon is impossible although partial eclipses, i e eclipses when the moon passes through the earth's shadow far enough off the central line to pass outside the umbra, are quite common

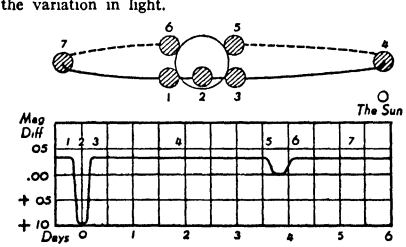
Because of the fact that the plane of the moon's orbit is inclined to the plane of the **ecliptic**, an eclipse of either the sun or the moon may occur only when the moon is close to one of the **nodes**, i e close to the plane of the ecliptic, and must also be in **conjunction** (for an eclipse of the sun) or in opposition (for an eclipse of the moon) Hence eclipses of the sun occur with the moon in new **phase**, and eclipses of the moon with the moon in full phase Since the earth-moon system revolves about the sun once each year the line

of nodes would pass through the sun twice in each year if the direction of that line were fixed in space. However, due to a **perturbation** known as regression of the moon's node, the line actually passes close to the sun three times each year The period when the line of nodes is close to the sun is known as an eclipse season. Two solar eclipses, either total or partial, must occur each year, and five may take place No lunar eclipse need occur in any year, although three are possible. The minimum number of eclipses in any year is two, both solar, while the maximum number is seven, five of the sun and two of the moon (1935), or four of the sun and three of the moon (1981) Considering the earth as a whole solar eclipses are more common than eclipses of the moon However, since each eclipse of the moon is visible over a large portion of the earth's surface while eclipses of the sun are observed only over very restricted areas, for any particular locality eclipses of the moon are more common than eclipses of the sun The sequence of eclipses may be determined by an ancient method known as the **Saros**

The progress of an eclipse of the sun is designated by a series of "contacts" first contact coming when the edge of the penumbra *B* first touches the sun, second contact when the sun first passes into the umbra *A*, third contact when the umbra leaves the sun, and fourth contact when the last edge of the penumbra leaves the sun Accurate recording of the times of the contacts gives accurate information regarding the complicated motions of the moon

Such phenomena as **flash spectrum**, solar **corona**, **Bailey's beads**, etc may be observed only during a total eclipse of the sun, and expeditions are always dispatched to observe the phenomena An eclipse of the moon is of comparatively little scientific importance At the time of such an eclipse the moon is not completely dark, but is illuminated by light which is refracted into the umbra by the atmosphere of the earth, and the moon is visible with a dull reddish light. (W K G)

ECLIPSING BINARY. When the **orbit** plane of a **binary star** lies so nearly in the line of sight of the observer that the components undergo mutual **eclipses** the object is known as an eclipsing binary In case the binary is also a **spectroscopic binary** and the **parallax** of the system is known we have one of the most valuable specimens for stellar analysis Eclipsing binaries are **variable stars**, not because the light of the individual components vary, but because of the eclipses The most notable of the eclipsing binaries is the star **Algol** (β **Persei**), so named the "demon star" by the Arabs in all probability because they noticed the variation in light.



Apparent relative orbit and light curve of the eclipsing binary 1H Cassiopeiae (Curve and orbit determined by Joel Stebbins from his observations with the photoelectric photometer at the University of Illinois)

The **light curve** of an eclipsing binary is characterized by periods of practically constant light with periodic drops in intensity In the figure we have a characteristic light curve of such an object. In this case the eclipse of the larger and brighter primary star by the secondary is **annular**, while the eclipse of the secondary by the primary is total

The **orbit** of an eclipsing binary may be determined from a study of the light curve In addition to the seven **elements** of the orbit it is also possible to determine the relative sizes of the individual stars in terms of the radius of the orbit In the determination of the orbit of a spectroscopic binary it is impossible to determine the semimajor axis, a, and the inclination of the orbit plane, i, independently, but a quantity ($a \sin i$), expressed directly in linear units (i e miles or kilometers) may be determined If a star is both an eclipsing and spectroscopic binary we can determine all seven elements of the orbit, including a and i, in angular units from the light curve, and the quantity ($a \sin i$) in linear units from the spectroscopic data Hence, we can determine the radius of the orbit in linear units and then get the sizes of the individual stars in linear units Since from the period we can get the relative masses of the two stars, and can get the relative sizes from the combination of the photometric and spectroscopic orbits, we are able to determine the densities of the individual stars (W K G)

ECLIPTIC. The great circle cut out on the **celestial sphere** by the plane containing the **orbit** of the earth is known as the ecliptic The ecliptic is the fundamental plane for the system of **spherical coordinates** in which celestial **latitude** and **longitude** are measured The ecliptic is also the reference plane to which the planes of the orbits of all the members of the **solar system** are referred.

The plane of the ecliptic is inclined to the plane of the **equator** by an angle of approximately 23° 5, known as the obliquity of the ecliptic The two planes intersect in a line known as the line of **nodes** The points where this line of nodes intersects the celestial sphere are known as the **equinoxes** The apparent motion of the sun in the ecliptic about the earth, due to the actual motion of the earth in its orbit, causes the sun to pass through each one of the equinoxes once each year The point where the sun crosses the equator from south to north is known as the **vernal equinox**, and the opposite extremity of the line of nodes is the autumnal equinox Due to **precession** the direction of the line of nodes is continually changing relative to the stars At present the vernal equinox is in the **constellation** of **Pisces** and is continually moving along the ecliptic in a direction contrary to the annual motion of the sun at such a rate that it will complete one revolution of the ecliptic in approximately 25,000 years (W K G)

ECLOGITE. This is a coarse, granular rock composed chiefly of **garnet** and **pyroxene** with subordinate amounts of various minerals such as rutile, **magnetite**, **apatite**, etc **Hornblende** sometimes is present replacing the pyroxene, often to the extent that a garnet **amphibolite** is produced The origin of eclogites is obscure, they may result in part from the deep seated **metamorphism** of **gabbroic** rocks, but some may have resulted from crystallization of a primary **basic magma** under conditions of great pressure They may represent segregations in a highly basic magma analogous to segregations of basic minerals in **granites** and other common **igneous rocks** Seemingly confirmatory evidence of this idea is found in the chunks of eclogite-like material found in the **kimberlite** of South Africa (E S C S)

ECOLOGY. The biological science that deals with the relations of organisms and the environment, including relations with other organisms The relations of the individual are the subject matter of **autecology** and those of groups belong to **synecology** In all of its divisions the science is now complex

The living organism is inevitably exposed to certain physical factors which vary over the surface of the earth The force of gravity causes stresses in its body and influences the pressure under which it must live It is immersed in a fluid medium, either water or air, whose pressure on a given unit of surface depends on the amount of material above and so upon the altitude at which the organism lives The pressure of water in the ocean is roughly one ton per square inch per mile of depth That of air is approximately fifteen pounds per square inch at sea level and lessens rapidly at higher altitudes The oxygen content of these media influences respiration and their physical characteristics are important in locomotion Many animals float and swim in water but relatively few fly and none can float permanently in the air On the ground the friction between the body and the earth necessitates other types of locomotion and burrowing forms also must be specially adapted

The temperatures to which the animal is subjected are extremely important, since they affect its physiological processes directly The adaptation of animals to temperatures is often complex

Light is important both for its effects on the living substance and as a factor in vision

Since water is an essential constituent of living matter, the presence of an adequate supply is of fundamental importance to living things On land variation is extreme Between the dearth of water in arid regions and its abundance in marshes, and between the rainy and dry seasons of some areas, many factors interact in maintaining a supply which is sufficient only for animals that are adapted to conserve it Even in such regions occasional years of drought impose severe conditions

The food supply, like water, is a fundamental need Since animals depend upon organic food this relationship is essentially one of living things with each other

As a result of all of these factors, animals are restricted to parts of the earth where tolerable conditions prevail Any species is found in its characteristic environment where it is associated with others that require similar conditions These groups form the communities of the ecologist By common agreement four main types are recognized land communities, communities of waters and shores, communities of the seashore, and fresh water communities Land communities are those of deciduous forests, evergreen forests, grasslands, deserts, arctic and alpine regions, and minor subdivisions In the sea are found the pelagic communities of the open waters, benthonic communities of the bottom, and littoral or shore communities, and in fresh waters similar subdivisions are recognized in addition to those of still and running water

Some of the major results of the adjustment of animals to the environment are expressed under **distribution** (A W L)

ECONOMIZER. Any device the presence of which in a machine or cycle of machinery is nonessential, but which effects a saving, usually of the raw material, may be, with reason, named an economizer Thus an attachment for the carburetor of a gasoline engine, designed to increase the energy delivered per unit of fuel used, may be called an economizer

The economizer of a steam power plant is a heat exchange surface the purpose of which is to recover waste heat in the flue gas by absorbing it in the boiler feed water Such economizers often form an integral part of the boiler surface, with heating surface in the form of tubes Heat is recovered from flue gas by passing it through the tube surface into the feed water stream, which circulates inside the tubes Ordinarily, no steam is produced in the economizer, though steaming economizers have occasionally been built (F T M)

ECTOCYST. Zooecium.

ECTODERM. Germ layers.

ECTONEURAL SYSTEM. A portion of the nervous system of **echinoderms** which forms a plexus under the ectoderm and a radial nerve along each arm or equivalent radius (A W L)

ECTOPROCTA. A class including most members of the phylum **Bryozoa** The included species live in colonies of many forms and are characterized by the retractile tentacles and by the anus lying outside of the circlet of tentacles

The class is divided into two orders

Order Gymnolaemata **Lophophore** circular. Mouth usually closed by a flap called the operculum. Marine

Order Phylactolaemata Lophophore horseshoe shaped or oval Fresh water species. (A W L)

ECZEMA. A loose term indicating any irritant or inflammatory skin disease characterized by watery discharge with formation of scales and crusts The term covers many skin diseases (R S M)

EDEMA. Swelling due to excessive tissue fluids The causes of edema are many Some of the most common are, circulatory disease, **kidney** disease, **varicose veins**, local inflammation, marked **anemia** and certain **allergic** conditions The common sites of edema are the ankles, sacral region, face, and lungs, although edema may be general in certain advanced kidney or heart conditions. (R S M)

EDENTATA. Ant-eaters, sloths and **armadillos.** An order of mammals without teeth in the front part of the jaws and with no enamel on the teeth. The feet bear claws (A W L)

EEL. Pisces, Teleostei Elongate slender fishes (**Pisces**) without pelvic fins and in some species lacking pectoral or median fins Several families, including the true eels (*Anguilla*), the muraenas (*Muraena*), and the **conger eels** (*Leptocephalus*) The true eels are both marine and fresh water animals and the muraenas and conger eels are marine The muraenas are also called morays in some places They are found in the warmer seas, especially about coral reefs

Eels are eaten but they do not rank among the important food fishes (A W L)

EEL-GRASS. *Zosterna marina* Najadaceae Eel-grass is a common plant of sandy or muddy ocean shores The plant has a creeping somewhat fleshy stem which roots freely at the nodes and has short erect branches Usually it grows in salt water from a foot to over four feet deep, and is frequently found in tidal pools The long linear leaves have sheathing bases and float more or less erect in the water The very peculiar flowers consist of a single **carpel**, containing a single **ovule**, two flat **stigmas**, and a **stamen**, which has two half **anthers** joined by a slender connective These flowers are borne on a long flat **spadix** The pollen grains are thread-like and have a specific gravity equal to that of the salt water in which they grow Thus when mature they float in the water, neither rising nor falling, as they are carried by the currents to the large flat stigma The fruit is an **achene.**

Eel grass is an illustration of a plant which has forsaken a land environment and returned to the water There are a half dozen species occurring along the shores in various parts of the world.

Quantities of eel grass are raked up and dried It is used for packing, for stuffing for various objects, in the manufacture of certain kinds of wall board and for insulation in walls

The plants suffer periodically from a certain disease which seriously depletes their numbers. In some regions the natural growth of eel grass has been practically wiped out by this disease

Fresh water eel grass, *Vallisneria spiralis*, is an entirely different plant, with an interesting method of **pollination.** (R M.W)

EELWORM. Nemathelminthes, Nematoda A roundworm, *Ascaris lumbricoides*, six to fifteen inches long, parasitic in the adult stage in the small intestine of man and the domestic animals and during development in other tissues of the body They sometimes occur in large numbers in children, who take in the young **larvae** in water or on raw foods, such as fruits and vegetables (A W.L.)

EFFICIENCY. The general significance of this term as applied to a device or machine may be expressed as the ratio of output to input of energy or of power If a direct-current motor, for example, is operating on 4 amperes at 100 volts (the power input is 400 watts), and if the motor actually delivers only 280 watts of mechanical power, its efficiency at that load is (280 watts — 400 watts, or 70 per cent) In general, the efficiency of a machine varies somewhat with the conditions under which it operates Usually there is a load for which the efficiency is a maximum This may be illustrated by a heavy block-and-tackle For a small load the efficiency would be very low, because of power wasted in bending the ropes, for an excessive load it would again be low, on account of the large friction which would then develop, while for intermediate loads, higher efficiencies would prevail

The concept may be extended to other than purely mechanical systems Thus, the efficiency of an electric lamp may be expressed in candles or lumens of luminous flux (output) per watt of electric power (input), or that of an automobile horn in watts of acoustic power (noise) per watt of electric input Various types of heat engine exhibit different thermodynamic efficiencies, i e, the ratio of the work derived in the engine to the heat energy applied to it (L D W)

EFFLORESCENCE AND LOSS OF WATER. When a substance evolves moisture upon exposure to the **atmosphere**, the substance is said to be effloresCent, and the phenomenon is known as efflorescence At ordinary temperatures the vapor pressure of water is as follows.

Temperature, °C	Water Vapor Pressure, in mm Mercury	
	At Saturation	At 50% Humidity
0	4 6	2 3
10	9 2	4 6
20	17 5	8 8
30	31 8	15 9
40	55 3	27 7

If the substance has a higher water vapor pressure than corresponds to that of the atmosphere at the given temperature, water vapor is evolved from the substance until the water vapor pressure of the substance equals the water vapor pressure of the surrounding atmosphere

Substances that are ordinarily effloresCent are **sodium** sulfate decahydrate, **sodium** carbonate decahydrate, **magnesium** sulfate heptahydrate, **ferrous** sulfate heptahydrate

When the saturated solution of a substance in water has a water vapor pressure greater than that of the surrounding atmosphere, evaporation of the solution takes place leaving the substance

See **Deliquescence** for the converse phenomenon. (R.K.S)

EFFUSIVE The term applied by geologists to molten material (lava) which has been poured out on the surface of the earth from a vent or fissure, as distinguished from ejected volcanic material (ashes and bombs) and injected **magmas** (plutonic rocks) (R M F)

EGG. The female reproductive cell or **gamete**

EGGPLANT. Potato Family.

EGRET. Heron.

EIDER. Aves, Anseriformes *Somateria* **Ducks** of several species which breed in the far north along rocky coasts They are noted for the fine down with which they line their nests This material has a high commercial value and is collected for market (A W L)

EINSTEIN EQUIVALENCE PRINCIPLE. One of the interesting features of the theory of general **relativity** emphasizes the fact that the weights of bodies and the **forces** which they oppose to **acceleration** are proportional, each being in direct ratio to the masses of the bodies The relativity theory points out that they are really indistinguishable Everyone is familiar with the sensations of increased or reduced weight caused by upward or downward acceleration in a passenger elevator If the elevator moved without noise or jar and if one could not see out, an accelerated motion in any direction would occasion forces which one would be unable to distinguish from that due to a gravitational field A cream separator or a centrifuge, or a bucket of water whirled about the head without spilling it, illustrate how **centrifugal force** (also due to inertia) may imitate gravity It is this relationship which is enlarged upon in relativity theory as the principle of equivalence (L D W)

EINSTEIN SHIFT. According to the **relativity theory**, when radiation quanta leave a massive source like the sun or a **star**, they are retarded by the gravitational attraction and hence lose energy This means that they lose **frequency** and that the wave length λ increases For a star of radius R and mass M, the fractional increase in wave length is

$$\frac{\Delta\lambda}{\lambda} = \frac{G}{c^2} \cdot \frac{M}{R},$$

in which G is the **gravitation constant** and c is the **electromagnetic constant** (speed of light) The coefficient $G/c^2 = 7.414 \times 10^{-28}$ centimeters per gram. For the sun, $M = 2\,3 \times 10^{33}$ grams and $R = 1\,394 \times 10^{11}$ centimeters Then $\Delta\lambda/\lambda = 1\,23 \times 10^{-6}$, so that each solar spectrum line should be shifted toward the red by a little over a millionth of its own wave length

Measurements of this precision are hardly possible at present But there are other stars so massive and so dense that the shift has actually been observed and found to be of the correct order of magnitude (L D W)

EINSTEIN THEORY. Relativity.

EJA. Reptilia, Sauria The desert saw viper of Egypt, a vicious poisonous **snake** (A W L)

EJACULATORY DUCT. The portion of the male genital duct between the duct of the **seminal vesicle** and the **urethra** (A W L)

EJECTAMENTA. Volcanism.

EJECTOR. Any mechanism or device which can in some fashion remove an object or a material from a certain position, is rightfully called an ejector Thus many machines are equipped with ejector elements the function of which is the removal of a part from one position to another The pump which moves a fluid from some place where it is not desired is an ejector.

A device employed to remove non-condensable gases from a steam condenser is called an air ejector The steam jet ejector is a widely used type, especially on large condensers It consists of a steam jet receiving steam at a pressure from 100 to 250 pounds per square inch The steam issues from the jet with high velocity, picking up such particles of air or other gas as may be entangled in the steam jet The jet is then decreased in velocity, and a pressure built up In this way, such gas as is entangled with the steam jet is compressed (F T M)

ELAEOLITE. Syenite.

ELAIOPLAST. A minute body in the cytoplasm of some cells, supposed by some cytologists to be a form of plastid about which fat is deposited (A.W L)

ELAND. Mammalia, Artiodactyla. The largest African antelopes. The body is like that of a cow but the head is smaller and the horns are moderately long, straight, and spirally twisted There are several species of the genus *Taurotragus* (A W L)

ELASTIC AXIS. Flexure.

ELASTIC CURVE. The curve of the neutral surface of a structural member subjected to loads which cause bending is called the elastic curve The ordinates between this curve and the original position of the neutral surface represent the deflections due to bending (C W C)

ELASTICITY. The property whereby a body, when deformed, automatically recovers its normal configuration as the deforming forces are removed Each of its several types is probably due to the action of intermolecular forces which are in equilibrium only for certain configurations

Deformation, or more briefly, strain, is of various kinds, in each case its measure is a certain abstract ratio For example the elongation of a rod under tension is expressed as the ratio of the increase in length to the unstretched length Linear compression is the reverse of elongation They are both accompanied by a fractional change in diameter, the ratio of which to the elongation is called the Poisson ratio Shear is a strain involving change of shape, such that an imaginary cube traced in the unstrained material becomes a rhombic prism The measure of shear is the tangent of the angle through which the oblique edges have been made to depart from their original perpendicular direction Volume strain is the ratio of a decrease in volume to the normal volume **Flexure** or bending, and torsion or twisting, are combinations of these more elementary strains A straight rod bent into a plane curve undergoes elongation on the convex side and linear compression on the concave side, while there is an intermediate neutral layer which suffers neither

For every strain there arises, in an elastic substance, a corresponding stress, which represents the tendency of the substance to recover its normal condition Stress is expressed in units of force per unit area Tensile stress, for example, is the ratio of the force of tension to the normal cross section of the rod subjected to it Shearing stress is the force tending to push one layer of the material past the adjacent layer, per unit area of the layers Pressure, expressed in like units, is the stress corresponding to volume compression, etc

For each type of strain and stress there is a modulus, which is the ratio of the stress to the corresponding strain In the case of elongation or linear compression, it is commonly called Young's modulus, we also have the shear modulus and the bulk modulus or rigidity Hooke's law states that up to a certain stress limit, known as the elastic limit, Young's modulus is constant Beyond this limit the law fails to hold and the material becomes permanently deformed Somewhat beyond the elastic limit is the yield point, at which the material ceases to behave as a true solid and begins to flow The ultimate strength marks the stress at which the material finally gives way and breaks Following is a brief table of certain elastic constants for some typical materials, all expressed in pounds per square inch·

Material	Young's Modulus	Shear Modulus	Bulk Modulus	Elastic Limit (Tension)
Aluminum	$10\ 2\times10^6$	$3\ 6\times10^6$	$7\ 0\times10^{11}$	9×10^3
Cast iron	16 8 "	7 4 "	9 6 "	25 "
Copper	14 5 "	6 1 "	12 0 "	9 "
Nickel	32 0 "	11 6 "	17 0 "	23 "
Rolled steel	30 0 "	11 6 "	16 0 "	30 "

When a solid is subjected to a strain of any character, there are through each point of it three mutually perpendicular axes which retain that relationship as the strain proceeds They are the strain axes, and the strains and stresses along these axes are called principal strains and stresses Crystalline materials in general have different elastic constants in different directions. (L D W)

ELASTIC LIMIT. The maximum unit stress which can be obtained in a structural material without causing a permanent deformation is called the elastic limit. See Ultimate Strength. (C W C)

ELATERITE. A variety of bitumen which is elastic when fresh but becomes hard and brittle when exposed to the air. (R M F)

ELECTOSOME. A term applied to chondriosomes supposed to elaborate special chemical compounds of the cytoplasm See Cell. (A W L)

ELECTRET. Dielectric Absorption.

ELECTRIC AND MAGNETIC DOUBLE REFRACTION. In 1875 Kerr discovered that glass and many other isotropic, transparent solids and liquids exhibit double refraction like crystals, when placed in a strong electric field, and in 1905 Cotton and Mouton, after some preliminary results by Kerr and others, demonstrated the corresponding phenomenon with a magnetic field These are now known respectively as the Kerr electro-optical effect and the Cotton-Mouton effect In both cases the magnitude of the effect, as measured by the phase difference produced per unit thickness of medium, is, for a given substance, wave length, and temperature, proportional to the square of the field intensity The optic axis of the doubly refracting substance corresponds to the direction of the imposed field

Of the two phenomena the Kerr effect is much more pronounced and is as yet the only one of practical importance. The Kerr cell, in which nitrobenzene, a liquid, is commonly employed because of its large and quick response to the electric field, has in recent years been extensively used as an electro-optical control or shutter for light beams; for example, in the recording of sound pictures This is accomplished by utilizing the vibration of the extraordinary ray due to variations of the electric field intensity, which, in turn, are controlled by the sound waves to be recorded (L D W.)

ELECTRIC AND MAGNETIC UNITS. The measures of electrical quantities are based upon two quite distinct principles, giving rise to two distinct systems of electric units, which differ not only in size but in their physical makeup or dimensions, just as oil is measured and sold either by the gallon (volume) or by the pound (mass).

(1) In the electrostatic system, the fundamental unit is that of quantity of **electricity**, defined as the charge which, concentrated upon a small sphere, repels a similar equal charge at unit distance (in a vacuum) with unit force. The c.g.s. electrostatic unit charge is the "statcoulomb," in which the unit distance is 1 centimeter and the unit force is 1 dyne. It is equal to about 3.3×10^{-10} coulomb. Based on this is the seldom-used e.s.u. current or "statampere," which is 1 statcoulomb per second.

(2) The electromagnetic system, on the other hand, is founded upon the unit **electric current**, viz., the **abampere**, from which is derived the absolute **ampere**. The abcoulomb is 1 abampere per second, and the absolute **coulomb** is one-tenth of it. Aside from these are the international coulomb and ampere, defined electrochemically.

For some purposes it is convenient to use an e.s.u. of **electric potential** or of **electromotive force**, viz., the "statvolt," which is that potential difference through which the transference of 1 statcoulomb of electricity requires the expenditure of 1 erg of energy. But the practical e.m.f. unit is the **volt**, similarly defined but in terms of the coulomb and the erg. The abvolt depends on the abcoulomb and the erg in the same way. There is also an international volt.

The practical unit of electrical **resistance** is the **ohm** (either absolute or international), equal to 10^9 abohms. The resistivity of a substance is commonly expressed in terms of the ohm-centimeter; i.e., as the resistance between opposite faces of a 1-centimeter cube of the substance.

The practical unit of **capacitance** is the farad, which is 1 coulomb/volt, and is thus electromagnetic. The "abfarad" is the fundamental c.g.s. unit, 1 abcoulomb/abvolt or 10^9 farads. The microfarad (0.000001 farad) is commonly used in actual measurements.

The practical and fundamental c.g.s. units of **inductance** (or mutual inductance) are respectively the henry (defined under **Inductance**) and the abhenry, equal to 10^{-9} henry. The millihenry (0.001 henry) is usually more convenient.

The purely magnetic units begin with the concept of the unit magnetic pole (See **Magnetism**). The **oersted** and the **gauss** are respectively the units of magnetic intensity and magnetic induction. Often more convenient than the maxwell or "line" as a unit of **magnetic flux** is the "volt-second," or 10^8 maxwells. Magnetomotive force and magnetic potential may be expressed either in gilberts or in ampere-turns (See **Magnetic Circuit**). (L.D.W.)

ELECTRIC CELL. The electric cell is composed of two dissimilar metals or materials which are immersed in a solution capable of acting upon them chemically. A primary cell is one composed of two dissimilar electrodes which are immersed in a solution of an acid which acts more readily on one of the electrodes than on the other. The result of this chemical reaction is the production of an electromotive force. If the electrodes are connected by an external circuit, the electromotive force will maintain a flow of current through the circuit composed of the external connections, the electrodes, and the electrolyte. As current flows the chemical energy resulting from the action of the acid on the electrodes is converted into electrical energy.

A secondary cell is one in which electric current must first be passed between the electrodes of the cell under the influence of an externally generated electromotive force. The chemical action resulting makes the cell capable of giving off electric current by means of a secondary reversed chemical action. A group of secondary cells is a storage **battery**.

The physicist Volta discovered in 1800 that when two dissimilar metals were immersed in a solution such as sulfuric acid, they produced an electromotive force. By experimenting with different metals, he was able to arrange them in an electro-chemical series which will show the relative electromotive force, and which of two elements used in a cell will be the positive, and which the negative electrode. A typical electro-chemical series is as follows (For further details, see **Reactions Involving Oxidation-Reduction**):

Zinc
Iron
Tin
Lead
Copper
Silver
Platinum
Carbon (non-metal)

If any two of these metals are immersed in sulfuric acid the one nearest the top of the electro-chemical series will be the positive electrode, and current will flow from it in the solution and to it in the external circuit.

A Voltaic cell is shown in Figure 1. A simple cell of this type would soon become polarized. As current flows around the circuit, the following reaction takes place:

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

The hydrogen thus liberated by the chemical reaction gathers on the negative electrode and, as a result, the electromotive force diminishes and finally disappears. This action is known as **polarization**, and must be overcome in any practical cell.

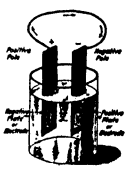


Figure 1. Elementary cell.

There are many types of primary cells, amongst which might be mentioned the Daniell cell with zinc in sulfuric acid, and copper in copper sulfate; the LeClanche cell, using zinc and carbon in an aqueous solution of ammonium chloride; the Weston cell, with mercury and cadmium in a solution of cadmium sulfate. Depolarization in the Daniell cell is accomplished by absorption of the hydrogen by the copper sulfate, which is separated from the acid-filled portion of the cell by a thin porous partition, through which the hydrogen may pass. In the LeClanche cell, manganese dioxide, a substance which gives off oxygen to combine with the hydrogen, is used as a depolarizer. The Weston cell is a voltage standardizing apparatus, and is not designed to produce a flow of current, but rather to yield a standard voltage for comparison. Its voltage is 1.0183 volts at 20° C.

The most widely used primary cell is the dry cell, whose popularity is the result of its portability and simplicity. Having no liquid electrolyte, the dry cell offers no danger from spilled acids; moreover, it is inexpensive and reliable, and long-lived when used for supplying intermittent currents, as for ringing doorbells, or with telephones, etc. The common dry cell (Figure 2) has an electromotive force of about 1½ volts. The electrodes are zinc and carbon, with the former being in the shape of a cup some 2½ inches in diameter by 6 inces high for the standard type, although smaller sizes are used in flashlights. The carbon electrode is centralized in the zinc cup, and the space between carbon and zinc filled with the necessary electrolyte and depolarizer. The electrolyte is a damp sal ammoniac compound, and the depolarizer is manganese dioxide. The open end of the zinc cup is then sealed off with pitch or cement and binding posts are connected to the zinc and carbon. (F.T.M.)

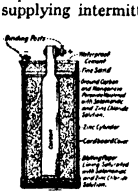


Figure 2. Dry cell.

ELECTRIC CIRCUITS. The simplest type of electric circuit may be considered as beginning at any point and continuing without branching until that point is reached again. Along this closed path electricity moves

because in some portion or portions of the path an **electromotive force** E is applied to it, doing work on the electricity and causing it to progress against the **resistance** as an **electric current** It is convenient to divide the total resistance R of the circuit into two parts, the internal resistance R_i, viz, the resistance of that part in which the electromotive force is applied, and the external resistance, R_e, of that part in which no electromotive force is active. The current is the same through the whole of such a simple circuit, and its value, if constant, is given by **Ohm's law:**

$$I = \frac{E}{R} = \frac{E}{R_i + R_e}. \qquad (1)$$

Let two points A and B be selected on the circuit and let the **electric potentials** at those points be respectively and V_A V_B If the resistance of the part of the circuit between A and B is R_{AB} and if the part of the total electromotive force E applied to the circuit between these points is E_{AB}, then for the section AB, Ohm's law takes the special form

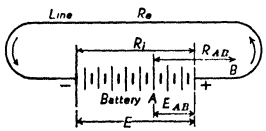


Diagram of simple circuit showing internal and external resistance The two points A and B are selected at random, part of battery may or may not be included between them

$$I = \frac{V_A - V_B + E_{AB}}{R_{AB}}, \qquad (2)$$

in which E_{AB} is + or — according as it acts with or against the current. (The latter is illustrated by the part of a circuit containing a storage battery being charged or a motor exerting its back electromotive force) We may equate (1) and (2), since the current is the same in all parts of the circuit, the potential difference between any two points A and B may then be calculated, thus

$$V_A - V_B = \frac{R_{AB}}{R} E - E_{AB} \qquad (3)$$

If there is no active electromotive force in the part AB, then (2) gives $I = (V_A - V_B)/R_{AB}$ For any two pairs of points, A,B and C,D, since I remains the same, we then have

$$\frac{V_A - V_B}{V_C - V_D} = \frac{R_{AB}}{R_{CD}}, \qquad (4)$$

the so-called "law of potential drop"

If the circuit has appreciable **inductance,** Ohm's law in its simple form (1) applies only so long as the current is constant (See **Alternating Currents** and **Alternating Current Circuits**) Also, a circuit may be broken by a **condenser,** or have a condenser in parallel with it, or it may have appreciable **distributed capacitance;** in any such case its behavior upon the application of an electromotive force departs from Ohm's law Divided circuits and networks, especially if they involve inductances or capacitances and carry variable currents, present somewhat complicated problems (See **Kirchhoff's Laws of Networks**) (L D W)

ELECTRIC CONDUCTION. The conduction of electricity in material substances is of two general kinds· (1) a migration of ionized (and hence electrified) atoms or molecules, as in **ionized gases** and electrolytes, and (2) a process in which the atoms are in the main stationary as in metals This article deals with the second type only

The electric conductivity of solids has an almost unbelievable range For silver and sulphur (the best and the poorest among elements), the ratio is something like 1000 billions of billions to 1. Their resistivity is, of course, in the inverse ratio (See **Resistance.**) Metals, as a class, aside from being almost immeasurably better conductors, differ in several respects in their conduction from non-metals **For example,** the conductivity of pure metals consistently decreases with rising temperature, while the non-metallic solids, including carbon, generally have maximum conductivity at one or more temperatures Selenium has most extraordinary properties (See **Photoconductivity**) Some metals exhibit **superconductivity** near the **absolute zero** of temperature. The alloying of metals, and even the admixture of small quantities of impurities, often profoundly affects the conductivity Thus "constantan," an alloy of copper and nickel, shows almost no change of conductivity with temperature The **Wiedemann-Franz law** expresses the remarkable relation which exists between the electric and the thermal conductivities of metals The various **thermoelectric phenomena, thermionic phenomena,** the **Hall Effect,** etc, must also be taken into account by any theory of metallic conduction

The idea proposed by Weber (long before electrons were known) and elaborated by Drude and Lorentz (with the aid of electron theory) has, until recently, completely dominated our thinking about metallic conduction It supposes that good conductors contain electrons free to move about among the relatively fixed atoms, that when an electric field is applied to the conductor, the electrons drift along through it, colliding with the atoms and producing heat, and that poor conductors are such because few of their electrons are free Tolman and Stewart (1916) tried suddenly stopping a metal rod in rapid longitudinal motion, and found that it became negatively charged at the forward end, as if the electrons had piled up there A large number of experimental facts are in qualitative agreement with this theory But two great difficulties are encountered lack of even approximate quantitative agreement in many details, and the existence of certain stubborn anomalies, such, for example, as superconductivity and the conflict between **Dulong and Petit's law of specific heats** and the principle of **equipartition of energy.** At present it appears that the solution of the difficulty may be a revision of our concept of the **electron** and its behavior, in terms of **wave mechanics.** (L D W)

ELECTRIC CONDUCTIVITY. Resistance.

ELECTRIC CURRENTS. Electricity is a tangible thing, with some of the properties of ordinary matter, and among them the ability to move Whenever it moves, we have an electric current Since electricity may exist as separate electrons, protons, or positrons, or in collected charges of these entities, the electric current presents a variety of aspects Usually we think of the progressive motion of electrons in a conductor, called **electric conduction,** or the two-way traffic of charged ions called "electrolytic conduction", but the current may consist of a flight of electrons or other charged particles through a vacuum, or it may be a bodily movement of an electric charge, like that on one of the carriers of a **static machine.** Also there is that singular process assumed by Maxwell to take place in a **dielectric** or even in a vacuum, to account for the behavior of electromagnetic fields and radiation, and called the "displacement current" A current may be continuous, that is a progressive movement of electricity in one direction (the so-called **direct current**), or it may consist of temporary surges called **transients,** or be merely a vibration of the electricity with very short amplitude, as in **alternating currents** and **electric oscillations.** In conduction currents, contrary to the usual impression, the actual net progress of the electricity is very slow, seldom more than a few centimeters a minute This is because of resistance and the continuous dissipation of energy in accordance with **Joules' law.** The speed of the electrons in a vacuum tube may, on the other hand, reach thousands of miles per second Electric impulses, or "compression waves," in a conductor also travel with great speed (in a telephone wire, some thousands of miles per second), and it is this property that gives elec-

tric communication the lightning-like rapidity commonly associated with electric currents. To drive electricity against its inertia or against the opposition of obstacles such as massed atoms or molecules requires **electromotive force.** If the electricity moves through any region where there is such opposition but no battery or other source of electromotive force to supply energy (as in a resisting wire), its motion is maintained at the expense of its own energy. The **electric potential** changes as the electricity progresses, by an amount proportional to the potential energy which the electricity must thus give up. This leads to the familiar "law of potential drop." See **Electric Circuits, Ohm's Law, Ampere, Electromagnetism,** etc. (L.D.W.)

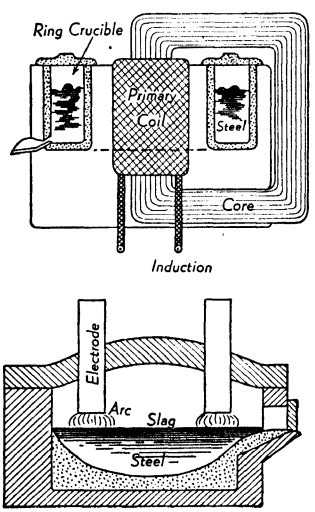
ELECTRIC DEGREE. **Degree.**

ELECTRIC DISPLACEMENT. **Dielectrics.**

ELECTRIC EEL. Pisces, Teleostei. A true **eel,** *Electrophorus electricus,* of the rivers of northern South America. It reaches a length of six feet and is capable of giving a powerful electric shock. (A.W.L.)

ELECTRIC FIELD. **Electrostatics; Fields of Force.**

ELECTRIC FURNACE. The electric furnace is usually thought of as equipment designed and operated for the purpose of melting and alloying metals. It is especially successful in the manufacture of alloy steels. In the electric steel furnace, the effect of the electricity upon the metal is purely heating, having no electrochemical action. The heating effect of the modern furnace is secured either by induction or by the use of the arc. In the induction furnace, the molten metal itself forms a secondary circuit of what is, in effect, a **transformer.** As the accompanying figure shows, a primary



Electric furnaces.

coil is wound upon a core corresponding to the core of the transformer. A single short circuited coil forms the secondary. This coil is not wire, but is composed of the metal itself being melted. The crucible in which the melting takes place must be of the ring type, surrounding the magnetic core. The higher the frequency of the electric circuit, the more effective the inductive heating.

Several different arc furnaces have been invented, among which a highly successful type is the Heroult furnace. In this furnace the source of heat is an arc which is drawn between the electrode and the bath of molten metal. In a single-phase arc furnace, the path of the current is through an electrode and an air gap, into the slag floating on the pool of metal, through the metal to a position below the other electrode, thence again through the slag and air gap and into the electrode. Three-phase arc furnaces are also in use. There are three electrodes in the three-phase furnace.

The use of an electric furnace secures to the operator several advantages. First with respect to speed of melting, and temperature obtained, it is superior to other methods of making steel. Secondly, very special alloys are readily made, since the operation is carried out under complete control at all times with the exclusion of harmful gases. Oxidation, or reduction, is under fullest control, and can be varied at will. Thirdly, not only may the temperature be regulated, but it may be maintained steadily at any desired value for any length of time. These advantages have led to the use of the electric furnace for the production of the highest grade of steel, even though the expense is high on account of the large amount of electric energy entering into the process. (F.T.M.)

ELECTRIC HEATING. Electricity is employed for the generation of heat in industrial, commercial, and domestic use. When compared with direct heating from fuels, electric heating will show a much higher cost, since the equipment for converting heat energy into electrical energy fails to convert, at its best, some 70% of the heat units. Nevertheless, since electrical heating apparatus produces the heat at the very spot desired, and exactly in the desired amount, the difference in cost is not so pronounced, because of the economy of electric heating apparatus. For localized heating, such as cooking, soldering and welding, electric heating is especially good; also it is used where cost is not an important item, viz., apartments, shipboard, hospitals, etc.

Heat may be obtained from electrical energy by means of resistance heating, induction heating, and the arc. Resistance heating is used in most domestic appliances, industrial ovens, and the like. Arcs are used for welding, lighting, and furnaces. (See **Electric Furnace, Arc Lamp.**) Induction heating has been employed in welders, furnaces, and therapeutic devices.

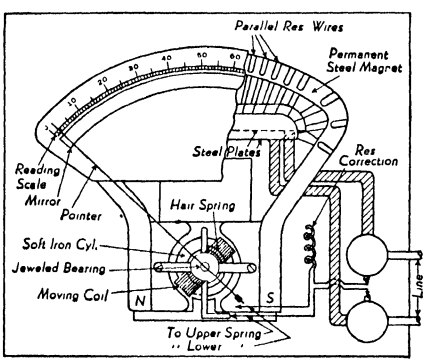
The amount of heat developed in resistance heating is proportional to the resistance of the heating element, and to the square of the current flowing. The electrical energy converted into heat when I amperes flow through a resistance of R ohms for t seconds is $I^2 \times R \times t$ watt seconds. There are 1,055 watt seconds in a British Thermal Unit. In resistance heating, it is essential that the resistor have little or no tendency to oxidation, a relatively high melting point, a high resistance so as to minimize the length of resistor, and minimum deterioration or embrittling upon repeated cycles of heating and cooling. Resistance wire used at present imperfectly meets these specifications. Nickel chromium steel wire is used in round and flat ribbon forms in various heating appliances. Insulation is usually by porcelain supports or mica. If, due to the convenience of application of heat, and the close control which can be exercised over temperature in electric heating, the product being subjected to heat can be made better, or with less labor, or with less wastage and spoilage, the higher cost of electric heating may often be more than overcome by savings in other lines. This has been true in cases such as ironing in laundries, cooking in candy manufacture, maintaining of glue pots, soldering irons, etc., at constant temperature, the even browning of loaves in bakers' ovens, the heating of presses and matrices, and a host of other heating applications. (F.T.M.)

ELECTRIC IMAGE. Electrostatics.

ELECTRIC INDUCTION. Electrostatics.

ELECTRIC INSTRUMENTS. The most common electrical instruments are the various meters which, when properly applied and connected, indicate or record the characteristics of flow in an electrical circuit, characteristics which are, by nature, undeterminable by visual inspection of the conductors The principal electrical instruments are the **ammeter,** to show flow of current, the **voltmeter,** to show electrical pressure on a circuit, the **wattmeter,** for power, the watt-hour meter, for electrical energy, the synchroscope, which is used to effect parallel operation of current-carrying machinery; the power-factor meter, the volt-ampere meter or volt-ammeter, and the ground detector Indicating instruments are used chiefly for operating guidance, recording instruments, for operating supervision and calculation of performance, and integrating types for cost allocations.

The electrical meter (See **Integrating Meters**) is commonly a comparatively rugged instrument, enclosed in an iron case having a glass front through which the register of a pointer on a scale may be read Few electrical meters for direct current service are applicable to an alternating current circuit, and vice versa The operating principles of meters include electro-magnetic induction,

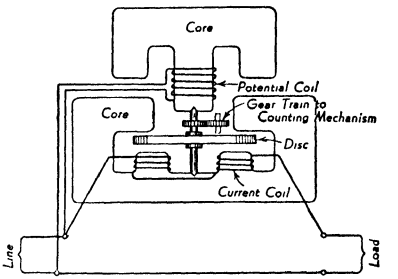


Direct current ammeter

magnetic attraction, and resistance heating A typical direct current ammeter consists of a light coil mounted in the field of a permanent magnet When the coil is energized by passing the current through it, a torque (See **Statics**) is set up which tends to set the coil to include a maximum of flux lines A pointer is attached to the moving coil, and the motion of this system is opposed by a coil spring The spring controls the throw of the pointer, which otherwise would run completely off the scale for all currents As it is impossible for the delicate moving coil of this instrument to carry large currents, a shunt is employed The current through the shunt bears a definite ratio to the current through the ammeter, so that the ammeter can be calibrated to read directly the current which is being metered The shunt is often incorporated within the case of fixed-range instruments

The voltmeter is similar in construction to the ammeter One difference arises from the fact that ammeters are used to measure currents, and must embody a low resistance shunt in parallel with the moving coil, while voltmeters are used to measure potential difference, and so must have high resistance coils in series with the instrument coil

In alternating current practice, induction type instruments are the most frequently found An induction type meter depends on the interaction of an inducing and an induced current In the type shown in the figure just below, a laminated iron core is surrounded by one or more coils of wire When current flows through the coils, an alternating magnetic flux is set up in the air gap of the core The effect of a rotating field may be



Induction watthour meter

secured through the action of more than one group of coils, in which the currents differ in **phase.** A drum or disk, usually of aluminum, is supported by pivots in the air gap of the core, and a torque is produced by the rotating field reacting on currents induced in this movable element A hair-spring produces counter torque and brings the pointer to rest when the torque produced by the coil is equal to that of the spring This principle is similarly applied in the induction voltmeter Another type of alternating current ammeter has a thin piece of soft iron, roughly triangular in shape, bent into the form of a cylinder Another piece of rectangular form is so bent that it is co-axial with the first, and is rigidly attached to a spindle mounted on jeweled bearings. These two iron pieces are encircled by a coil, so as to be included in the field A pointer is attached to the spindle When a current is passed through the coil, the iron pieces are similarly magnetized, and repel each other, thus a torque is exerted on the shaft, and moves the pointer against spring pressure

Practically all modern alternating current watt-hour meters operate on the split-phase induction motor principle The single phase watt-hour meter is universally used as a meter for the kilowatt-hour consumption of domestic customers. The essential parts of the watt-hour meter are a current coil, a potential coil, and a rotating disk The current coil is connected in the line, and the potential coil is across the line Both coils are mounted on iron cores, and placed in close proximity to the rotating disk The alternating flux produced by these windings sets up eddy currents in the disk, and these eddy currents, in turn, set up fields which react on the field of the opposite coil The combined action of the two coils sets up a torque which, at any instant, is proportional to the instantaneous values of the voltage and the current which is in phase with it, hence the meter acts independently of the power factor of the circuit, and measures watt hours, not volt-ampere hours The speed at which the disk rotates is proportional to power being used, therefore, the number of revolutions the disk turns is proportional to the total energy consumed By means of a gear train properly calibrated, the total energy consumed is indicated.

The synchroscope is a synchronism indicator for the guidance of station operators when paralleling machines. It indicates the phase relation between two alternating current circuits The usual use is in connection with the joining of an incoming machine to the bus The General Electric synchroscope resembles a small alternating current motor in construction The field is connected to the line and the armature to the incoming machine. When the frequency of the machine is dif-

ferent from that of the line the resultant field in the synchroscope constantly changes its position, thus making the armature revolve in one direction When the frequencies are the same the field is stationary in space and the pointer comes to rest in a position so as to show the phase difference between the two voltages When the phase difference is zero the pointer will come to rest on the mark indicating perfect synchronism and the switch can be closed (F T M)

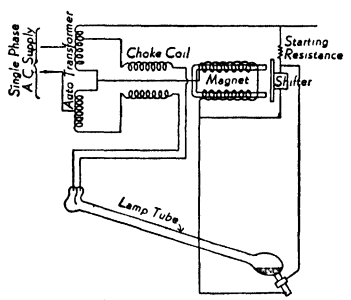
ELECTRIC INSULATION. Any **dielectric** is an electric insulator, but experience has demonstrated the value of certain solids, such as glass, porcelain, rubber, mica, silk, paraffin, etc, for practical use Oil and air also are often used where the cooling of the conductor is necessary or where very high voltages are employed Insulating material is commonly applied to a conducting surface for the prevention of current leakage, and to protect materials and persons in the vicinity of the surface Electrical insulation is sometimes applied continuously to a conductor in the form of a complete covering like the rubber insulation on wires, or else the insulation may be applied at regular intervals like the porcelain insulating supports on an electrical bus-bar With solid insulators, mechanical strength is often a consideration, as are also incombustibility, flexibility, non-hygroscopic character, high surface resistance, the ability to withstand high temperatures, the possibility of being machined or molded, and moderate cost Low dielectric constant would also be desirable in cases where distributed **capacitance** is to be minimized

The primary requirement of an insulator, however, concerns its insulating strength, that is, the maximum voltage per unit thickness which the material will sustain without electric breakdown or sparkover (This is quite apart from its resistivity) In reckoning this with alternating voltages, the maximum or peak voltage must be used, which is $\sqrt{2}$ or 1 41 times the effective voltage at which the service is rated (Thus the insulation on a 11,000-volt line must be able to sustain 15,600 volts) Solid insulators are sometimes subject to surface leakage, or conductivity due to films of moisture or other impurities, as well as to true conductivity of the insulator itself The latter is not serious except in the case of the mountings of electrometers, ionization chambers, etc, where quantitative accuracy is desired, and for which one of the best insulators is found to be sulphur

Vulcanized rubber compound and varnished cambric are the principal materials for insulating wires For standard low voltage wiring, the rubber is usually about 3/64ths of an inch thick Rubber insulated wires are covered with a protective braid Slow-burning wires are insulated with layers of braid impregnated with fire resistant compound (L D W, F T M)

ELECTRICITY. The electrification of amber by rubbing with wool or fur was observed many centuries ago Not until the work of Volta, late in the eighteenth century, was electricity recognized through any but electrostatic phenomena, and investigations on the properties and applications of **electric currents** were among the most brilliant features of nineteenth-century physics Even in the 1890's physicists were still asking, "What is electricity?" It had then long been known that an appropriate application of energy will separate electricity into two components, designated as positive and negative, that bodies charged with these components attract each other, and that the energy of separation is yielded upon the reunion of the two components It remained for J J Thomson to recognize the **electron**, and for the recent analysis of **atomic structure** to identify the proton and the positron As a physical magnitude, methods have been devised for measuring quantities of electricity, not only in terms of the elementary electronic charge, but in larger units determined by electrostatic, electromagnetic, or electrochemical effects. (See **Electric and Magnetic Units**) Among the most important aspects of the subject are the magnetic properties of moving electricity (**electromagnetism**) and the incorporation of both components of electricity in the structure of all atoms and molecules of matter. See **Electrostatics.** (L D W)

ELECTRIC LAMPS. The principal electric lamps are the **arc lamp**, the vapor lamp, and the incandescent resistance lamp The vapor lamp, as illustrated by the mercury vapor lamp, gives light from the passage of electric current through mercury vapor, which causes the latter to glow by incandescence The mercury liquid is contained in the vapor lamp in a state of high vacuum, so as to be readily vaporized When the tube is cold it is necessary to strike an arc by tilting the tube until an electrode dips in the pool of mercury The accompanying figure shows the principle of the electrical connections of a single-phase, alternating current Cooper-Hewitt lamp The quality of light from the vapor lamp is bluish-green in color, and has a tendency to distort the colors of objects viewed in it However, this light is good for industrial purposes, as it permits small details to be more easily seen by workmen than does white light On account of the intense light delivered by the mercury vapor lamp, fewer units are necessary for adequate lighting of large manufacturing areas



Mercury vapor lamp

In the ordinary incandescent lamp, light is emitted from a highly heated resistance wire having a high melting point so that it may remain in a state of incandescence many hours without fusing or breaking The resistor or filament, is hermetically sealed in a glass bulb, which is evacuated, or which is filled with inert gas, such as nitrogen Most modern incandescent lamps have filaments of drawn tungsten wire, and go by the name of Mazda lamps The incandescent lamp is rated on the basis of the power input required Measured in watts, the standard sizes are the 25, 30, 40, 60, and 100-watt lamps Lamps both smaller and larger than these generally used sizes are commercially available The lumens per watt of power consumed average about nine for the modern incandescent lamp The average life has been raised until it is now about 1,000 hours per lamp

One of the most striking developments of the present century has been the growth of electric lighting The reason for this growth is to be found in the multiple advantages of electric lighting over other methods of illumination Principal advantages might be summarized as follows·

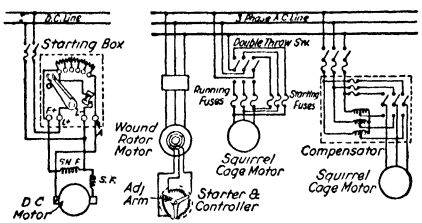
1 Convenience in use
2. Adequate illumination, eliminating physical handicaps resulting from eye strain
3 Safety from fire hazard of oil and gas lights
4 Artistic lighting units made possible by the use of electricity. (F T M)

ELECTRIC MOMENT. **Electrostatics.**

ELECTRIC MOTOR CONTROL. The operation of an electric motor is usually desired on the constant speed basis, but occasionally a variable speed motor is needed, and proper control to make this possible must be incorporated in the installation Constant speed motors must have control for starting and stopping

Control of a motor may be simple if the motor is driving a small machine, but it may become quite bulky and complicated in the case of variable-speed motors of large capacity Motor controllers are called upon to meet many different conditions For instance, across-the-line starting is used in the interest of reliability whenever practicable Large 2300-volt motors are protected by oil circuit breakers, smaller 440- or 220-volt motors by air breakers, fuses, magnetic starters, contactors, etc, as well as by oil circuit breakers Magnetic switches, contactors, oil switches, and knife switches are used to start and stop motors which are connected directly across the line

The location of motor-starting equipment depends on its size, the voltage of the motor, the type of starting employed, the location of the motor, and centralization of control The simple control switch is often mounted on a wall or column near the motor If the control equipment is bulky, as in the case of control for a 200-hp slip-ring motor, a special motor-control panel may be installed near the motor, this being used whether the control is manual, automatic, or electrical remote



Some methods of starting electric motors

When a motor is to be started other than across-the-line, two methods are employed to limit the current taken during the starting period One is to decrease the impressed voltage, the other to add resistance of the rotor circuit The ordinary direct current starting box is a device for insertion of voltage consuming resistance in the armature circuit This system is rarely used to start alternating current motors Stator connections can be altered, or resistance can be added to the rotor circuit of slip-ring motors, using the drum controller Also, impressed voltage is reduced by the use of starting compensators In some plants a special starting bus is provided for all 2300-volt auxiliaries The starting bus is energized at 1150 volts by a three-phase transformer of sufficient capacity to start the largest auxiliary Starting then becomes a matter of throwing the motor directly on the 1150-volt bus until its speed is satisfactory for 2300-volt connection (F T M)

ELECTRIC MOTORS. An electric motor is a machine which, receiving energy in the form of electricity, converts it into mechanical form Since there are so many different types of electric motors, it seems logical to begin a discussion of them with some attempt at classification of the principal types Such a classification is given below, and let the reader note that the motors here mentioned are diagramed in the same order in the illustrations

A Direct current types
- 1 Shunt
- 2 Series. } Straight or Interpole
- 3 Compound

B Alternating current types.
- 1 Synchronous (3 phase).
- 2 Induction
  - a. Polyphase.
    - (1) Squirrel cage rotor.
    - (2) Wound rotor
      - (a) Slip ring
      - (b) Brush shifting.
  - b. Single phase
    - (1) Split phase
    - (2) Repulsion-induction.
    - (3) Universal
    - (4) Condenser

Electric motors are built in a range varying from outputs of 1/100 of a **horsepower** up to well over 1,000 horsepower A 50-horsepower motor is considered a large one, and the great bulk of electric motors now in use range between one-quarter and ten horsepower Standard motor sizes above the small fractional sizes are ¼, 1/3, ½, ¾, 1, 1½, 2, 3, 5, 7½, 10, 15, 20, 25, 30, 40, and 50-horsepower Standard 60-cycle synchronous speeds are 3600, 1800, 1200, 900, 720, 600, 514, and 450 revolutions per minute Full load induction motor speeds are 2% to 5% less than these The efficiency of the electric motor ranges from 75% to 95% It is higher in large motors than in small Induction motors are more efficient the higher the rated speed, but direct current motor efficiency is little affected by speed Efficiency is often secondary to reliability, nevertheless it is a factor to be considered, particularly if the drive is heavy and the motor is well loaded over a considerable part of the time **Direct current** motors are much less frequently employed than **alternating current**, because of the preponderance of alternating current over direct current systems However, speed control and starting torque are so excellent with direct current that it is frequently used in alternating current territory where these characteristics are important Supply of power is taken from a motor-generator set at 110 or 220 volts The extra expense of the motor-generator installation lays some handicap upon the employment of direct current motors, and a number of methods have been devised to vary the speed of alternating current types, but, in the main, the latter are constant speed

The losses sustained by a motor in converting electrical to mechanical power arise chiefly through the electrical and magnetic characteristics The mechanical simplicity of a motor enables it to be designed with almost negligible friction The losses are, then, the **resistance** losses occasioned by current flowing through the conductors of the **armature**, the **field**, or the **controller**, and the core losses of **hysteresis** and eddy currents The cores of all motors must be built up of laminations insulated from one another by lacquer or enamel, otherwise this core loss becomes excessive The motor is so compact that in large sizes, although the efficiencies are high, the heat liberation per unit volume becomes sufficient to need the positive ventilation secured by fans and impellers In the small open frame motor the windage of the motor itself is generally sufficient for cooling Larger sizes are cooled by air forced through the windings by impellers mounted on the motor shaft, or by external fans In sheltered locations a simple open frame is employed, but motors may be had completely enclosed so that they may be installed where they will be exposed to the weather Intermediate between these are such frames as the drip proof types which are protected from overhead drips, the enclosed and ventilated, and the totally enclosed, the latter being cooled by ventilating air brought to it in ducts. The totally enclosed type would be necessary, for example, in an atmosphere wherein a spark or incipient fire could create an explosion

The relation between input, output, and efficiency are expressed by the following equations, wherein

P = horsepower output
E = efficiency
I = line current
V = line voltage
f = power factor

For all direct current motors

$$P = \frac{EIV}{746}$$

For single phase alternating current motors

$$P = \frac{EIVf}{746}.$$

For three phase alternating current motors

$$P = \frac{\sqrt{3}EIVf}{746}.$$

The frames of motors are frequently of cast iron, although welded construction has been employed successfully The **magnetic circuit,** of course, is of ferrous material, and the conductors are copper Insulating material is rubber, cambric, varnish, lacquer, enamel, asbestos, mica, wood, and fiber **Brushes** are laminated spring copper or carbon The usual position for which a motor is desired is with horizontal shaft, in which case the bearings are held by suitable recesses in the main frame casting, and lubrication achieved by one of the methods outlined under **bearings.** Vertical shaft motors are built having thrust bearings to carry the weight of the motor and any externally attached weight The end thrust for horizontal shaft motors connected to belts or gears can readily be carried by plain collar thrust bearings But if the drive itself sets up an additional end thrust, special thrust bearings may be necessary

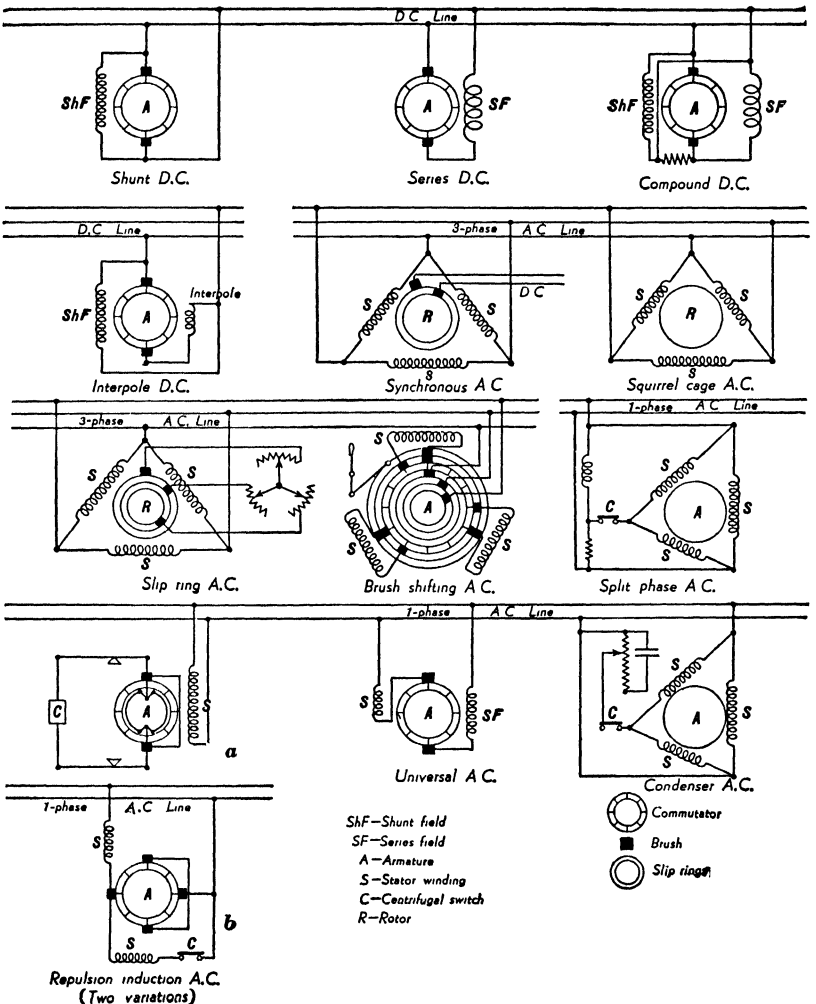
Important individual characteristics of electric motors include the following starting torque, normal speed, **speed regulation,** reversability, efficiency, and cost Motors are selected upon the basis of the voltage available, the peak load, the necessary reliability, the desired speed range, and the **load factor.** It is common practice to use polyphase motors for all motors larger than three horsepower, although single phase motors larger than this will occasionally be found In order to secure the most economical size, 2300 volts is employed where possible for motors of output exceeding 100 horsepower, 440 volts is suitable for medium sized motors, and 220 volts for small motors, except that fractional horsepower motors are almost always 110 volts The size of wire leading from the supply to the motor is made adequate to deliver the rated current at not more than two or three per cent voltage drop A feeder supplying one motor should, according to the electrical code, have conductors of a current capacity not less than 110% of the rated motor current However, much larger conductors may be required to take care of the starting current The capacity of wires carrying the starting current of an A C motor started by a **compensator** should be 200% of the rated current if the rated current is above 30 amperes or 250% if the rated current is below 30 amperes In the case of across-the-line starting, 300% of the rated current should be used Direct current motors started by a starting box should have leads with current-carrying capacity about 125% that of rated current. All motors should receive some sort of protection, either **fuses,** thermal **cutouts,** or circuit **breakers** actuated by **relays.**

The circuits of the principal types of electrical motors will now be explained briefly The reader should consult the illustrations for amplification of the text The shunt motor has a wound **armature,** the ends of the windings of which are brought to a **commutator,** upon which rest **brushes.** The incoming leads are connected to these brushes so that line voltage is impressed across the windings of the armature The stationary **field coils** are connected across the brushes in shunt arrangement so that they receive a constant voltage In the illustration, only one coil is shown, but any practical machine would be multi-polar When the motor is running, the coils of the armature cut the lines of force of its own **magnetic field,** and so generate an internal voltage known as the counter electro-motive force The sum of this counter electro-motive force and the resistance drop through the armature must equal the impressed voltage Consequently the current taken is much larger when the motor is revolving slowly than when it is up to speed. This also explains why weakening the shunt field current (and thereby the lines of force) causes the armature to increase its speed, since it is necessary for it to do so in order to build up the same electro-motive force in a weaker magnetic field The torque of the motor is produced by the magnetic attraction existing between the magnetism of the stationary field and the electromagnetic field surrounding the armature conductor

Unlike the shunt motor, whose field current is practically constant at all speeds, the series motor produces a field which is maximum during starting and decreases as the motor comes up to speed For this reason, the series motor has a powerful starting torque, and is used for hoists, traction motors, and the like The shunt motor is essentially a constant speed type, the series, a variable speed type A motor having better speed regulation and starting torque can be obtained by a compound winding having both shunt and series fields However, the simplicity of the shunt field motor, coupled with the possibility of effecting a reasonable variation in speed by a variable resistance in the field circuit, has caused it to be widely used It has been found, though, that any considerable weakening of the field is accompanied by sparking at the commutator, due to the demagnetizing **armature reaction.** Small poles, located between the shunt field poles, and wound with series coils, will compensate for the distortion of the field flux, and such motors are known as interpole motors

In the alternating current field, the above classification shows a primary division into synchronous and induction types Of these, the **induction motor** is by far the more important, but the strictly constant speed feature of the synchronous motor has caused its selection in certain cases The **synchronous motor** is practically an **alternator** operated inverted It has a three-phase stator winding which carries the main line current The field is wound on the rotor and is excited by direct current brought to it by brushes resting on slip rings The synchronous motor is stable only when operating at a synchronous speed corresponding to the frequency of the system, and if it is loaded to where it lags ever so slightly behind this synchronous speed, it quickly "falls out of step" and comes to rest The disadvantages of the synchronous motor are principally two It requires direct current excitation, and has very weak starting torque In fact, the single-phase synchronous motor has no starting torque, but with three phase the motor may be made self-starting if copper bars similar to the rotor of a squirrel cage motor are embedded in the rotating field and connected to end rings To start the motor, the direct current field is open-circuited and the stator windings connected to the line The motor will then come up to speed, operating as a squirrel cage induction motor, after which the field current may be applied, upon which the rotor will lock itself into step with the frequency of the system A synchronous motor is generally used only in large sizes where it has the advantage of providing some power factor correction, since one of the characteristics of this motor is that a leading current will be drawn if the direct current field is over excited, and this can be adjusted to neutralize the lagging current drawn by induction type motors

The three-phase squirrel cage motor is the simplest and most reliable electric motor made It has a powerful starting torque, and good efficiency, and would probably replace all other types were it not for the following reasons: It is essentially a constant speed motor, it



Electric motor diagrams.

draws a lagging current, and it is not built single phase. The stationary windings are connected either in **Delta** or **Y**, as may suit the individual design, and are so arranged as to produce a rotating field in the space occupied by the rotor The rotor is a shaft upon which is built up a laminated steel core carrying embedded in its surface copper bars which are parallel to the shaft. The inductive action of the field on this "cage" (if the core were removed, the bars would resemble the familiar squirrel exercising cage) sets up in the latter induced currents whose magnetic field reacts against the rotating field set up by the stator winding, producing a torque. If the rotor were turning in synchronism with the rotating field there would be no induction and no rotor currents. Therefore it is seen that the rotor can not possibly operate at full synchonous speed, even though idling The difference in speeds is known as the slip, and a certain amount of slip is necessary to secure inductive action As mentioned before, this varies from 2% to 5% of synchronous speed A squirrel cage motor with rotor blocked acts like a transformer with short circuited secondary, thus explaining the high starting torque.

There are installations where a polyphase motor is wanted, having some degree of speed control, and which may be brought up to speed more slowly than is customary with the squirrel cage motor. For this service the more expensive wound rotor and brush shifting types may be used on three phase circuits. The wound rotor principle is employed chiefly on large motors. As its

name implies, the wound rotor has polar windings in the rotor, the ends of which are joined either in Y or Delta, and brought to three slip rings The currents induced in the rotor are brought out through these slip rings to an external three-phase resistance, which may be varied at will from zero to maximum The operation is much like that of a squirrel cage motor, except that, for starting, the rotor current is decreased by inserting the maximum of resistance in the external circuit This is gradually decreased as the motor comes up to speed, until all of the resistance is short circuited and the motor is operating inductively with a normal slip Given constant torque, this motor may be varied in speed by varying the external resistance, but it is somewhat less efficient than the brush shifting type, because of the energy consumed in the resistance The brush shifting motor is used where considerable speed variation is desired at good efficiency, as, for instance, when driving fans or pumps of large size The brush shifting motor has the primary winding on the rotating armature, similar to direct current practice This winding is connected to the three-phase line through slip rings Another winding, called an adjusting winding, is also placed on the rotor, in fact, in the same slots, but is connected with a commutator, which is made fairly wide The three phase stator secondary windings are brought out individually to six brushes which bear on the commutator, and are connected as shown in the diagram Each set of three brushes is joined by a yoke, so that they may be moved simultaneously, and each pair is placed on opposite ends of the commutator When these yokes are moved with respect to one another, they cause to be included a certain number of commutator segments in each secondary coil When each pair of brushes is on a common commutator bar, the motor runs as a straight induction motor at slip frequency By moving the brushes apart by rotating a yoke, the voltage induced in the commutator coil is added to that in the secondary, and the motor speeds up These voltages may be subtracted by moving the brush in the opposite direction, resulting in slowing down the motor Since the forces needed to move the yoke are very small, it may be readily operated by the light pressures produced in an automatic control system

Turning next to the single phase motor, it is entirely possible for a single phase motor to operate inductively like the squirrel cage motor, provided it can be brought up to speed, but a single-phase squirrel cage motor has no starting torque, so there have been developed numerous ways of doing this for single-phase motors, most of which are of small size In the split phase motor, an inductance and resistance are used to displace the voltage at the mid point so as to get an arrangement resembling a two-phase impressed voltage Of course the starting torque obtainable is inferior to that of a polyphase motor, but is sufficient to start a motor attached to a drive requiring low starting torque A fan illustrates this service For heavy starting duty the starting torque of a single phase motor is created by repulsion, which shifts over to induction as the motor comes up to speed Several systems have been invented, two of which are illustrated At *a*, the armature windings are brought out to a commutator, upon which rest two brushes connected externally by a low resistance conductor A stator winding is connected across the line The short circuited armature has induced in it the large current necessary to secure starting torque As the motor comes up beyond a certain speed, a centrifugally operated switch lifts the brushes from the commutator and applies to it a ring which short circuits all the segments When this is done the motor operates as a straight induction motor This principle, known as repulsion-induction—i e, repulsion starting and induction running—is employed in most small motors which are to produce large starting torques on single phase supply At *b* is another repulsion-induction principle, less complicated mechanically Here the switch operates during starting, and is closed for induction operation

A universal motor is a series motor which may be operated on either direct or alternating current. It is usually employed in small sizes only, there being a compensating coil to prevent armature sparking and to improve the power factor

The condenser motor is a split-phase motor, having the phase displaced by capacitance rather than inductance It is superior to the former in starting torque, efficiency, and power factor, but more expensive and bulky To operate it successfully, the voltage across the condenser must be stepped up by an **auto-transformer.** A centrifugal switch is used to disconnect the condenser when the motor is up to speed and operating inductively at slip frequency (F T M)

ELECTRIC NETWORKS. Kirchhoff's Laws of Networks.

ELECTRIC OSCILLATIONS AND ELECTRIC WAVES The most important early researches in this field were carried out by Heinrich Hertz, who, about 1888, discovered that when an electric discharge takes place in a circuit having suitable **inductance** and **capacitance,** the resulting oscillations of the **electricity** therein give rise to ether waves, usually some meters in length The existence of these waves was proved by their inducing oscillations in a similar circuit set up at a distance He found that this Hertzian radiation (as it is now called) can be reflected by metal surfaces and refracted by large blocks or prisms of dielectric material, just as light is reflected and refracted, and that it exhibits corresponding interference phenomena The applications of Hertzian waves in radio are treated elsewhere

The natural frequency of an oscillatory circuit or "Hertz oscillator" having resistance R (ohms), inductance L (henrys) and capacitance C (farads) is given by the equation

$$f = \frac{1}{4\pi}\sqrt{\frac{4}{LC} - \frac{R^2}{L^2}} \text{ (cycles per second)}$$

In using such formulae, the high-frequency values of R, L, and C must be employed, these being in general different from their low-frequency or steady-current values The tuning condensers and inductance coils used in obtaining currents of desired frequencies are familiar to every radio amateur High-frequency currents produced in this way range from 10 kilocycles per second for the longest radio waves (30 kilometers) to at least 75,000,000 kilocycles per second for the ultrashort waves (4 millimeters), detected some years since by Nichols and Tear and bordering on the infrared (See **Electromagnetic Radiation**)

Electric waves may be propagated on long wires, somewhat as sound waves travel through a long tube By terminating the wire in a small capacitance, the waves may be reflected and made to form interference nodes as do sound waves in an organ pipe The wave length may be thus determined by what is known as the Lecher oscillator method, using two parallel wires

It is often desirable to introduce into a communication line, such as a telephone circuit, a combination of inductances, or of inductances and capacitances, so designed as to form an effective barrier to currents of certain frequencies or frequency ranges, while others are allowed to pass through Such arrangements, called wave filters, find many applications in modern electro-acoustic technology (L D W)

ELECTRIC POTENTIAL. If a charge of **electricity** is moved from one region of space to another, it encounters in general electric forces which either help or hinder the transfer and which therefore add to or subtract from the potential energy of the charge Let us suppose that a positive unit charge has been brought

into the region A from a region so remotely beyond the borders of the material universe that no electric forces exist there In general, a certain amount of work, V_A, has been done against the electric forces encountered on the way in, consequently V_A may be regarded as the potential energy which the unit charge has acquired in the process This work per unit charge, V_A, is called the electric potential of the region A It is a scalar quantity, and may be either positive or negative, for example if A is in the vicinity of a large negative charge, the unit positive charge has been attracted and has done work, or lost potential energy, during its journey, and V_A is therefore negative If a second region B is at a potential V_B less than V_A, the unit charge loses potential energy in moving from A to B, in the amount $V_A - V_B$ Thus, in an electrolytic cell, a positive ion migrates from the high-potential to the low-potential electrode, and does work in heating the solution Negative charges tend to migrate from lower- to higher-potential regions, this is illustrated by the electrons in a wire

The absolute zero of potential is of course that at an infinite distance from the universe, but for practical purposes an arbitrary zero is used, commonly that of the earth's surface (which is by no means constant) The ordinary unit of electric potential is the **volt.** See **Electromotive Force.** (L D W)

ELECTRIC POWER. Electric power is the product of **electric current** and **electromotive force**, that is, multiplication of current flowing by **voltage** forms the basis of the calculation of electric power In a **direct-current circuit**, the current measured in amperes, multiplied by the voltage between wires, is the power in **watts** A thousand watts constitutes the kilowatt, a larger and more frequently employed unit of electric power

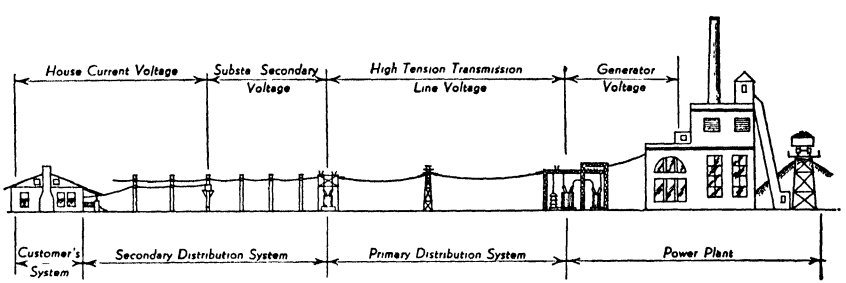
The voltage and current may not be in phase with each other in an **alternating current circuit.** This factor needs to be taken into account in determining electric power in an alternating current circuit, for it is only that component of the current which is in phase with the voltage that produces electrical power The out-of-phase component produces the "wattless power" The power factor measures the fraction of the current that is in phase and available for true power It is equal to the cosine of the phase difference between voltage and current In a single-phase alternating current circuit having current of I amperes, voltage of E volts, and power factor f, the true power is EIf watts In a three-phase circuit, it is $\sqrt{3}\ EIf$ watts See **Alternating Current, Direct Current** (F T M)

ELECTRIC POWER TRANSMISSION. If power could be generated for the same cost at any point in the country, there would be no need for electric power transmission But since the larger the electrical generating unit, the lower the unit cost of production, there has developed the method, so extensively used at present, of generating electric current in large **central stations.** From this has arisen the need for electric power transmission to carry the energy so produced to the users. The system of distribution extending from the generating station to the user is of varying complexity, depending on the number of customers and their location relative to the plant From the standpoint of economy in power transmission, it is desirable to have the plant near the center of the load served, but other factors, such as suitability of sites, proximity of fuels, real estate costs, water supply, etc., are prominent influences bearing on the location of the generating station

The physical system of conductors, whereby the generators are connected with the customers' lines, may be separated into two parts These are shown in the figure The primary distribution system generally consists of a transmission line carrying three phase alternating current from the switchboard of the plant to a **substation** located near the load served A secondary distribution system extends from the substation to the customer's site. The primary system is generally known as the transmission line, the secondary system as the distribution network The first is characterized by relatively high voltage, the second by medium and low voltage

Energy may be transmitted electrically in overhead wires or underground cables as an electronic flow under pressure The flow is measured in amperes The voltage is the electric pressure Electrical energy is proportional to the product of these two quantities This energy can not be transmitted without some losses, the principal one being a resistance loss, which depends upon the current flow and the size of the wire In transmitting a given amount of energy, this loss may be reduced by increasing the voltage, since any voltage increase will allow a decrease of current Or, from another viewpoint, for a given amount of energy, and a given permissible loss, higher voltages will permit the use of smaller wires The foregoing should serve to show that, where practicable, electric power should be transmitted at high voltages For various reasons this is not feasible in the distribution networks, but is so on transmission lines In consequence, the operating voltages of the latter range upwards from 6600 volts to over 200,000 volts Commonly employed system voltages are 33,000, 66,000, 132,000, and 220,000 However, the higher voltages are strictly for overhead lines, cable transmission usually being limited to voltages lower than 40,000 volts

These economic transmission voltages are higher than those under which power generating and utilizing apparatus can be operated, and a voltage transformation is essential if high transmission line voltages are to be used By far the simplest and most effective means of accomplishing this is to employ a static **transformer.** The transformer may be used only with **alternating current,** and this goes far in explaining the prevalence of the alternating current method of power transmission, because in many other respects high voltage direct current is a superior means of transmission As is shown in the diagram, the generator voltage is increased in the switch-



Elements of a Power System

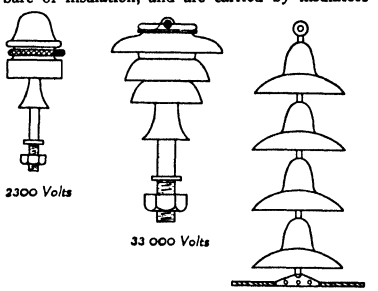
yard transformer to some economic transmission line pressure The transmission line extending from station to load center may be of any length, as dictated by the geography of the locale; however, it does not commonly exceed 100 miles Above some such distance the transmission line losses grow to where it becomes financially more attractive to build the generating station closer to the load and carry the energy to it by rail or water in the form of fuel At the receiving end of the transmission line, the voltage decreasing transformer reduces pressure to that which may be handled readily by the distribution network This is often 2200 volts At this voltage the energy flows through the network to the pole type transformers located close to the customer, or group of customers, it serves At these transformers the voltage is reduced to 110 or 220 volts, in accordance with the customer's needs

The energy loss occasioned by current flowing against the line resistance is not the only loss of energy in power transmission The long stretches of parallel conductors have a capacitive effect, causing them to draw a current much as a **condenser,** even though the switches at the far end of the line are open Furthermore, at high voltages, the air surrounding the conductors becomes partially ionized, and there exists a brush or **corona** discharge which represents a leakage of energy The latter, as a matter of fact, is a limiting factor in the raising of electrical pressure on the transmission line, and tends to offset the savings due to low current flowing when high voltages are used Good transmission line design requires proper coordination of voltage, wire size, and line losses, so that the desired power may be transmitted at a minimum total annual cost

When current flows on a long transmission line, the **induction** of the line itself, plus its **capacitive** effect, combine with the **resistance** loss to give a voltage at the discharge end which varies with the load, even though the voltage is constant at the generator end This feature is known as transmission line regulation, and is susceptible of prediction and analysis by well developed theories of the electrical engineer From the standpoint of the equipment served, it is desirable that this line regulation be offset so that lamps, heaters, etc , may operate on standard voltage Induction regulators and tap-changing transformers are among the means employed to offset transmission line regulation Furthermore, it is not difficult to demonstrate that the economy of power transmission varies as the square of the **power factor,** making it extremely desirable to operate the transmission line at unity power factor On account of the induction characteristics of most electrical loads, and the capacitive effect of a transmission line itself, the current on a transmission line will tend to vary from lagging to leading, or vice versa with load, although customarily it tends to be lagging For this reason, the synchronous motor is frequently employed for power factor correction, it being well known to have the electrical feature of drawing leading or lagging current, depending upon the amount of field excitation Where this is not done, static capacitors are often added to improve the power factor

The sheer physical extent of the ordinary transmission line makes it a likely victim of lightning, and no extensive transmission line could be successfully operated without adequate lightning protection This may consist of **lightning arrestors** strategically placed, or an overhead grounded guard wire Direct strokes are usually immediately dissipated by flash-over on the insulators, the lightning then finding its way down the pole to the ground High frequency induced waves (2000 to 5000 cycles) may not possess flash-over potential, and will travel along the line until relieved by an arrestor, or dissipated in resistance loss Aside from lightning, a line should be protected against overload and short circuits This is commonly the function of transformer fuses, substation circuit breakers, and generator circuit breakers.

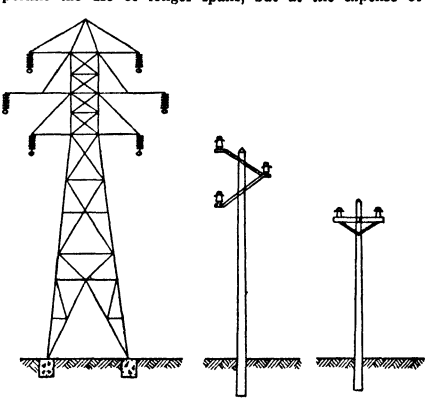
Turning from electrical to mechanical characteristics of electric power transmission, we find the material employed as conductor is universally either copper or aluminum The former is used in most cases, but the latter is in use for the very high voltage lines where, because of the larger diameter permitted by the lower density, it is effective in reducing corona loss Except for very low voltage distribution network lines, the wires are bare of insulation, and are carried by insulators of



Insulators.

porcelain or glass of a design suitable for the voltage employed Sometimes these insulators are mounted rigidly on the cross arm of the poles, but for the higher voltages they depend from the poles, and are known as suspension insulators On high voltage lines, each insulator is a chain of separate units, so that the voltage from line to pole may have a uniform gradient across the insulator The distribution network and the low voltage secondary transmission lines are generally supported by wooden poles having cross arms The pole most commonly used at present is of Southern pine, well creosoted These poles should be sufficiently high so that, at the middle of the span between them, the bottom of the wire sag has a minimum clearance over the ground As specified in the safety code governing the industry, this clearance varies with the voltage and with the surroundings, for example, in rural districts, for line voltages of 15,000 volts, 18 feet clearance should be maintained

The spacing of poles must be chosen with due regard for temperature and sag conditions Larger sags in the wire between poles give lower stresses in the wire, and permit the use of longer spans, but at the expense of



Typical supports.

the use of taller poles, needed to maintain the minimum clearance previously mentioned. Consequently, the observer may see extremes of design representing individual designers' viewpoints, varying from relatively low, closely spaced poles, with little sag, to long spans where tall poles are spanned by wire having a much greater sag At the same time, the effect of contraction caused by lowering of temperature in winter, and the loads suffered during storms, particularly sleet storms, must be guarded against While high voltage lines are frequently constructed on exceptionally high wooden poles (i e, 50 to 80 feet), the steel pole or steel tower is the more frequently used A common arrangement for high tension transmission lines is the four-legged steel tower, as diagrammed in the accompanying sketch This tower is conveniently arranged to support two three-phase circuits, and is frequently built as high as 100 feet, which permits extremely long spans because of the considerable amount of sag permissible One hundred and ten thousand-volt transmission lines, so supported, are frequently run with no more than six or eight towers per mile (F T M)

ELECTRIC RATES. An electric utility company derives its revenues directly from the customers it serves on the basis of monthly billings The customers' meter readings are put into the rate structure and the amount due from that customer determined The apparent simplicity of the process is misleading, for the establishment of the rate structure that will fulfill the requirements of a successful working rate is a matter of no inconsiderable difficulty From the public's standpoint the rates should meet the following conditions

1 Rate schedules should be simple
The problem of setting up a schedule that will fairly distribute the costs is aggravated by the necessity of its being comprehensible to the public as well as to the rate expert
2 Rate schedules should be uniform over large territorial areas
There is much yet to be accomplished here Persons in one community frequently are paying on one basis, and those in the neighboring community on another which is so different as to be unintelligible to the first
3 Direct service from producer to consumer
This requires the elimination of the energy jobber, subcontractor, or middleman
4 Distribution of costs in such a way that persons creating a desirable and relatively inexpensive type of load may enjoy the full use and benefit of electrical appliances

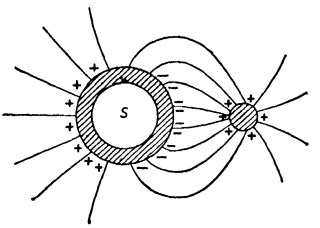
Scientific electric rate-making might be said to have originated with Dr John Hopkinson, an Englishman who lived in the last half of the nineteenth century The Hopkinson rate theory was based on two charges, one a fixed annual charge per kilowatt of maximum demand, the other a small unit charge against each kilowatt hour of energy used Other early leaders in rate-making theory were W J Green and Arthur Wright in 1896, and H L Doherty in 1900

The following elements enter into the cost of electrical energy to the consumer

Fixed element
Energy element
Variable load element
Customer element
Investors' profit

The first of these is governed by the extent of plant investment and the current financial rates It remains a fixed sum regardless of the amount of energy sold The second is directly proportional to the plant output The third, the variable load element, is governed by the characteristics of the load served, the load factor, the abruptness of the peaks, etc The customer element will be proportional to the number of customers and nearly independent of both the plant investment and its kilowatt hour production The profit is that which any sound normal business is expected to make. (F T M)

ELECTRIC SCREENING. The experiments of Faraday revealed that any region completely enclosed by metal or other good **conductor**, however thin, is entirely free from **electrostatic** fields due to anything going on outside the enclosure This is not because conductors are impervious to electric fields, but is due to the fact that the free **electrons** in the conducting shell surrounding the enclosure instantly adjust themselves so as to offset the effect of any electrostatic force that would otherwise penetrate the interior Even a cage of fairly coarse screen wire is quite effective Since **electromagnetic radiation** involves electric fields, we have here an explanation of why metals are opaque to it The screening effect of conductors is utilized in many kinds of electrical apparatus, as by enclosing electroscopes and the wires leading to them in metal cases or conduits, the placing of metal covers over radio tubes, etc Whole buildings are sometimes covered with sheet iron to prevent induction sparks due to lightning from setting fire to inflammable contents, such as gasoline or explosives (See **Electrostatics**) (L D W)



Showing induction and external field Space S is completely shielded

ELECTRIC SYSTEM PROTECTION. The protection of **alternating current** cable networks and overhead transmission lines is a large and important field of electrical power engineering The need for protection should be obvious The nature of electrical phenomena is such that trouble may develop and lead to considerable damage to equipment before attendants are aware of it or before they can perform the protective operations manually Not only will failure to protect the electrical equipment endanger the equipment itself, what is more important, it may also endanger life Failure of generating station equipment involves more than the cost of repairs to such It may mean complete shutdown or restricted output, bringing loss of revenue, complaints, and ill will of customers Though often complicated, the protective system is not excessively expensive compared to the value of the equipment it protects.

Protection is mainly against sustained overloads, high temperatures, and internal faults In the case of **generators** or **transformers**, sustained overloads and high temperatures can usually be taken care of by the control room staff, guided by instruments indicating the magnitude of these abnormalities They may be assisted by automatic relays giving audible or visual warning of these abnormalities when a predetermined value is exceeded But upon internal fault developing, the equipment should be quickly and automatically disconnected The internal faults may be short-circuited turns, open circuits, phase to phase short circuits, or grounds

The protective system should be satisfactory from the following points (1) Selectivity The protective system should be able to distinguish which portion of a section-

ENDOTHERMIC REACTION. Thermochemistry.

ENERGY. Energy is probably to be regarded as the most fundamental of all physical entities, though within the past few years our concepts relating to it have undergone quite revolutionary changes.

From the elementary and older point of view, energy is thought of as an intangible something transferred to bodies of matter when **work** is done upon them, and delivered up by such bodies whenever they do work upon other bodies. Thus, let a free body be acted upon by a steady force of 6 pounds until it has moved from rest a distance of 100 feet in the direction of the force. The work thereby done upon the body is 600 **foot-pounds** and since the moving mass is now capable of doing 600 foot-pounds of work upon other bodies by collision or otherwise, we think of this 600 foot-pounds as something which has been transferred and conserved throughout the process.

Considerations of this kind have led, in the past, to regarding energy primarily as that which is thus communicated and conserved whenever work is done by one body upon another. But in the nineteenth century, Joule and others discovered the equivalence of heat and energy. And when it was established that light is a form of energy traveling through space apparently independent of any matter, it became necessary either to construct a dynamics for light and to invent an **ether** in which to carry on its operations, or else to accept energy, at least radiant energy, as having an objective existence of its own, coordinate with that of matter itself.

In the measurement of energy, we still adhere to the elementary concept and utilize its familiar relationship with the dynamic magnitude, work. We even express energy in work units; though there is today no more logical reason for doing so than for adhering to the old water-temperature **caloric** in measuring heat. Thus the practical energy units are, in pure physics, the **erg** or centimeter-dyne, in engineering, the foot-pound.

Whenever energy is obviously associated with the motion of masses of matter,—the form in which we sense its existence most readily,—it is called **kinetic energy.** But since work may be done in such a way as not to affect the motion of matter, but to alter its situation or condition in other ways (as when a battery is charged or a clock wound), we must also recognize the existence of latent or **potential energy.** Much of the activity going on in the material world involves the continual transformation of energy from one of these states to the other.

Early experimenters observed that when a **machine** is so constructed as to operate with negligible friction, the work done by the machine is equal to that done upon it. Thus, if a weight of 20 pounds is lifted 7 feet by means of a single movable pulley, the operator, though obliged perhaps to exert only 10 pounds of force on a cord, must draw that cord upward 14 feet. In each case the work done is 140 foot-pounds. The extension of this principle to a multitude of complex cases finally led to the doctrine of conservation of energy, recognized in various aspects by different physicists toward the middle of the nineteenth century. This doctrine, in concise form, states that the total quantity of energy in existence remains unaltered throughout all the changes which take place in the material universe. It is thus analogous to the earlier doctrine of the conservation of **mass.**

Modern research in **relativity** and atomic physics has cast some doubt upon the literal truth of both of these doctrines. Einstein, in studying the relativistic connection between matter and energy, arrived at the conclusion that energy, like mass, possesses inertia and gravitational attraction, in such degree as to make the unit of energy equivalent to $1/c^2$ units of mass (in which c is the speed of light); so that 1 gram of matter has the same inertia and gravitational attraction as c^2 ergs, or 8.986×10^{13} **joules,** of energy. Subsequent observation has supported not only this view, but the further theory that in certain circumstances matter may be actually converted into energy, and perhaps energy into matter, in the same ratio. Thus if the sun emits its radiant energy without drawing upon any source of supply other than that arising from the transformation of its mass, the Einstein **proper energy** principle leads to the conclusion that its mass must be diminishing at the rate of some 4,600,000 tons per second. If all the **stars** are likewise sacrificing their mass to keep up their radiation output, and if this energy is not somewhere recreated into matter, it is clear that the conservation doctrine is not universally valid, unless applied to the totality of both matter and energy together as a single entity. See **Available Energy.** (L.D.W.)

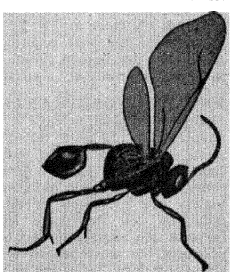
ENERGY LEVELS. Quantum Theory.

ENGINE. In common usage, the term engine is used widely for devices which produce motion. In stricter technical sense, an engine is said to transform energy, especially heat energy, into mechanical work. Among the prime movers, those in which the power originates in a piston and cylinder are classed as engines, while those with purely rotative motion are known as turbines. See **Diesel Engine, Otto Engine,** and **Steam Engine.** (F.T.M.)

ENOL. Tautomerism.

ENRICHMENT. Also "secondary enrichment." The term applied by students of ore deposits to the natural processes by which the lower levels of an ore deposit are enriched at the expense of the upper levels, or the original protore. Particularly applied to **lodes** in which the **sulfide** ores have been concentrated by the leaching of the upper levels of the **vein** and redeposition below the **groundwater** table. Important ore minerals belonging to this type are **chalcocite** and **argentite.** (R.M.F.)

ENSIGN FLY. Insecta, Hymenoptera. Small parasitic **insects** whose abdomen is elevated on a slender stalk above the thorax. It has been likened to a flag and gives the common name to the group. The ensign flies make up the family Evaniidae. All species are parasitic in the eggs of cockroaches. (A.W.L.)



Ensign fly.

ENSTATITE. The mineral enstatite is an **orthorhombic pyroxene,** rarely in distinct crystals, usually found as fibrous or lamellar masses or perhaps compact. It has one easy cleavage parallel to the prism, brittle with uneven fracture, hardness 5.5, specific gravity 3.1-3.3, luster pearly to vitreous, sometimes somewhat metallic in **bronzite,** a variety of enstatite carrying up to 15% ferrous oxide FeO. Color grayish to greenish or yellowish white, green and brown. Chemically enstatite is a silicate of magnesium, $MgSiO_3$. It occurs in igneous rocks which are high in magnesium content, like **gabbros, diorites, pyroxenites,** etc., and less commonly in metamorphic rocks. Meteorites of both the stony and metallic types have been shown to contain enstatite. It has been found at many places in Europe, Czechoslovakia, Austria, Bavaria, Germany, Norway and South Africa. In the United States it occurs in Putnam and St. Lawrence Counties, New York; Lancaster

The extent of chemical change is dependent in each case upon the amount of current which passes One equivalent (See **Chemical Composition**) of **element, compound or radical**, is liberated per 96,500 coulombs of current (1 coulomb equals 1 ampere-second) (Faraday, 1833) at each electrode The positive electrode *in the solution* is called the anode, and the reaction at the anode occurs by loss of negative charge of the anion. The negative electrode *in the solution* is called the cathode, and the reaction at the cathode occurs by loss of positive charge of the cation The process itself is called electrolysis.

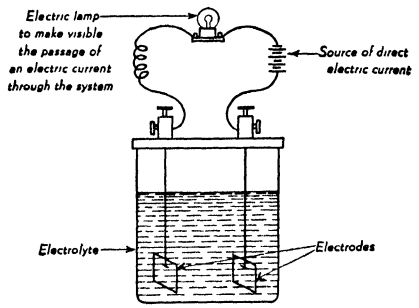


Diagram showing electrolysis of solutions

In electrolysis of dilute solutions of the alkali and alkaline earth (Groups I and II, see **Chemical Composition**) salts or bases, oxygen (1 volume) is evolved at the anode and hydrogen (2 volumes) at the cathode This is equivalent to the electrolysis of water When the above salts are **chlorides** and the electrolyte not dilute, the reaction is more complicated at times More or less **chlorine** is evolved with or without **oxygen** according to the composition, concentration and mixing of the solution, the temperature, and the substance of which the anode is composed Thus, with **sodium** chloride solution (1) chlorine is separated at the anode and **sodium** hydroxide at the cathode when a semi-porous diaphragm is used to separate mechanically but not electrically the anode and cathode compartments, (2) sodium **hypochlorite**, when the solution without a diaphragm is mixed by rapid stirring, (3) **sodium chlorate**, when the warmed solution without a diaphragm is mixed and the current is passed a long time, and, with sodium chloride fused, sodium metal at the cathode Graphite or amorphous carbon is used as a resistant anode, iron or nickel as cathode, and asbestos cloth as a diaphragm

In electrolysis of many metallic salts, other than those of the alkali and alkaline earth metals, the metal is deposited at the cathode **Copper** or **lead** is refined or deposited on another metal or on graphite by electrodeposition, **nickel, silver, gold, zinc, cadmium** or **chromium** is deposited in electroplating of objects, and **aluminum, magnesium, sodium** or **calcium** is produced.

The electrical conductivity or conductance of an electrolyte depends upon the composition and concentration of the electrolyte, and on the temperature Its value is expressed as reciprocal ohms, or mhos, and the equivalent conductivity is the conductivity of one equivalent weight of the substance at the given concentration and temperature when measured in a cell having two parallel platinized electrodes 1 centimeter apart In practice, the conductivity cell has two **platinum** electrodes each about 1 square centimeter in area and is calibrated by the use of a standard solution.

ELECTRICAL CONDUCTIVITY OF POTASSIUM CHLORIDE SOLUTION AT 18° C.

Gram Mols per Liter of Solution	Conductivity (Mhos)	Difference in Conductivity between Successive Dilutions (Mhos)
1	98 2	13 7
0 1	111 9	
0 01	122 5	10 6
0 001	127 6	5 1
0 0001	129 5	1 9

The equivalent conductivity at zero concentration or infinite dilution is obtained by extrapolation of the curve plotted from the above values, and is in the case of **potassium** chloride at 18° C , 130 1 mhos For **hydrochloric acid** the value is 379 5 and for **potassium** hydroxide 236 6

The equivalent conductivity for each of the common anions and cations has been determined.

Hydrogen (H^+)	314	mhos
Sodium (Na^+)	43 5	
Potassium (K^+)	64 4	
Ammonium (NH_4^+)	64 5	
Hydroxyl (OH^-)	172	
Chloride (Cl^-)	65 5	
Nitrate (NO_3^-)	61 7	
Sulfate ($\frac{1}{2}SO_4^{--}$)	68	
Acetate ($C_2H_3O_2^-$)	34 6	

From these values the equivalent conductivity of acids, bases, salts may be ascertained, and in the case of electrolytes of low conductivity, for example, **acetic acid** and **ammonium** hydroxide, furnishes the accepted values

The conductivity depends upon the velocity of each **ion** and upon the viscosity of the solution Since the total current passing a given cross-section of the solution is carried partly by anions and partly by cations, the more rapidly moving ions (anions or cations, as the case may be) carry more than half of the current The fraction of the current carried by anions and by cations is proportional to the relative speed of each group The result is that the faster ions crowd around their electrode to a greater degree than the slower ions around their electrode—the discharge at the electrode is strictly proportional to the current passing and is equivalent at each electrode Under a potential gradient of one volt per centimeter at 18° C the speed of ions is as follows

H^+	10 8	centimeters	per	hour
Na^+	1 26	"	"	"
K^+	2 05	"	"	"
OH^-	5 6	"	"	"
Cl^-	2 12	"	"	"
NO_3^-	1 91	"	"	"

These values are practically in the same ratio as the equivalent conductivities of the ions

The modern theory of electrolytic dissociation was announced by Arrhenius (1887) and extended by Milner (1912), Debye and Huckel (1923) and Onsager (1926) In the case of strong **electrolytes** like salts, **hydrochloric, hydrobromic, nitric acids, sodium, potassium**, quaternary **ammonium** (not ammonium), **calcium, barium** hydroxides, the dissociation into ions is complete Changes in conductivity with changing concentration are due to the electrical effects of the ions upon each other Each ion of positive or negative charge is surrounded in the solution by an ionic atmosphere of negative or positive charge, respectively Weak electrolytes include ammonium hydroxide and many organic bases (See **Amines**), and practically all of the organic and some inorganic acids. These are slightly dissociated into ions

Conductivity ratios at 18° C. of some weak acids are as follows:

Acid	Concentration	Ratio of Conductivity at Given Concentration to Conductivity at Zero Concentration at 18° C.
Carbonic	0 1 molar	0 002
Acetic	1 0 normal	0 004
Hydrosulfuric	0 1 molar	0 0007
Hydrofluoric	1 0 normal	0 07
Boric	0 1 molar	0 001

Such acids are slightly ionized and the values given in the last column above represent practically the equilibrium fraction ionized at the corresponding concentration and temperature thus

$$\text{Non-ionized Acid} \rightleftarrows H^+ + \text{Anion}^-$$

$$\text{Concentration} \quad \frac{1-x}{v} \qquad \frac{x}{v} \qquad \frac{x}{v}$$

Where 1 is the original amount, $1-x$ the amount non-ionized under the conditions, and v the volume of solution

Ostwald showed that, in each case of a weak electrolyte

$$\frac{\frac{x}{v}\times\frac{x}{v}}{\frac{1-x}{v}} = \frac{x^2}{1-x}\times\frac{1}{v} = \text{Constant}$$

This constant is called the ionization constant of the acid or the base See **Acids, Bases, Salts** The less the ionization of the acid (or base), the nearer the constant approaches in value the product of the concentration of the two ions

The intensity aspects of electrochemical reactions are discussed in the article on **Reactions Involving Oxidation-Reduction** (R K S)

ELECTRODE. In an **electric circuit**, part of which is composed of other than the usual conductor of copper, or other metal, the terminal connecting the conventional conductor and the conducting substance is an electrode Examples of electrodes are to be found in the electric **battery**, where they dip in the electrolyte, the **electric furnace**, where the electrodes connect the external circuit with the heating arc, and in the electric chair, where the electrodes connect the external shocking circuit with the body For electrode potentials, see **Reactions Involving Oxidation-Reduction** (F T M)

ELECTRODELESS DISCHARGE. There are two ways in which a current may be maintained in a rarefied gas without the introduction of **electrodes** into the gas (1) A tube containing the gas may be placed between external metal plates having a rapidly alternating, high potential difference The tube then acts as the **dielectric** in a **condenser**, and the gas may become luminous with a discharge across the tube similar to that with internal electrodes (2) The tube may be surrounded by a **helix** through which a high-frequency current is passing In this case the luminosity takes the form of a ring, inside the tube, coaxial with the turns of the helix This is due to the alternating electric intensity induced by the current in the helix The discharge has the characteristics of the positive column in an ordinary discharge tube, except that it forms a closed ring Striations sometimes appear, in radial planes If the oscillations in the helix are intense, the ring discharge is confined to the space immediately inside the tube wall, if less so, it extends farther inward. The discharge is facilitated by ultraviolet radiation traversing the gas Volatile impurities in the tube, such as sulfur or phosphorus, impair the discharge and may stop it With some gases there is a distinct **phosphorescence**, called the "afterglow," persisting for some seconds after the helix oscillations cease. There is evidence that this effect is associated with impurities and is of chemical origin. (L D W)

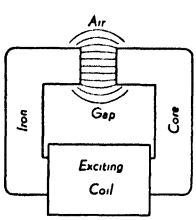
ELECTRODE POTENTIAL. Reactions involving Oxidation-Reduction.

ELECTROLYSIS. The process of decomposition of an **electrolyte** by the passage through it of an **electric current** is electrolysis. In electrolysis, the body of the electrolyte must surround two **electrodes**, one called the anode, the other, cathode Current flows from the anode to the cathode, and the dissociated parts of the electrolyte are liberated at the surface of the electrodes, that moving toward the anode being the anion, and, to the cathode, the cation For example, a solution of copper sulfate, commonly called bluestone, is an electrolyte When a current is passed through it between two electrodes, the copper sulfate is broken down into metallic copper, which is deposited on the cathode in the form of a copper plate The molecule of water is caused to liberate its oxygen, which appears at the anode, while the hydrogen unites with the sulfate iron to form a solution of sulfuric acid Electrolysis of a damaging, uncontrolled nature sometimes occurs in buried water pipes or the reinforcement of concrete It originates from stray lighting or traction currents A damp soil is essential to action of this nature (See **Electrochemistry; Reactions Involving Oxidation-Reduction**) (F T M)

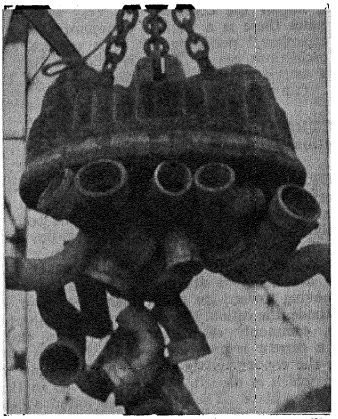
ELECTROLYTE. This term is commonly applied to substances which either in the molten state or in **solution** conduct **electricity** by transfer of **ions** The term is not applied to the metals in elementary form Another usage is to apply the term electrolyte to the conducting solution itself The more important electrolytes are solutions of salts, acids, or bases, usually in water. (See **Acids, Bases, and Salts; and Electrochemistry**) (R K S, F T M)

ELECTROLYTIC DISSOCIATION THEORY. Reactions Involving Recombination of Ions.

ELECTROMAGNET. A **magnet** whose field is produced by an **electric current**, and which is largely demagnetized upon cessation of the current, is an electromagnet In order to obtain the strongest field possible, highly permeable soft iron or steel is employed for the **core** of electromagnets In an electromagnet the current flows through a solenoid, which is a conductor wound in the form of a **helix**, and which produces a strong magnetic field coaxial with the helix The core is placed inside the helix in order to give a magnetic path of the least reluctance Electromagnets are found in a number of different forms, such as the plain solenoid with cylindrical core, or the horseshoe electromagnet, much used in electric bells, telegraph instruments, and telephones Very powerful electromagnets are often used to move masses of iron, such as scrap iron, and have the advantage that the loading or unloading of the crane to which the magnet is attached is simply a matter of applying or disconnecting the electric current



Sketch of electromagnet having two poles, one of a large variety of designs



Typical electromagnet, carrying load. (*Courtesy Electric Controller & Manufacturing Co.*

For practical calculations we may write the Bosanquet law $\phi = \mathcal{M}/\mathcal{R}$ for the flux in a **magnetic circuit** in more useful approximate form:

$$\phi = \frac{nI}{5l/2\pi\mu a} = \frac{nI}{0.796l/\mu a}.$$

This refers to a simple, closed magnetic circuit of length l (centimeters), uniform permeability μ, and uniform cross-section a (square centimeters), excited by a magnetomotive force nI (ampere-turns). The denominator is the reluctance of the circuit. If either the permeability or the cross-section is not uniform, this reluctance must be separated into parts, each having its own value for l, μ, and a. For example, let us calculate the ampere-turns nI required to produce an induction of 2200 gausses in the air between the poles of an electromagnet having an iron core of permeability 1500 and cross-section 40 square centimeters, the distance around through the iron being 78 centimeters and the single air-gap 6 centimeters wide. The required flux is 40 square centimeters $\times$ 2200 gausses = 88,000 lines or maxwells. The reluctance of the iron part of the circuit if 0.796×78 centimeters $\div 1500 \times 40$ square centimeters $= .001$ reciprocal centimeter, and that of the air-gap, 0.796×6 centimeters $\div 1 \times 40$ square centimeters $=$ 0.119 reciprocal centimeter (taking the permeability of air as 1); so that the total reluctance is 0.12 reciprocal centimeter. That is, 88,000 maxwells $= nI \div 0.12$ reciprocal centimeter, or $nI = 10{,}560$ ampere-turns. The result, though only roughly approximate, is sufficiently accurate for practical purposes. It is to be noted that since the air-gap contributes by far the larger part of the reluctance, the flux is very sensitive to variations in its width. (F.T.M., L.D.W.)

ELECTROMAGNETIC CONSTANT. The speed of propagation of electromagnetic waves such as light, in a vacuum, commonly denoted by c, appears so frequently in physical formulae that it has become one of the most important of all physical constants. This is especially true since the advent of multitudes of formulae of **relativity** involving this factor. The precise determination of its value has justly, therefore, engaged the attention of the ablest experimenters.

Early attempts to measure the speed of light failed from lack of any adequate conception of the magnitude of the quantity to be measured. The first inkling of the truth was arrived at by Roemer in 1675, when he surmised that certain irregularities in the observed recurrence of the eclipses of Jupiter's satellites were due to the fact that time is required for the light to traverse the varying distance from Jupiter to the earth. The value thus calculated was not far from those obtained by the best experimental methods. The first direct determination was made by Fizeau (1849), who sent out a beam of light between the teeth of a rapidly revolving cogwheel, to be reflected by a distant mirror and returned in time to be stopped by the next tooth. Foucault (1854) improved upon this by using a revolving mirror, the beam finally reflected from which, after its return from a distant fixed mirror, was deviated because of the slight rotation of the revolving mirror during the journey of the light out and back. This method was later perfected and refined by Michelson and others. Michelson's final value (1930) was 299,772 kilometers per second.

Aside from direct determinations of c as the speed of light, the constant has been deduced from measurements of standing electric waves on wires (Mercier, 1923), the result of which was 299,782 kilometers per second; and from the measured ratio of the abcoulomb to the c.g.s. electrostatic unit charge, the numerical value of which (according to Rosa and Dorsey, 1906) is 2.99781×10^{10}, giving $c = 299{,}781$ kilometers per second. A careful comparison of the results of the direct and the indirect methods by Edmondson (1934) and others has led to the suspicion that the former are subject to some unexplained periodic influence, possibly associated with changes in the long base lines used in the measurements. The agreement and constancy of the indirect results are considerably better. (L.D.W.)

ELECTROMAGNETIC FIELD. It is commonly stated that a wire carrying an **electric current** is surrounded by a **magnetic field** whose lines of force are circles with the wire as their axis. This statement implies that the magnetic field is directly traceable to the moving **electricity** in the wire. There is, however, another aspect of the matter. Each electric particle projects into space a radiating field of electric force, whose lines may be thought of as bristling out from the wire like the fur on the tail of an angry cat; and as the particles move along the wire the lines of force move with them. According to the theory of Maxwell, it is the motion of these lines of electric force that sets up the magnetic field transverse to them. More generally, a variable electric field, with moving lines of electric force, is always accompanied by a transverse magnetic field; and conversely, a variable magnetic field, with moving lines of magnetic force, is accompanied by a transverse electric field. The joint interplay of electric and magnetic forces here described is what is called an electromagnetic field, and is considered as having its own objective existence in space apart from any electric charges or magnets with which it may be associated. An essential feature of the theory is that this process, whatever it is, represents a flow of energy at right angles to both electric and magnetic components. The flux density of this energy (corresponding to the intensity of radiation) is represented by what is known as the Poynting vector. **Electromagnetic radiation** is, on this theory, the propagation of these electric and magnetic stresses through space with the speed of light, somewhat as the much slower waves of elastic stress are propagated through steel. The conditions in an electromagnetic field are expressed mathematically by the well-known **Maxwell's equations.**

When an electric charge is set into motion, it builds about itself an electromagnetic field, and this implies a distribution of energy throughout space. The density of this energy at any point of the field is proportional to the product of the electric and magnetic **vector** components and the sine of the angle between them (vector product). The total field energy can be obtained by suitable integration, and is greater than that of the purely electric field of a stationary charge. Maxwell's theory treats this excess as kinetic energy, thus endow-

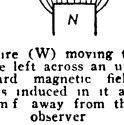
ing the moving charge with an "electromagnetic mass" and an "electromagnetic momentum" inherent in its electrical character. That this may be the nature of all mass and momentum at once suggests itself when we consider the electrical constitution of matter, discovered since Maxwell's time (L D W)

ELECTROMAGNETIC INDUCTION Probably the most noteworthy of the many scientific contributions of the renowned Michael Faraday was his discovery in 1831 of electromagnetic (or more properly magneto-electric) induction As exhibited in the usual experimental arrangements, this phenomenon is the setting up, in a circuit, of an **electromotive force** by reason of the variation of the magnetic flux linked with the circuit, the magnitude of that electromotive force being, as Faraday found, proportional to the rate at which the flux through the circuit, or the "linkage," varies If the flux linkage with the circuit, in maxwell-turns, is expressed by $N\phi$ (the actual flux, ϕ, times the number of turns, N), the electromotive force generated by its variation, in volts, is

$$E = \frac{N}{10^8}\frac{d\phi}{dt}.$$

(See **Volt**) The electromotive force is positive (counter-clockwise) when $\frac{d\phi}{dt}$ is positive, that is, when the flux is increasing, negative when it is decreasing, as viewed by one looking in the direction of the magnetic induction

Another aspect of the matter is that if a conductor moves through a magnetic field, or if a magnetic field sweeps over a conductor, in such a way that the conductor cuts across the lines of force, the electricity in the conductor experiences forces at right angles to the field and to the (relative) motion More general still is the Maxwell concept that when magnetic lines of force move sidewise, their movement results in an electric field at right angles to the magnetic lines and to their motion (See **Electromagnetic Field**)



Wire (W) moving to the left across an upward magnetic field has induced in it an e m f away from the observer

Faraday's discovery was almost accidental Happening to thrust a bar magnet into a coil connected with a **galvanometer**, he noted a momentary deflection of the needle If the north pole is thrust downward into the coil, so as to increase the flux linked with the coil, the current will be counter-clockwise as viewed from above, and reverses on drawing the magnet out again

The far-reaching consequences of this simple observation can hardly be overestimated It was the forerunner of the invention of electric generators and alternators, of the original Bell telephone, of the **induction coil**, of the transformer, of the induction motor, of **magnetic damping** devices, and of many other electric appliances It is the basis of **Lenz's law** and of the **Wilson experiment**, and the explanation of eddy currents The volt and the **henry** are definable in terms of it The phenomenon is called mutual induction when the variation of current in one circuit causes a variation of magnetic flux through, and hence an electromotive force in, another coupled circuit It is a curious fact that the linkage through one circuit A due to unit steady current in a neighboring circuit B is equal to the linkage through B due to unit current in A, hence the mutual inductance of two circuits is the same, whichever is the primary circuit If the circuits are closely coupled and have high self-inductance, and if an alternating electromotive force E be applied to A, the resulting alternating current induces an electromotive force in B approximately equal to $\frac{n_B}{n_A}E$; in which N_A and N_B represent the numbers of turns in the respective circuits The principle is utilized in induction coils and in potential transformers (L D W)

ELECTROMAGNETIC MASS. Electromagnetic Field.

ELECTROMAGNETIC RADIATION. A century ago light was believed to be a transverse wave motion in an **ether** behaving like an elastic solid Intensive study of the **electromagnetic field**, however, led James Clerk Maxwell (1873) to substitute electric and magnetic for elastic forces in the theory of light propagation According to his view, light is the result of vibrating electric charges These set up alternating **electric** and **magnetic fields** at right angles to each other and to the direction of propagation, which pass on the energy from one portion of the ether to the next as an electromagnetic wave (Poynting's theorem states that the rate of this energy transfer is proportional to the product of the electric and magnetic intensities) The theory was very successful in explaining many of the electrical and magnetic properties of light, such as the **Faraday effect** and the **Kerr effects.**

Maxwell suggested that it should be possible to produce waves of much longer wave length than light by causing electricity to oscillate in a conductor This was a forecast of the **Hertzian radiation,** upon which radio transmission depends, and which exhibits many of the characteristics of light, such as reflection, refraction, diffraction, interference, polarization, etc, but on a gross scale Other researches showed that the **infrared** and **ultraviolet** radiations have these same properties It was therefore natural to classify them together as the same phenomenon in different frequency ranges **X-rays** for a time could not be identified with this group, but their diffraction by crystals finally demonstrated their wave character and they now take their place next to the ultraviolet Meanwhile the **quantum theory** put a new aspect on the whole matter, and incidentally added the **gamma rays** to the radiation family The table below gives the approximate wave-length ranges of these various types of radiation Whether the very penetrating **cosmic rays** contain radiation of still higher frequency remains to be determined See also **Thermal Radiation.**

TABLE OF ELECTROMAGNETIC RADIATION

Type of Radiation	Approximate Range of Wave Length (in Centimeters)
Gamma Rays	10^{-10} to 10^{-9}
X-rays	10^{-9} to 10^{-7}
Ultraviolet Radiation	10^{-7} to 4×10^{-5}
Visible Light	4×10^{-5} to $7\ 7 \times 10^{-5}$
Infrared	$7\ 7 \times 10^{-5}$ to 0 4
Hertzian Radiation	0 4 to 3×10^{6}

(L D W)

ELECTROMAGNETIC UNITS. Electric and Magnetic Units.

ELECTROMAGNETISM. The pioneer discovery of the magnetic effect of the electric current was made by Oersted at Copenhagen in 1820 In experimenting with battery currents, he happened to bring a compass needle near a wire in which there was an electric current, and noted that the needle was deflected Such a wire is surrounded by a magnetic field so that, to one looking along the wire in the direction from the positive to the negative battery-terminal (the so-called "direction of the current"), the direction of the field, as indicated by the north pole of the compass needle, is clockwise (Ampère's rule).

If the wire carrying the current is placed in a magnetic field perpendicular to its direction, this field reacts

with that due to the current in such a way as to give the wire a lateral thrust, perpendicular to both the wire and the field in which it is placed For a wire of length l (centimeters) carrying current I (amperes) and placed across a field of intensity H (oersteds), this lateral force is given by the equation $f = HlI/10$ (dynes); which follows from the definition of the **ampere**. An electric motor is driven by forces thus produced

If the wire is bent into a circular loop of radius r (centimeters), still carrying current I (amperes), there is produced at its center, perpendicular to the plane of the loop, a magnetic field of intensity $H = \pi I/5r$ (oersteds) This, and the statement in the preceding paragraph, may be shown to be interdependent If more loops are added, forming a coil of n equal turns close together, the resulting field is n times as great By winding the n turns along a cylinder, forming a "helix" of radius r and axial length a, one obtains something greatly resembling a bar magnet, the ends of the helix corresponding to the poles The field intensity at the center of the axis of this helix (without any core) is

$$H_o = \frac{2\pi nI}{5\sqrt{4r^2 + a^2}} \quad \text{(oersteds)}.$$

If we now insert an iron core, we have an **electromagnet**, and the helix supplies the magnetomotive force nI ampere-turns for a **magnetic circuit** composed partly of iron and partly of air

More general calculations of electromagnetic effects are based up **Ampère's law**, the **Biot-Savart law**, and **Maxwell's equations**. (L D,W)

ELECTROMETERS Electroscopes and Electrometers

ELECTROMOTIVE FORCE. Various means have been discovered whereby **electricity** may be propelled against any opposition such as the **resistance** of a conductor or the electromagnetic reaction of a motor. Thus we have batteries, generators, thermels, photovoltaic cells, etc , each of which has this electrical driving influence called electromotive force The process of driving electricity against opposition requires the expenditure of energy The electricity must have work done on it, and it, in turn, does work on something else In an automobile headlight circuit, the electricity is able to do work on the lamp because, as it passes through the battery it receives a supply of potential energy The **electric potential** where it emerges from the battery is therefore different from that at the entrance, and it is for this reason that there is a current through the lamp The measure of the electromotive force of the battery is the work done on each unit of electricity as it passes through the battery If this work is one joule per coulomb, the electromotive force is one **volt**. Frequently electromotive force is identified with difference of potential This is permissible when the electricity gives up none of the energy while it is being received, so that the resulting potential difference does actually correspond to the accession of energy But the terminal potential difference of a generator and its electromotive force are in general not equal (See **Electric Circuits**) And it would be perfectly possible to arrange a circuit in which the electricity does work as fast as it receives energy and therefore moves along at constant potential, this is the case, for example, in a symmetrically placed, circular transformer secondary of one closed turn. (L D W)

ELECTROMOTIVE SERIES. Reactions involving Oxidation-Reduction.

ELECTRON. The first clear indication that electricity is composed of equal, elementary charges was afforded by **electrolysis** This gave, as the charge carried by a chlorine ion, 1.6×10^{-19} **coulombs** (negative); for the hydrogen ion, 1.6×10^{-19} coulombs (positive); for oxygen 3.2×10^{-19} coulombs (negative), for aluminum, 4.8×10^{-19} coulombs (positive), etc We here have a common factor 1.6×10^{-19} coulombs or 4.8×10^{-10} electrostatic units Sir J J Thomson (1897) succeeded in making a rough measurement of the charges carried by the **ions** of gases Millikan used a much more precise method It consists in measuring the speed with which a minute liquid drop is dragged along in an electric field when it picks up one or more stray air ions, the force acting on it being then deduced from the speed, and the charge, in turn, calculated from the force and the field intensity He found this charge to be always a multiple of 4.77×10^{-10} electrostatic units—the same as that revealed by electrolysis

Cathode rays and the beta rays from **radium**, when subjected by Thomson to measurement by a type of **mass spectograph** method, were found to be composed of particles having a negative charge of this value and a mass of about 9×10^{-28} gram This mass is only about 1/1847 that of the lightest atom known,—hydrogen For many years, no other particle was discovered having a mass comparable with it The name "electron," suggested by Johnstone Stoney, is now given to any negative particle of this charge and mass, regardless of its origin There is every evidence that not only are cathode and beta rays composed of electrons, but that swarms of these particles pervade all matter and play an important part in many physical processes such as **electric conduction, thermal conduction, magnetism, photoelectric phenomena, thermionic phenomena**, the emission of light, etc , as well as in chemical reactions

In recent years it has been necessary to modify the concept of the electron as a mere electric particle and to recognize that it has wave characteristics, with a frequency and a wave length According to **wave mechanics**, an electron traveling with speed v is associated with a "de Broglie wave" train of wave length $\lambda = h/mv$ (in which m is the electronic mass and h is Planck's constant), traveling with a speed greater than the speed v of the electron or even that of light, c, and equal to c^2/v This concept gives the same frequencies for radiation emitted by atoms as the older Bohr theory (See **Davisson-Germer Experiment.**) (L D W)

ELECTRONICS. The activity and the control of **electrons** have in recent years developed into an important field of physical science, called electronics **Cathode rays, thermionic phenomena**, and **photoelectric phenomena** are separately treated elsewhere, as are also **electric conduction, thermoelectric phenomena**, and the **Hall effect** and allied effects in metals

It was early learned that cathode rays are deflected by either a magnetic or an electric field This has lately been utilized in various devices dependent upon the control of electronic motion, such as the **oscillograph** and the "electron gun" (a negatively charged tube with a source of electrons at one end) The fundamental facts are

(1) An **electric field** accelerates a free electron in the direction antiparallel to the electric intensity and with a force equal to $10^7 Xe$ (dynes), in which X is the intensity in volts per centimeter and e the electronic charge, in coulombs The acceleration is therefore $10^7 Xe/m$, where m is the electronic mass Since for an electron the **charge-mass ratio** e/m is 1.77×10^8 coulombs per gram, the acceleration of an electron in a field of intensity X (volts per centimeter) is $1.77 \times 10^{15} X$ (centimeters per second per second)

(2) If there is a component X of the field at right angles to the electronic motion, the electron moving with speed v (centimeters per second), follows a curve whose radius of curvature is $r_X = 5.66 \times 10^{-16} v^2/X$ (centimeters)

(3) A magnetic field produces no acceleration in its own direction, but if there is a component of it, H (oersteds), at right angles to the electronic motion, the electron is deflected at right angles to both its motion and to the component H, following a curve of radius $r_H = 5\,66 \times 10^{-8} v/H$

By designing electrodes and coils or magnetic pole-pieces so as to produce non-uniform electric or magnetic fields in various desired configurations, it has been found possible to act upon streams of electrons very much as lenses and optical instruments act upon rays of light, bending them, diverging them, or converging them to a focus **Infrared** images formed on a photosensitive cathode give rise to an emission of electrons which, directed by "electron lenses," produce a visible image on a fluorescent screen We thus have "electron microscopes" and "electron telescopes", indeed, a whole new field of "electron optics" (L D W)

ELECTRON OPTICS. Electronics.

ELECTRON-VOLT. This is a convenient unit of energy for calculations in **electronics** and in connection with **ionization** or excitation of atoms or molecules When an electric charge e is transferred from a region where the **electric potential** is V_1 to one where the potential is V_2, its potential energy changes by an amount equal to $e(V_1 - V_2)$ If the charge e is the electronic charge $1\,591 \times 10^{-19}$ **coulomb** (as it is when the transferred particle is an **electron**, a **proton**, a **positron**, etc), and if the potential difference $V_1 - V_2$ is one **volt**, the corresponding change in energy is equal to $1\,591 \times 10^{-19}$ **joule** or $1\,591 \times 10^{-12}$ erg, and is called an electron-volt Thus if a doubly ionized positive oxygen molecule moves in an electric field through a potential-drop of 500 volts, it receives $2 \times 500 = 1000$ electron-volts or $1\,591 \times 10^{-9}$ erg of energy, and since the mass of the oxygen molecule is about $5\,28 \times 10^{-23}$ grams, this energy would give the molecule, if unimpeded, a speed of about $7\,76 \times 10^{6}$ centimeters per second or 48 1 miles per second Careless writers often abbreviate electron-volt to volt, a practice which should be discouraged (L D W)

ELECTROPHORUS. The simplest of all **static machines**, devised by Volta in 1816 It consists of a slab of some resinous substance, such as sealing wax or vulcanite, which is negatively charged by rubbing with fur A metal plate provided with an insulating handle is placed upon the electrified slab The contact is localized at a few points, so that instead of taking the negative charge off the slab, the metal plate becomes charged by induction, positively on the under side and negatively on the upper The negative induced charge is now removed by grounding with the finger, and upon being lifted by means of the handle, the plate becomes positively charged all over, often strongly enough to yield bright sparks Very little of the negative charge on the slab is removed in this process, and it may thus be used over and over to induce an indefinite number of positive charges The energy is of course furnished by the operator in pulling the metal plate away from the slab If a slab of glass is used, and rubbed with silk, it becomes positive and the induced charges on the plate are then negative The instrument is useful in lecture-table demonstrations, in charging electrometers, etc (L D W)

ELECTROPLATING. The coating of an object with a thin layer of some metal through electrolytic deposition is known as electroplating (See **Electrochemistry**, also **Reactions Involving Oxidation-Reduction**) The process is widely used in numerous industries, either for the purpose of rendering a lustrous or non-corrosive finish on some article, or, as in electrotyping, being the principal part of the process In electroplating, the general object is to employ the article to be plated as the **cathode** in an **electrolytic** bath composed of a solution of the salt of the metal being plated. The other terminal, the **anode**, may be made of the same metal, or it may be some chemically unaffected conductor A low voltage current is passed through the solution, which electrolyzes and plates the cathodic articles with the metal to the desired thickness In this way table utensils are **silver** plated, various parts are made weather-proof by **cadmium** or **chromium** plating, and a high finish may be imparted through **nickel** plating **Copper**, **zinc**, and **gold** are also plated As the plating proceeds, the strength of the solution must be kept up by the addition of crystals of the plating salt, or a renewal of the anode if it is of the plating metal A firm bond between the anode and the deposited metal is to be secured when the two metals are of a type which tends to alloy If this is not the case, some intermediate metal, which will alloy between the base and the plate, is first deposited For example, in silver plating, the iron would otherwise form a poor bond with the silver, so a thin layer of copper is first deposited on it

Because of the excellent conducting properties of a metallic salt solution, only a low voltage is required As this must be direct current, the process of electroplating calls for a supply of current from special low voltage direct current generators The voltage will be of the order of six volts or less between anode and cathode

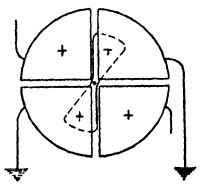
Some of the solutions used to plate various metals are as follows for silver or gold plating, double **cyanide** of the metal and **potassium**, copper plating, copper sulfate, nickel plating, nickel ammonium sulfate (See also **Galvanizing**) The articles to be plated must be thoroughly and effectively cleaned of all grease and dirt by washing in caustic or acid solutions While the above is a brief outline of the process of electroplating, in commercial operations there are many troublesome angles which would not be suspected from the foregoing Irregularity of the plate, poor surface graining, "trees," insufficient bond, and other troubles creep in The overcoming of these requires the use of various expedients, such as careful control of temperature, or the addition of certain colloids and other compounds which have been found effective in preventing formation of defects on the plated articles

A particular and specialized branch of electroplating is the preparation of plates from printers' type, artists' engravings, etc This art is known as electrotyping, and is an important phase of electroplating To make a book plate, for example, melted wax is run over the printers' type as it is locked up in its frame, so that an impression of the type is made in wax The surface of this wax impression is then made conducting by coating it with **graphite** This is then put in an electroplating bath of copper sulfate, and a thin shell of copper built up over the wax mold The shell can then be separated from the mold and backed up with type metal to give it body Finally it is mounted on a wooden block for rigidity (F T M)

ELECTROSCOPES AND ELECTROMETERS.

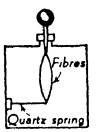
These are instruments for detecting small charges of **electricity**, or for measuring small voltages, or sometimes, indirectly, very small **electric currents** One of the earliest sensitive electroscopes consists of two narrow strips of gold-leaf hanging together in a glass jar Upon being charged, they stand apart on account of their mutual repulsion One leaf may be replaced by a stiff strip of brass, so that only the remaining leaf can move The Wilson electroscope has a single gold-leaf which, on being charged, is attracted by a grounded metal plate tipped at such an angle as to give maximum sensitivity If the movement of the gold-leaf in an electroscope is observed through a microscope whose ocular is provided with a calibrated scale, the instrument becomes an electrometer, capable of measuring potential differences in microvolts (Some forms of electrostatic **voltmeter** operate on the same principle) If the **capacitance** of the charged system is known, the rate of

movement of the electrometer index may be used to measure the current from the discharging body, ionization currents are often thus measured.



Quadrants and strip of quadrant electrometer

The quadrant electrometer has a thin, oblong, metal plate suspended horizontally in the interior of a flat, circular metal box cut into four quadrants. One pair of opposite quadrants and the suspended strip are connected to the source of potential, the other pair of quadrants is grounded This causes the strip to turn toward the grounded pair against the torsion of the suspending wire Several electrometers have been designed, depending upon the lateral deflection of a lightly stretched, silvered or platinized quartz fiber, they are called string electrometers The Wulf electrometer employs two such fibers side by side, on being charged, they bulge apart The displacement of the fibers is observed in a micrometer microscope Some of the special electrometers used for work with **cosmic rays** are of this type Recently the thermionic vacuum tube (See **Triode**) has been adapted to the amplification of exceedingly feeble discharge currents, thus serving as an electrometer (See **Capillary Electrometer**) (L D W)



Quartz fiber electroscope or electrometer

ELECTROSTATIC UNITS. Electric and Magnetic Units.

ELECTROSTATICS. While moving **electricity** has certain properties peculiar to its motion (See **Electric Currents, Electromagnetism**), in electrostatics we are concerned with phenomena exhibited by electricity whether in motion or at rest The outstanding elements of the subject are electric charges, electric fields, electric induction in conductors, and electric polarization in dielectrics

Owing to the tremendous mutual repulsion of all electricity for electricity of the same kind, it is impossible to gather together any considerable quantity of free electricity, positive or negative, in a limited space To place a single coulomb of either sign on a metal sphere 10 centimeters in diameter would require 4.5×10^{17} ergs of energy, equal to continuously running output of a 100-horsepower motor for a week, and its sudden release would rival the explosion of a carload of dynamite But we can collect and experiment with very small charges It is found that their attractions and repulsions obey **Coulomb's law** of inverse squares, and are also definitely dependent upon the **dielectric constant** of the surrounding medium Faraday showed that any charge, imparted to a conductor, at once seeks the outside surface and so distributes itself there as to produce no influence anywhere inside The **electric potential** of such a conductor is uniform both over its surface and throughout its interior

The space outside in the neighborhood of the charge is, however, an electric field, as shown by the fact that a small charged body placed anywhere in it is urged by a definite force in some definite direction. Such a field may be mapped out by lines of force as in the case of a **magnetic field** (See **Fields of Force**) The electric intensity at any point of an electric field is measured by the force exerted upon a free unit charge placed at that point, and its direction is that of the force on a positive charge.

If a pair of equal, opposite charges at a fixed distance apart, called an "electric dipole," is placed in an electric field, it experiences in general a torque (like a bipolar magnet in a magnetic field). The maximum torque thus produced by a field of unit intensity is called the "electric moment" of the dipole, its magnitude is the product of either charge by the distance between them

When a neutral conductor is placed in an electric field, it develops charges on opposite sides, the positive charge being on the side toward which a free positive charge is urged The conductor has thus acquired an electric moment This is thought to be due to a shifting of the **electrons** in the conductor until the region inside the conductor again attains the condition of zero intensity and uniform potential (See **Electric Screening**), and the process is called electric induction The **electrophorus**, for example, utilizes this principle, as do other **static machines** When a concentrated charge is brought near a large conducting surface, the charge thereby induced on the latter has in some respects the effect of a second concentrated charge, of opposite sign to the first, and lying behind the conducting surface, which gives rise to the idea of an "electric image," sometimes useful in electrostatic calculations

If the object placed in the electric field is a dielectric or non-conductor, while there is no true induction, something like a stress, called an **electric polarization**, develops within the dielectric This condition is the essential feature in the operation of a **condenser**, and its existence profoundly affects the **capacitance** of the conductors whose charges are responsible for the field (L D W)

ELECTRUM. Electrum is a native alloy of **gold** and **silver** in which the latter metal may be present in quantities up to 40% Electrum from the Urals is said to carry 20% **copper** The color of electrum is a pale yellow or yellowish white and the name is derived from the Greek word mentioned in the Odyssey, meaning a metallic substance consisting of gold alloyed with silver This same word was also used for the substance **amber**, doubtless because of the pale yellow color of certain varieties (E S C S)

ELEMENT, CHEMICAL. Chemical Composition

ELEMENTARY CHARGE. Electron.

ELEMENTARY QUANTUM OF ACTION. Planck's Law.

ELEPHANT. Mammalia, Proboscidea The largest existing land animals Characterized by massive structure and by the elongation of the nose and upper lip to form a long prehensile proboscis or trunk The two upper incisors develop into long tusks in the male and the broad grinding molar teeth grow into position gradually as they are worn off during the life of the animal

Two species of elephants are recognized, the Indian, *Elephas maximus*, and African, *Loxodonta africana*. The former averages eight to nine feet in height and the latter about ten feet, although occasional specimens of both species considerably exceed these figures The African elephant has much larger ears than the Indian and its tusks average somewhat heavier

The Indian elephant is tamed for use as a beast of burden and for handling heavy materials, such as timbers It does not breed freely in captivity, hence wild herds are the source of supply The animals are caught or trapped by various methods

Elephant tusks are the chief source of ivory, single tusks running from ninety to almost two hundred pounds in weight (A W L)

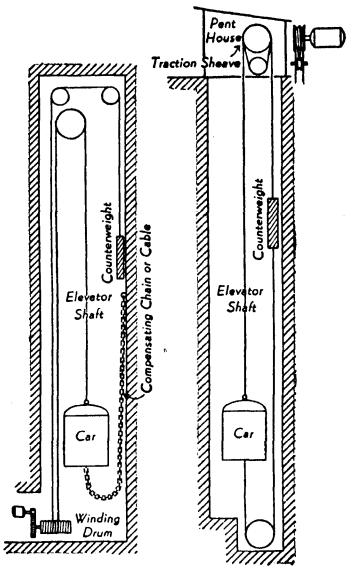
ELEPHANTIASIS. Filariasis.

ELEPHAS. Fossil mammals.

ELEVATORS. Elevators are hoists for lifting passengers and freight within the confines of a building, usually by means of a car operating vertically in an

elevator well—an open vertical shaft extending from top to bottom of the building. The direct acting hydraulic elevator with a long **piston** working in an upright **cylinder** set deep in the ground, carrying on top of it the car, has been superseded by electrically driven elevators because it had limitations as to height of the building that it could serve, and operating speed.

The electric elevator may be of the winding drum type, or of the traction sheave type. Both of these are



Elevator types.

illustrated in the accompanying figure. The winding drum elevator has a drum with spiral groove on its face, on which is wound a turn or two of wire rope. The ends of this rope are connected respectively to the counterweight and to the car. In actual practice two ropes are attached to each, this having the advantage of smaller rope size, permitting greater flexibility. The counterweight moves in a direction opposite to the car, and has a mass sufficient to balance the weight of the car plus from 30% to 40% of its maximum live load. The winding drum is driven by an electric motor through a reduction gear consisting of helical gears, or worm and spur gears. The reduction on freight elevators is larger than passenger elevators, since they are required to carry heavier loads, and high speed is not as essential. Since the rope winds around the winding drum, whose surface is grooved, it moves back and forth on the surface of the drum as the elevator is operated, and the face of the drum then is proportional to the height of the building. This limits the height to which winding drum elevators can be applied, and the high lift, high speed passenger elevators necessary for tall office buildings are of the traction sheave type, also illustrated.

The car of a traction elevator is moved by friction existing between traction sheave and rope. A secondary, or idler sheave, near the traction sheave, provides for the return of the rope around the traction sheave a second time, as this has been found necessary in order to develop the high degree of friction required. The traction sheave may be used without reduction gearing between motor and sheave. The gearless traction elevators are driven by large slow-speed motors having the traction sheave mounted on the same shaft with armature and brake pulley. These electric elevators may be used in the tallest buildings, since the face of the traction sheave is independent of building height. The motor and sheave must be mounted atop the elevator well. Elevator speeds, formerly limited to 100 to 200 feet per minute, have, with the gearless traction type, been advanced as high as 1000 feet per minute. (F.T.M.)

ELK. Mammalia, Artiodactyla. In European usage, *Alces*, the animal called the moose in North America. In American usage, *Cervus*, a large **deer** of the western and northern parts of the continent, also called the wapiti. (A.W.L.)

ELLIPSE. An ellipse is one of the class of curves called **conic sections**. It may be obtained by cutting a right circular **cone** by a plane which cuts all the elements of the cone but which is not perpendicular to the axis of the cone.

An ellipse is the **locus** of a point which moves so that the sum of its distances from two fixed points remains constant. The fixed points are called the foci, the point midway between them is called the center. The line through the foci and the line through the center perpendicular to the preceding line are axes of symmetry, and

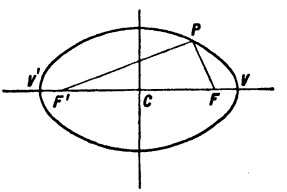


Figure 1. Ellipse.

the curve is symmetric about the center. See Figure 1. The line through the foci cuts the curve in two points called the vertices; the segment (or length) jointing the vertices is called the major axis; the distance between the points where the line through the center perpendicular to the line through the foci cuts the curve is called the minor axis. The major axis is equal to the constant sum of the focal radii in the definition of the curve.

The length of the semi-major axis is usually denoted by a, and the length of the semi-minor axis by b; the distance between the center and a focus is usually denoted by c.

The chord through either focus perpendicular to the major axis is called the latus rectum (or focal width) of the ellipse.

The eccentricity of the ellipse is the ratio $c/a = e$ of the distance between center and focus to the semi-major axis; it is a proper fraction ($e < 1$). It determines the shape of the curve; if e is near 0, it is nearly circular, and if e is near 1, it is elongated (narrow).

The standard equation of an ellipse in **rectangular coordinates** is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1,$$

where a and b are the semi-major and semi-minor axes, respectively, and the center is at the origin and the major axis is along the X-axis.

The relation between the semi-axes a and b and the distance c between center and focus is $b^2 + c^2 = a^2$.

The two lines $x = \pm \frac{a}{e}$ are called the directrices of the ellipse $\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$. They have the property that the ratio of the distance of any point on the ellipse from a focus to

the perpendicular distance of the point from the corresponding directrix is equal to the eccentricity

The equation $\frac{(x-h)^2}{a^2}+\frac{(y-k)^2}{b^2}=1$ represents an ellipse with center at (h, k) and axes of symmetry $x=h$ and $y=k$

The ellipse may be constructed geometrically in several ways

One method is the following, by continuous motion Place two tacks in a drawing board at the foci F and F' and wind a string about them as indicated in Figure 2 If a pencil is placed in the loop FPF' at the point P and is moved so as to keep the string taut, then P describes an ellipse If the major axis is to be $2a$, the length of the loop FPF' must be $2a+2c$, where $2c$ is the distance between the foci

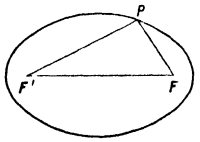


Figure 2
Construction of ellipse

A construction by ruler and compasses is as follows (Figure 3) Draw circles on the major and minor axes AA' and BB' as diameters From the center O draw any radius intersecting these circles in M and N respectively From M draw a line MR parallel to the minor axis, and from N a line NS parallel to the major axis These lines will intersect in a point P on the ellipse

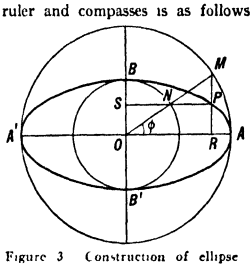


Figure 3 Construction of ellipse

The angle AOM is called the eccentric angle for the point P The two circles are called the major and minor auxiliary circles

The simplest **parametric equations** of an ellipse are.

$$x = a\cos\phi, \quad y = b\sin\phi,$$

where ϕ is the eccentric angle of the point $P(x, y)$, and a and b are the semi-axes of the ellipse

The equation of the **tangent** to the ellipse $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ at the point (x_1, y_1) is $\frac{x_1x}{a^2}+\frac{y_1y}{b^2}=1$

The equation of the tangent with slope m to the ellipse $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ is $y=mx\pm\sqrt{a^2m^2+b^2}$

The area of an ellipse is πab, where a and b are the semi-axes

Some of the applications of the ellipse are.

The orthogonal projection of a circle on a plane oblique to the plane of the circle is an ellipse

Elliptical gears are used in machines, such as hay presses and power punches, where a slow, powerful motion is needed in a part, only, of each revolution

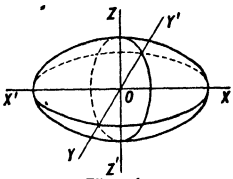
The arches of stone and of concrete bridges are frequently constructed in the form of semi-ellipses

The **orbits** in which the **planets**, including the earth, revolve around the sun, are ellipses.

A crescent, such as the crescent **moon**, is bounded by a semi-circle and a semi-ellipse (L L S)

ELLIPSOID. The **surface** represented in **rectangular coordinates** by the equation $\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1$ is an ellipsoid, it is one of the **quadric surfaces.** It has a center at the origin, three principal axes (of symmetry) along the coordinate axes, all elliptic sections, and semi-axes a, b and c It is a closed surface.

The volume of an ellipsoid with semi-axes a, b, c is $\frac{4}{3}\pi abc$.



Ellipsoid

If $a=b$, one set of sections is circles, and the surface is called an ellipsoid of revolution, which may be generated by revolving an ellipse about its major or minor axis

The ellipsoid of revolution obtained by revolving an ellipsoid about its minor axis is called an oblate spheroid, the one obtained by revolving about the major axis is called a prolate spheroid (L L S)

ELLIPTIC COORDINATES. Elliptic coordinates are three numbers which determine the position of a point in space, they are used in certain special types of problems of geometry and mathematical physics

The **surfaces** represented by the equation in **rectangular coordinates**

$$\frac{x^2}{\lambda-a}+\frac{y^2}{\lambda-b}+\frac{z^2}{\lambda-c}-1=0,$$

where λ is a variable parameter, with $a>b>c>0$, form a family of **confocal quadrics** Through each point (x, y, z) of space there pass three surfaces of the family The equation above has three roots $\lambda_1, \lambda_2, \lambda_3$ for λ for a given set of values of x, y, z These three roots $\lambda_1, \lambda_2, \lambda_3$ determine the point (x, y, z), and are called the elliptic coordinates of the point (L L S)

ELLIPTIC GEOMETRY. Non-Euclidean Geometry

ELLIPTIC HYPERBOLOIDS Hyperboloids

ELLIPTIC INTEGRALS AND FUNCTIONS.

Any **integral** of the type $\int R(x, y)dx$, where R is a **rational function** of x, y, and where y is a square root of a third or fourth degree **polynomial function** of x, is called an elliptic integral

These integrals may be expressed in terms of elementary functions and one or more of the following type forms of elliptic integrals

$$F(k,\phi)=\int_0^\phi \frac{d\phi}{\sqrt{1-k^2\sin^2\phi}} \qquad (0<k<1),$$

called the elliptic integral of the first kind in Legendre's form,

$$E(k,\phi)=\int_0^\phi \sqrt{1-k^2\sin^2\phi}\,d\phi \quad (0<k<1),$$

called the elliptic integral of the second kind in Legendre's form,

$$\pi(k,n,\phi)=\int_0^\phi \frac{d\phi}{(1+n\sin^2\phi)\sqrt{1-k^2\sin^2\phi}} \quad (0<k<1),$$

called the elliptic integral of the third kind in Legendre's form

The number

$$K=\int_0^{\pi/2} \frac{d\phi}{\sqrt{1-k^2\sin^2\phi}}$$

is called a complete elliptic integral of the first kind, and the number

$$E=\int_0^{\pi/2} \sqrt{1-k^2\sin^2\phi}\,d\phi$$

is called a complete elliptic integral of the second kind

In Jacobi's notation, $x=\sin\phi$, and the first two elliptic integral types become

$$F(k,\phi)=\int_0^x \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}},$$

with $$K = \int_0^1 \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}},$$

$$E(k, \phi) = \int_0^x \frac{\sqrt{1-k^2x^2}}{\sqrt{1-x^2}}\,dx,$$

with $$E = \int_0^1 \frac{\sqrt{1-k^2x^2}}{\sqrt{1-x^2}}\,dx.$$

The constant k is known as the modulus of the integrals, and the number k' defined by $k^2 + k'^2 = 1 (0 < k' < 1)$ is called the complementary modulus.

Tables of the elliptic integrals have been published.

If we put

$$u = \int_0^x \frac{dx}{\sqrt{(1-x^2)(1-k^2x^2)}}, \quad (-1 < x < 1),$$

this equation defines u explicitly as a function of x. The **inverse function** x regarded as a function of u is called the sine amplitude of u and is written $x = \sin \operatorname{am} u$ or $x = \operatorname{sn} u$. Two other functions are defined by $\sqrt{1-x^2} = \cos \operatorname{am} u$ or $\operatorname{cn} u$, and $\sqrt{1-k^2x^2} = \Delta \operatorname{am} u = \operatorname{dn} u$.

These three functions are type forms of elliptic functions.

An elliptic function in general is defined as a single-valued doubly periodic **analytic function of a complex variable**, whose only singularities in the finite part of the plane are poles. Any elliptic function can be expressed in terms of certain standard types of elliptic functions, of which the main types are those of Jacobi and those of Weierstrass. The Jacobi elliptic functions $\operatorname{sn} u$, $\operatorname{cn} u$, $\operatorname{dn} u$ have simple poles only, while the fundamental Weierstrass function $p(u)$ has double poles.

Elliptic functions are natural generalizations of the trigonometric functions and exponential functions, which are singly periodic functions. (L.L.S.)

ELLIPTIC PARABOLOID. **Paraboloids.**

ELLIPTIC POLARIZATION. **Polarized Light.**

ELONGATION. **Planetary motions.**

ELUVIUM. General term for unconsolidated, residual **sediments.** (R.M.F.)

ELYTRON. The front wing of an **insect**, modified to form a leathery or rigid wing cover which folds above the body and conceals the hind wings at rest. They usually meet in a straight line down the middle of the back. Elytra are characteristic of the beetles and earwigs. They are sometimes short, sometimes cover the entire posterior part of the body, and are sometimes united to form an immovable shield. (A.W.L.)

EMBIIDINA. A small order of rare **insects** which live in nests and galleries of silk under objects lying on the ground. The few known species are found in warm regions, including the southwestern United States. (A.W.L.)

EMBOLISM. The plugging of a blood vessel by a clot, or embolus, carried from some other part of the **circulatory system** by the blood current. Air embolism is a condition, rarely seen, caused by the introduction of considerable air into the vascular system. Fat embolism is embolism caused by oil or fat. In this condition death may result from the plugging of the capillaries of the brain or lungs. It is sometimes seen following fractures of bones—the fat escaping from the bone marrow. Pulmonary embolism is the plugging of the pulmonary arteries by a blood clot. This is usually fatal and occurs very suddenly, death resulting almost instantly or soon afterward. This condition may occur after phlebitis or infection of some vein of the body. When such an infection occurs, a soft clot forms in the vein. If a piece of this clot should become dislodged, it goes, in the normal course of circulation, toward the lung and thus may lodge in the pulmonary artery, which supplies the lungs. If the clot is not of sufficient size to obstruct this artery, it travels along the branches of the artery within the lung proper. Wherever it lodges in this arterial system, the clot shuts off the circulation to that portion of the lung supplied by that particular branch. This latter is not necessarily fatal, and the symptoms produced are in direct ratio to amount of lung tissue involved. Cerebral embolism is an embolism in the brain caused by a clot lodging in a branch of one of the blood vessels of the brain. Here again the symptoms produced depend on the part and amount of the brain involved, and on this depends whether death or paralysis, etc., result. This accident is known popularly as a stroke. (R.S.M.)

EMBRITTLEMENT. This is the rarest of all **boiler** "diseases," yet it cannot be said to be so rare as to be unimportant. A serious feature of embrittlement is that when failure occurs it may come as a disastrous explosion, because embrittlement affects the drums and its presence is not detectable except on minute scrutiny. Embrittlement is attributed to the presence of a certain concentration of sodium hydroxide in the absence of inhibiting agencies. The steel loses its toughness and cracks appear along the seams below the water line. They generally run from rivet to rivet, following the intercrystalline structure. In cases of embrittlement it has always been found that the feed water was high in sodium bicarbonate which broke down into sodium carbonate in the boiler and partially hydrolyzed. The reaction

$$Na_2CO_3 + HOH \rightarrow CO_2\uparrow + 2NaOH$$

assumes considerable proportions at the elevated temperature of the boiler water. Prevention of embrittlement consists of reducing the causticity or adding inhibiting agents such as sodium sulfate or phosphate. The A.S.M.E. recommendation consists of maintaining a ratio

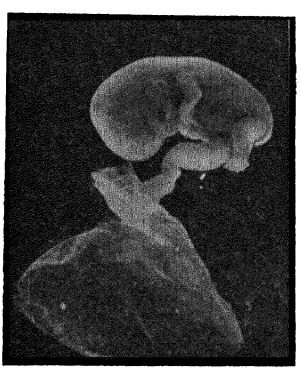
$$\frac{\text{sodium sulfate}}{\text{sodium carbonate}}$$

of 1 up to 150 pounds gauge pressure, 2 up to 250 pounds, and 3 for 250 pounds and over. No boilers meeting these ratios have experienced embrittlement. Recent developments have indicated that probably the more accurate expression for the inhibiting ratio is

$$\frac{\text{sodium sulfate} + \text{sodium carbonate}}{\text{sodium hydroxide}}$$

Embrittlement or cracking of metal need not be feared in boilers provided this ratio is maintained in excess of 2. (F.T.M.)

EMBRYO. The developing individual between the union of the germ cells and the completion of the organs which characterize its body when it becomes a separate organism.



Human embryo at six weeks. (Photo by Newton Miller.)

The term is difficult to limit because some development takes place after birth or hatching and in some species a considerable period of growth intervenes between the completion of the essential structures of the individual and its assumption of separate life In the latter stage the organism is called a fetus if it is a mammal, but this term is not applied to the similar period of birds and reptiles For the embryo in botany, See **Seed.** (A W L)

EMBRYOLOGY. The science which deals with the development of the individual from the union of the germ cells to the completion of its bodily structure Although the term **embryo** cannot be precisely limited, the science of embryology is concerned with all development prior to birth or hatching

Development of the fertilized ovum begins with the process of **cleavage.** Following cleavage a process of gastrulation gives rise to two or three **germ layers** and from this point the development of specialized tissues and organs goes on by gradual steps, all based on the subdivision and differentiation of many cells

The processes of change by which germ layers give rise to other structures are varied In some cases masses of cells grow out in solid protuberances from an existing source This process is called budding and is exemplified by the appearance of legs and other appendages on the surface of the body Other structures are developed by the pushing in or out of layers of cells If the new part pushes in the layer is said to invaginate, and if it pushes out, to evaginate Hollow organs may also be formed by the splitting of solid masses and parts may separate by splitting from such masses, either process is delamination A good example of evagination is the pushing out of a blind sac from the embryonic pharynx of vertebrates to form the respiratory system, and invagination is illustrated by the pushing in of ectoderm to form the stomodaeum which becomes the oral cavity in part The formation of the vertebrate excretory tubules as solid knots of tissue whose cavities arise by internal splitting is a case of delamination

The details of development of any species or group of animals are complex Vertebrate embryology has been worked out in great detail and is fairly uniform but the number of invertebrate forms is so great that their embryonic development cannot be concisely summarized

In the vertebrates, once the germ layers are formed their further development is the formation of organs and tissues and in some species **extraembryonic membranes,** with the exception of the mesoderm This layer gives rise to diffuse mesenchyme and its compact portions differentiate into three regions, the dorsal, intermediate, and lateral or ventral mesoderm The first subdivides into two longitudinal series of metameric masses, the mesodermal somites, flanking the middle line of the body where the notochord lies This skeletal primordium is independently derived from the same source as the mesoderm The lateral mesoderm splits to form an outer somatic layer associated with the body wall and an inner splanchnic layer which envelops the viscera The split forms the coelom or body cavity From this point the mesoderm, like the other germ layers, gives rise directly to organs of the body The organs and systems developed from each embryonic tissue are listed under **germ layers.**

In the field of experimental embryology an effort has been made to learn of the controlling factors in development by subjecting embryos and ova to various unusual conditions By exposure to chemical stimuli, unusual temperatures, radiation, and the effects of centrifuging, many abnormal results have been recorded. It is evident from these results that development, like the life of the organism, is conditioned by a delicate balance of environmental factors The response of inherited potentialities to this balance in the development of normal organic structure links embryology very closely with the subject of **heredity.**

It has become evident that one of the important factors in the embryological differentiation is the interaction between parts of the embryo which have come close to each other in the course of development This action is known as induction, the formation of a nervous system in the amphibian, for instance, being induced by the notochord The term organizer is also used in this connection (A W L)

EMBRYONIC FISSION. The subdivision of a single **ovum** at some stage in its development into parts which give rise to complete **embryos** Polyembryony

As a result of this process a single egg of many insects (parasitic **Hymenoptera**) and of some **rotifers** develops into several or many individuals (A W L)

EMBRYOPHYTA. All plants which are not **thallophytes** are sometimes grouped together and called embryophytes. It is characteristic of these plants that for a time at least the developing plant or **embryo** remains dependent on the tissue of the **gametophyte.** The embryophyta are also generally characterized by the existence of an **archegonium,** a multicellular female sex organ in which the egg is contained In the **angiosperms,** however, the reduction of the gametophyte has resulted in the loss of the archegonium

The embryophyta include all the **Bryophytes, Pteridophytes,** and **Spermatophytes.** (R M W)

EMBRYO SAC. Flower.

EMERALD. This beautiful green variety of the mineral **beryl** has been known since ancient times and always prized as a gem, both because of its color and relative rarity It is frequently cloudy or flawed, hence the expression "rare as an emerald without a flaw" The original source of emeralds seems to be the so-called Cleopatra's mines in Egypt, where in a range of low mountains about fifteen miles from the Red Sea, they are found in **schists.** The quality of these emeralds is not high, but there is much evidence of considerable workings in a former period

Although emeralds are found in the Urals and to some extent elsewhere the most important locality for emerald today is at Muso, Colombia, South America, about seventy-five miles northwest of Bogota These mines are believed to be in part at least the source of the emeralds which Cortez and the Spanish conquistadores ruthlessly seized and which were believed for a long time to have come from Peru

The word emerald is probably derived from the Persian (E S C S)

EMETIC. A substance or **drug** that induces vomiting, either by direct action on the stomach or indirectly by action on the vomiting center in the brain (R S M)

EMISSIVE POWER. Thermal Radiation.

EMPIRICAL DATA. Empirical Equations.

EMPIRICAL EQUATIONS. A table of pairs of values of empirical or statistical data may be represented graphically by plotting the corresponding pairs of values as **rectangular coordinates** (or **polar coordinates**) of points in a plane and joining these points by a broken line or by a smooth curve

The general problem in empirical equations is to find an equation which will represent the given data as accurately as possible The general form of the required equation may be known in advance from theoretical considerations, but in other cases nothing may be known about the form of equation in advance

If the given data are plotted as rectangular coordinates, and if the resulting points tend to lie along or very near a straight line, we may assume a linear law $y = mx + b$. To determine the coefficients m and b in this equation,

several methods are available; the method of average points, the method of average equations, and the method of least squares

The straight line law may be tested by use of the following theorem If the variable x has constant first differences Δx, (that is, differences between consecutive pairs of values of x), and y is a **linear function** of x, then y will have constant first differences Δy and conversely If the given table of data has the first variable at equidistant intervals, and if the first differences of the second variable are found by calculation from the table to be constant or very nearly constant, we may assume a linear law

In fitting a straight line to a set of empirical data by the method of average points, we first divide the set of points representing the data into two groups and find an average point for each group, i e , one whose coordinates are averages of the respective coordinates; then we find the equation of the line through these two average points

In the method of average equations, we substitute each pair of values of the empirical data in the assumed straight line equation $y = mx + b$, and thus obtain as many so-called observation equations as there are pairs of corresponding values. We then divide these equations into two groups as nearly equal in number as possible Then we add the equations of each group, thus obtaining two equations in m and b Solving these two equations for m and b gives the required linear law $y = mx + b$

The values of the coefficients obtained by the method of averages depend on the way the given points or the observational equations are grouped In accurate scientific work, the values of the coefficients are found by the method of least squares, this method may be somewhat longer than the method of averages

The method of least squares as applied to the linear law may be explained as follows Assume the required equation to be of the form $y = mx + b$, where m and b are to be determined Let (x_1,y_1), (x_2,y_2), , (x_n,y_n) be the given tabulated pairs of values of data Let (x_k,y_k) be any pair of values of the data, then corresponding to the value of x_k of x the corresponding value of y as calculated from the equation is $mx_k + b$, but the tabular value of y is y_k The difference between these two values of y, tabular and calculated, is $r_k = y_k - (mx_k + b)$, which is called the residual of the point (x_k,y_k) with respect to the line Corresponding to the n points there are n residuals Geometrically they represent the vertical distance between each point and the required line

Let us form the sum of the squares of these residuals: $r_1^2 + r_2^2 + \quad + r_n^2$, which is represented more briefly by the symbol Σr^2

The basic principle of the method of least squares in this case may be stated thus The values of m and b determined by the method of least squares are those that make the sum of the squares of the residuals Σr^2 as small as possible

It is found that the values of m and b that make Σr^2 a minimum are determined by the equations $\Sigma y = m\Sigma x + bm$, $\Sigma xy = m\Sigma x^2 + b\Sigma x$ To form these equations, we may proceed as follows· We write down two sets of equations The equations of the first set are formed by substituting the given pairs of values of x and y in the equation $y = mx + b$ The equations of the second set are formed by multiplying each equation of the first set by the coefficient of m in it. We obtain thus the following sets of equations·

$y_1 = mx_1 + b$	$x_1y_1 = mx_1^2 + bx_1$
$y_2 = mx_2 + b$	$x_2y_2 = mx_2^2 + bx_2$
$y_3 = mx_3 + b$	$x_3y_3 = mx_3^2 + bx_3$
etc.	etc

If we add the members of the equations in each of the two sets, we obtain two equations in m and b, which can be solved for these two unknowns, and these values put in the form $y = mx + b$ gives the required equation in the sense of least squares.

If the graph of the given data does not indicate a linear law, or if the test of the data by first differences does not show a linear law, it may be that the data may be fitted by a quadratic law This may be tested as follows.

If a variable x has constant first differences, and if the related variable y is a **quadratic function** of x, then y will have constant second differences $\Delta^2 y$ (that is, successive differences of the first differences Δy), and vice versa Hence, if $\Delta^2 y$ is found constant or nearly so, we may assume a quadratic law $y = ax^2 + bx + c$

If we decide that the given data may be fitted by a quadratic (or parabolic) law $y = ax^2 + bx + c$, we may determine the coefficients a, b, c by the method of averages or by the method of least squares.

In the method of average points, we divide the data into three groups nearly equal in number, and find three average points, one for each group Substituting the coordinates of these three average points in the above equation, we obtain three equations with three unknowns, which may be solved for a, b, c

By the method of average equations, we substitute the given data in the assumed equation, divide the resulting equations into three groups nearly equal in number, add the equations of each group, then solve the resulting three equations for a, b and c

In the method of least squares for the quadratic law, we proceed as follows Form three sets of equations, the first set being the equations obtained by substituting the given data in the general parabolic law equation $y = ax^2 + bx + c$, the second set is obtained by multiplying each equation of the first set by the coefficient of b in it, and the third set by multiplying each equation of the first set by the coefficient of a in it Add the corresponding members of each set of equations, obtaining thus three new equations in three unknowns a, b, c Solving these equations for a, b and c gives the coefficients of the required equation

If a linear or quadratic law does not fit the given data, we may try plotting the data on **logarithmic paper.** If the resulting points tend to lie on a straight line, an equation of the power law type $y = ax^n$ is indicated.

For, if we assume the law $y = ax^n$, and take logarithms, we obtain $\log y = \log a + n \log x$ Put $\log y = Y$, $\log a = A$, $\log x = X$, and the equation becomes $Y = A + nX$, a linear law, giving a straight line graph If X and Y (i e , $\log x$ and $\log y$) are plotted on ordinary squared paper, or if x and y are plotted on logarithmic paper, we should get a straight line The equation of this straight line may be found by one of the previous methods for the linear law, obtaining A and n Then a will be the anti-logarithm of A, and the coefficients a and n are known, which may then be substituted in $y = ax^n$.

If, when plotted on logarithmic paper, the data does not give a straight line, we may try plotting it on **semi-logarithmic paper;** if these points tend to lie on a straight line, an equation of exponential type $y = ae^{bx}$ is indicated

For, if we assume the equation $y = ae^{bx}$, and take (common) logarithms, we get $\log_{10} y = \log_{10} a + bx \log_{10} e$ Put $\log_{10} y = Y$, $\log_{10} a = A$, $b \log_{10} e = m$, and the preceding equation becomes $Y = A + mx$, a linear law Hence, if x and Y $(= \log y)$ are plotted on ordinary cross-section paper, or if x and y are plotted on semilogarithmic paper, we should obtain a straight line The equations of this straight line can be found by one of the previous methods for the linear law, giving A and m Then a may be found as the anti-logarithm of A, and b may be found from $m/\log_{10} e$ These values substituted in $y = ae^{bx}$ give the required equation

It may be in some cases that a polynomial law $y = a + bx + cx^2 + dx^3 + \quad .$ will fit the data better than any of the preceding types, the equation of lowest

degree is desired It is treated similarly to the quadratic law

Other forms of equations are sometimes useful The following forms may be reduced to the straight line law by suitable transformations

The law $y = a + bx^2$ may be reduced to a straight line law by the substitution $x^2 = X$, $y = Y$

The law $y = a + \frac{b}{x}$ reduces to the straight line law by the substitution $1/x = X$, $y = Y$

The law $y = \frac{x}{ax + b}$ can be written $\frac{x}{y} = ax + b$, so that if we put $x/y = Y$ and $x = X$, the equation becomes $Y = aX + b$, a straight line law (L L S)

EMPIRICAL PROBABILITY Probability.

EMPYEMA. A collection of **pus** in any cavity or organ of the body The term is generally used in describing a collection of pus in the **pleural** cavity This is a common complication of **pneumonia** In pneumonia a simple **pleurisy** with fluid develops which later may become infected, accompanied by formation of pus The treatment is surgical (R S M)

EMU, EMEU. Aves, Casuariiformes Large flightless herbivorous birds (**Aves**) of Australia They have very small wings but are fleet of foot

On some islands of the Australian region the emeus have been exterminated and in Australia itself they are said to be restricted to the wild interior and to be scarcer year by year The best known species is *Dromaeus novae-hollandiae* (A W I)

EMULSION. Colloids.

ENAMEL. Tooth.

ENANTIOMORPHISM. Isomerism.

ENCEPHALITIS (Inflammation of the brain) The causitive agents of this inflammation are injury, infection or the action of toxic substances on the brain tissue **Epidemic encephalitis** is considered elsewhere as a separate disease

Encephalitis may complicate any disease such as **syphilis, malaria, whooping cough, measles, scarlet fever, chorea, pneumonia, septicaemia, typhus,** and many others It may be caused by metals, (as lead encephalitis), carbon monoxide, Caisson disease, fracture of the skull with injury to the brain, etc

The symptoms may occur suddenly or gradually with lethargy, fever, headache and stiffness of the neck Often the temperature is excessively high **Paralysis,** deafness and other nervous manifestations are frequently present

The mortality is high in recognized cases, although many cases are not diagnosed, especially when of lesser degree After effects such as deafness, **epilepsy, dementia,** changes in personality, etc, are found in many cases that survive (R S M)

ENDEMIC. A term used in reference to a disease that is prevalent in a particular locality (See **Epidemic**) (R S M)

ENDIVE. *Cichorium endiva* **Composite Family.**

ENDOCARDITIS. Inflammation of the tissue that lines the various cavities of the **heart.** This infection may occur as part of a symptom complex of **rheumatic fever,** or as a complication of many acute infections, such as septicemia, due to the *Staphylococcus, Streptococcus, Pneumococcus, Gonococcus,* or *Influenza bacillus* Endocarditis is a complication that usually results fatally (R S M)

ENDOCARP. Fruit.

ENDOCRINE GLAND. A gland whose secretion is carried by the blood stream Also called ductless glands. These organs produce substances known as **hormones** which condition the action and development of other parts of the body either by activation or by inhibition

The principal ductless glands of the vertebrates are the thyroid, parathyroids, thymus, pituitary, pineal, adrenal or suprarenal, ovary and testis, and pancreas The first three develop as outgrowths of the **pharynx.** These endodermal parts lose their connections with the pharynx and become associated with mesodermal tissue in the adult The pituitary gland is made up of an anterior lobe derived from an ingrowth of ectoderm and a posterior lobe derived from the brain In the adult it is connected with the under side of the brain The pineal body is a protuberance on the dorsal surface of the brain The adrenals lie near the kidneys or in contact with them and consist of an outer cortex and an inner medulla, both endocrine in function The cortex arises from the lining of the body cavity and the medulla from cells of the sympathetic nervous system The ovary and testis are developed from mesoderm Although their primary function is the production of germ cells, they also produce hormones in some of their parts The pancreas is a digestive gland derived from and connected with the intestine Among its digestive cells are small islets of Langerhans which have no connection with its duct but produce a hormone

The action of these glands is considered under **hormone.** (A W L)

ENDODERM. Germ layers.

ENDOGENETIC. As used by geologists to denote processes originating within the earth (R M F)

ENDOMORPHISM. That phase of **contact metamorphism** which takes place in the intrusive **magma** rather than in the walls of the rock mass which it invades (R M F)

ENDOPRAGMAL SKELETON. An internal framework found in some **crustaceans** It is made up of **apodemes** derived from the exoskeleton (A W L)

ENDOPODITE. Biramous appendage.

ENDOPTERYGOTA. **Insects** whose wings are concealed beneath the integument of the **larva** during development Such insects have complete metamorphosis, hence this term is synonymous with **Holometabola.** (A W L)

ENDOSKELETON. Skeletal system.

ENDOSPERM Flower.

ENDOSTERNITE. A skeletal plate lying beneath the anterior part of the alimentary tract in some **crustaceans.** Mesodermal (See **Germ Layers**) in origin (A W L)

ENDOSTYLE. A groove lying in the median line of the ventral wall of the **pharynx** in the **tunicates,** lancelets (**Amphioxus**), and larval lampreys (**Cyclostomata**) It is ciliated (See **Cilium**) and secretes mucus Food particles swept into the pharynx are caught by the mucus and carried forward to peripharyngeal grooves which run around the pharynx to a dorsal median hyperbranchial groove In this groove the food is carried to the intestine

The thyroid gland of vertebrates evolved from the endostyle (A W.L)

ENDOTHELIUM. The delicate lining of the organs of **circulation** It is one cell in thickness and is continuous throughout the closed passages with the exception of the **sinusoids** The walls of capillaries are made up of little more than the endothelium. (A W.L)

ENDOTHERMIC REACTION. Thermochemistry.

ENERGY. Energy is probably to be regarded as the most fundamental of all physical entities, though within the past few years our concepts relating to it have undergone quite revolutionary changes.

From the elementary and older point of view, energy is thought of as an intangible something transferred to bodies of matter when **work** is done upon them, and delivered up by such bodies whenever they do work upon other bodies. Thus, let a free body be acted upon by a steady force of 6 pounds until it has moved from rest a distance of 100 feet in the direction of the force. The work thereby done upon the body is 600 **foot-pounds** and since the moving mass is now capable of doing 600 foot-pounds of work upon other bodies by collision or otherwise, we think of this 600 foot-pounds as something which has been transferred and conserved throughout the process.

Considerations of this kind have led, in the past, to regarding energy primarily as that which is thus communicated and conserved whenever work is done by one body upon another. But in the nineteenth century, Joule and others discovered the equivalence of heat and energy. And when it was established that light is a form of energy traveling through space apparently independent of any matter, it became necessary either to construct a dynamics for light and to invent an **ether** in which to carry on its operations, or else to accept energy, at least radiant energy, as having an objective existence of its own, coordinate with that of matter itself.

In the measurement of energy, we still adhere to the elementary concept and utilize its familiar relationship with the dynamic magnitude, work. We even express energy in work units; though there is today no more logical reason for doing so than for adhering to the old water-temperature **caloric** in measuring heat. Thus the practical energy units are, in pure physics, the **erg** or centimeter-dyne, in engineering, the foot-pound.

Whenever energy is obviously associated with the motion of masses of matter,—the form in which we sense its existence most readily,—it is called **kinetic energy.** But since work may be done in such a way as not to affect the motion of matter, but to alter its situation or condition in other ways (as when a battery is charged or a clock wound), we must also recognize the existence of latent or **potential energy.** Much of the activity going on in the material world involves the continual transformation of energy from one of these states to the other.

Early experimenters observed that when a **machine** is so constructed as to operate with negligible friction, the work done by the machine is equal to that done upon it. Thus, if a weight of 20 pounds is lifted 7 feet by means of a single movable pulley, the operator, though obliged perhaps to exert only 10 pounds of force on a cord, must draw that cord upward 14 feet. In each case the work done is 140 foot-pounds. The extension of this principle to a multitude of complex cases finally led to the doctrine of conservation of energy, recognized in various aspects by different physicists toward the middle of the nineteenth century. This doctrine, in concise form, states that the total quantity of energy in existence remains unaltered throughout all the changes which take place in the material universe. It is thus analogous to the earlier doctrine of the conservation of **mass.**

Modern research in **relativity** and atomic physics has cast some doubt upon the literal truth of both of these doctrines. Einstein, in studying the relativistic connection between matter and energy, arrived at the conclusion that energy, like mass, possesses inertia and gravitational attraction, in such degree as to make the unit of energy equivalent to $1/c^2$ units of mass (in which c is the speed of light); so that 1 gram of matter has the same inertia and gravitational attraction as c^2 ergs, or 8.986×10^{13} **joules,** of energy. Subsequent observation has supported not only this view, but the further theory that in certain circumstances matter may be actually converted into energy, and perhaps energy into matter, in the same ratio. Thus if the sun emits its radiant energy without drawing upon any source of supply other than that arising from the transformation of its mass, the Einstein **proper energy** principle leads to the conclusion that its mass must be diminishing at the rate of some 4,600,000 tons per second. If all the **stars** are likewise sacrificing their mass to keep up their radiation output, and if this energy is not somewhere recreated into matter, it is clear that the conservation doctrine is not universally valid, unless applied to the totality of both matter and energy together as a single entity. See **Available Energy.** (L.D.W.)

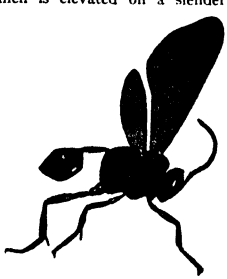
ENERGY LEVELS. Quantum Theory.

ENGINE. In common usage, the term engine is used widely for devices which produce motion. In stricter technical sense, an engine is said to transform energy, especially heat energy, into mechanical work. Among the prime movers, those in which the power originates in a piston and cylinder are classed as engines, while those with purely rotative motion are known as turbines. See **Diesel Engine, Otto Engine,** and **Steam Engine.** (P.T.M.)

ENOL. Tautomerism.

ENRICHMENT. Also "secondary enrichment." The term applied by students of ore deposits to the natural processes by which the lower levels of an ore deposit are enriched at the expense of the upper levels, or the original protore. Particularly applied to **lodes** in which the **sulfide** ores have been concentrated by the leaching of the upper levels of the **vein** and redeposition below the **groundwater** table. Important ore minerals belonging to this type are **chalcocite** and **argentite.** (R.M.F.)

ENSIGN FLY. Insecta, Hymenoptera. Small parasitic **insects** whose abdomen is elevated on a slender stalk above the thorax. It has been likened to a flag and gives the common name to the group. The ensign flies make up the family Evaniidae. All species are parasitic in the eggs of cockroaches. (A.W.L.)



Ensign fly.

ENSTATITE. The mineral enstatite is an **orthorhombic pyroxene,** rarely in distinct crystals, usually found as fibrous or lamellar masses or perhaps compact. It has one easy cleavage parallel to the prism, brittle with uneven fracture, hardness 5.5, specific gravity 3.1-3.3, luster pearly to vitreous, sometimes somewhat metallic in **bronzite,** a variety of enstatite carrying up to 15% ferrous oxide FeO. Color grayish to greenish or yellowish white, green and brown. Chemically enstatite is a silicate of magnesium, $MgSiO_3$. It occurs in igneous rocks which are high in magnesium content, like **gabbros, diorites, pyroxenites,** etc., and less commonly in metamorphic rocks. Meteorites of both the stony and metallic types have been shown to contain enstatite. It has been found at many places in Europe, Czechoslovakia, Austria, Bavaria, Germany, Norway and South Africa. In the United States it occurs in Putnam and St. Lawrence Counties, New York; Lancaster

County, Pennsylvania; Jackson County, North Carolina and near Baltimore, Maryland. The name enstatite is derived from the Greek word meaning *opponent*, in reference to its refractory nature; it is almost infusible. (E.S.C.S.)

ENTERIC CAVITY, ENTERON. The digestive cavity. This cavity forms by the splitting or invagination of the inner **germ layer** early in embryonic (See **embryology**) development and persists as a sac with one opening to the exterior in the **coelenterates** and flatworms. In this form it is also called the archenteron.

In animals with a tubular alimentary tract the enteric cavity becomes the primitive gut. Its endodermal lining becomes the glandular digestive tissue and gives rise to large glandular masses in some species, and in the terrestrial vertebrates also produces the respiratory system.

The tubular enteric cavity is supplemented by invaginated tubes of ectoderm at each end, the **stomodaeum** and **proctodaeum.** (A.W.L.)

ENTERITIS. Any inflammation of the small intestine, usually accompanied by fever, pain in the abdomen, **diarrhea** and other constitutional symptoms. (R.S.M.)

ENTEROCOELA. Animals whose bodies contain no other cavity than that used for digestion. **Coelenterates, ctenophores,** flatworms, **nemerteans,** roundworms and **rotifers.** (A.W.L.)

ENTEROPNEUSTA. **Hemichordata.**

ENTEROSTOMY. An artificial opening made surgically in the intestine so that it may communicate with the outside through the abdominal wall or communicate with another portion of the gastrointestinal tract. It may be temporary or permanent in character. (R.S.M.)

ENTEROZOA. Animals which have a digestive cavity, the **enteric cavity.** All animals but the **protozoans** and **sponges.** (A.W.L.)

ENTHALPY. The enthalpy of a substance is its total heat content, measured above some datum level. For example, the enthalpy of steam is measured above a datum of water at 32° F. The enthalpy of steam is the sum of the heat required to raise the water from 32° F. to the boiling point, vaporize it, and, if necessary, to superheat it. (F.T.M.)

ENTLADUNGSSTRAHLEN. This German term (meaning "discharge rays"), used by Wiedemann and adopted into English, refers to certain types of radiation emitted by electric sparks, apparently in the extreme ultraviolet range. At atmospheric pressure, short condenser sparks give radiation of wave length approximately 900 angstroms, while for long sparks from an induction coil the wave length is shorter, probably between 400 angstroms and 900 angstroms. At reduced pressures the wave length is still shorter. These radiations produce ionization in the air and are strongly absorbed by fluorite, which is thereby rendered thermoluminescent (an effect called radio-thermoluminescence). Experiments on the reflection of *Entladungsstrahlen* indicate their **total reflection** by glass or by celluloid with a critical angle of about 82°, which corresponds to a refractive index of 0.99. Work with these rays is difficult, as elsewhere in the far ultraviolet, on account of the absence of simple means of detecting them and because of their rapid absorption in air. (L.D.W.)

ENTOMOLOGY. The science that deals with all facts pertaining to **insects.** Because of the large number of insect species and their frequent economic importance the principal divisions of the science have been systematic entomology and economic entomology. Classification is difficult and intricate, and demands the constant service of specialists. The economic field is of such importance, especially to agriculture, that the national and state governments maintain organizations for the scientific study of insects which also assist in their control.

Although entomologists may specialize in insect **morphology** or physiology, work of this type is less extensive than more practical studies and is of more general biological interest, hence it takes its place largely in the subsidiary sciences of general biology. (A.W.L.)

ENTOMOSTRACA. A division of the class **Crustacea** formerly used to include all but the subclass **Malacostraca.** (A.W.L.)

ENTOPROCTA. A class of **Bryozoa.**

ENTRENCHED MEANDER. A river valley which has a distinctly meandering old age pattern (longitudinal profile), and a V-shaped or canyon shaped,

A rejuvenated region showing entrenched meanders. Yakima Canyon, Washington. (Hobbs, after G. O. Smith.)

youthful transverse profile. The meandering course of the river is inherited from the time when it flowed at, or close to, **base level,** that is on a relatively flat surface. Subsequent uplift of the region quickens the flow of the stream, hence its downcutting power, without necessarily altering its inherited meandering course. Entrenched meanders are therefore physiographic evidence of the rejuvenation of the erosive power of an old age stream. Entrenched meanders may suggest the first stage in a new **cycle of erosion,** but usually imply an interruption in the normal cycle due to relatively sudden uplift of the region before the entire area has been reduced to a **peneplain.** (R.M.F.)

ENTROPY. The physical interpretation of this thermodynamic term introduced by Clausius, has proved somewhat difficult.

In the mathematical treatment of thermodynamic processes there occurs very often a quantity, now relating energy to absolute temperature, now associated with the **probability** of a given distribution of **momentum** among molecules, and again expressing the degree in which the energy of a system has ceased to be **available energy.** Its mathematical form suggests that these are all aspects of a single physical magnitude. Application of the "second law" of **thermodynamics** leads to the conclusion that if any physical system is left to itself and allowed to distribute its energy in its own way, it always does so in a manner such that this quantity, called "entropy," increases; while at the same time the available energy of the system diminishes. This law applies to the universe as a whole, hence the proposition that the total entropy increases as time goes on. An interesting conclusion as to entropy in the vicinity of absolute zero is expressed by the Nernst heat theorem; viz., that all physical and chemical changes in this region take place at constant entropy. Any process during which there is no change of entropy is said to be "isentropic." This is true, for example, of an **adiabatic process** in which there is no dissipation of energy, i.e., one which is also a **reversible process.** In thermodynamic discussions entropy is commonly classed, along with temperature, pressure, and volume, as one of the variables defining the state of

a body, and is often graphed as such on thermodynamic diagrams (L D W)

ENVELOPES. If the curves of a family are tangent to the same curve or group of curves, the name envelope of the family is applied to the curve or group of curves

The envelope of the family of curves $f(x, y, \alpha) = 0$ where α is the variable parameter of the family, is given by the pair of equations

$$f(x, y, \alpha) = 0 \quad \text{and} \quad \frac{\partial f}{\partial \alpha} = f_\alpha(x, y, \alpha) = 0.$$

We may regard these as giving **parametric equations** of the envelope, or we may eliminate α between the two equations (L L S)

ENVIRONMENT. The assemblage of material factors and conditions surrounding the living organism and its component parts

Environment includes both external and internal factors In the external environment inanimate objects and the forces associated with them constitute the physical environment and the living things and their derivatives with which the animal may be associated constitute its organic environment Within its body it maintains an organization which constitutes an internal environment to which all of its parts respond directly, whether or not they may also have external contacts. **Ecology, Distribution** and **Habitat.** (A W L)

ENZYME. An organic **catalyst,** *i e*, a substance produced by a living organism that conditions some chemical action within the body and is not permanently altered in the process The inorganic catalysts of chemistry and the enzymes of biology are similar in many ways Both bring about specific chemical changes at a rate depending on the amount of active material present, and both influence the transformation of many times their own weight of material Enzymes are more complex than inorganic catalysts, although their composition is not definitely known They are regarded as disperse **colloids** in combination with **proteins.**

Enzymes have been classified in three principal groups (1) Hydrolytic enzymes, (2) Oxidases, reductases, and zymases, and (3) Catalase A large number have been studied in some detail

The hydrolytic enzymes facilitate the simplification of organic compounds by **hydrolysis** and are important in digestion, in the coagulation of **blood,** and in the formation of waste products and other substances in the body Their action (hydrolysis) is the splitting of molecules of the compound affected in association with molecules of water to form compounds of simpler molecular structure, in some cases as one step in a series of similar enzymatic actions For example, **starch** is hydrolyzed by the enzyme ptyalin in the saliva to produce maltose, and this **sugar** is hydrolyzed by maltase in the small intestine to form the simple sugar, **glucose,** which can be absorbed into the body

Some of these enzymes act on **fats** and allied substances and are called esterases, some act on starches and sugars and are called carbohydrases, and some act on **proteins** and related compounds and are grouped as proteases, amidases, etc

The oxidases and related enzymes bring about oxidation, reduction, and similar actions Among them tyrosinase acts on the substance tyrosine, an **amino acid,** to produce the pigments known as melanins, while glycolase acts on sugars to produce lactic acid, and zymase, also acting on sugars produces **alcohol** and **carbon dioxide.**

The enzyme catalase breaks down **hydrogen peroxide** into water and oxygen

Enough is known of the specific enzymes and their action to show that they play an extensive part in the chemical processes of the body It is entirely probable that many processes not clearly understood at present are enzymatic in nature, and that even the processes of reproduction and heredity are fundamentally of this kind The literature on the subject records many established and many conjectural processes

Enzymes are also used in various manufacturing processes, including the preparation of fibers and fabrics in the weaving industry, the removal of hair and subcutaneous tissue from hides preparatory to tanning, several stages of brewing, cheese making, and a number of processes in less familiar fields

Because the enzymes are associated with colloidal substances they are very difficult to isolate and purify nevertheless pepsin, urease and some others have been isolated in the crystalline state Enzymes are very unstable substances and often lose their catalytic ability without the concomitant loss of their other characteristics (denaturation) They are as a rule inactive at zero degrees Centigrade, increase in activity with rise in temperature, and are destroyed at high temperatures There is an optimum **hydrogen ion** concentration range for each enzyme Many of them require activators, coenzymes or accelerators for their action and are inhibited in their catalytic activity by minute traces of certain substances such as **hydrogen cyanide** The following is a list of the more important enzymes and the reactions they catalyze

Enzyme	Reaction
Lipase	Hydrolysis of **fats**
Diastase	Hydrolysis of **starch**
Maltase	Hydrolysis of maltose and alpha **glucosides**
Emulsin	Hydrolysis of beta **glucosides**
Lactase	Hydrolysis of **lactose**
Pepsin	Hydrolysis of **proteins** in acid medium to peptones
Trypsin	Hydrolysis of **proteins** to amino acids
Urease	Hydrolysis of **urea**
Rennin	Coagulation of **casein** in the presence of calcium
Tyrosinase	Oxidation of **tyrosine**
Luciferase	Oxidation of luciferin to produce light (fire-fly)
Catalase	Decomposition of **hydrogen peroxide**
Zymase	Alcoholic **fermentation**
Invertase	Inversion of cane **sugar.** (R K S, A W L)

EOCENE. A subdivision of the **Tertiary** of the geologic time-scale Type locality, near Paris, France Term first proposed by Lyell in 1832 The Eocene began approximately 60 million years ago and lasted for about 20–30 million years The greatest thickness of formations of this period occur in Wyoming The principal areas of deposition in the United States are (1) The unconsolidated marine gravels, **glauconite** sands and clays which overlap the Cretaceous marine sediments of the Atlantic Border; (2) The marine limestones, terrestrial sandstones and **lignites** of the Gulf Coast, (3) The marine sediments of the Pacific Coast, (4) The terrestrial intermontane deposits of the Western interior The plants of this period suggest world-wide warm climate The fossil plants include many of the modern genera, such as the beeches, dogwoods, walnuts, maples and elms Fossil vertebrate skeletons show that the mammals are now dominant, although many of the existing orders of reptiles and birds also lived at this time The mammalian fauna may be divided into two principal groups (1) the archaic types which did not survive the Eocene, and (2) the progenitors of the modern mammals, including the ancestors of the camels, pigs, horses, rats, and primitive monkeys The principal surviving archaic forms are the creodonts (primitive flesh-eaters), uintatheria (hippopotamus-like forms), and zeuglodons (marine mammals) The mineral resources of this period are described under the Tertiary. (R M F)

EOLITHS (Kentish) Paleontology of Mair.

EOSIN. Dyes.

EOSPHORITE. Childrenite.

EÖTVOS BALANCE. Gravitation and Gravity.

EOZOÖN The name of a "problematical" **fossil** in the Grenville limestone (marble) of Canada Since the Grenville formation represents one of the oldest known **sedimentary** formations, Eozoon has aroused considerable discussion among geologists and **paleontologists.** Originally described as a giant **foraminifera,** it is now known to be of inorganic origin, probably the result of **contact metamorphism** between the interbedded basic lavas (now **serpentine**) and the limestones The term Eozoon is derived from the Greek, meaning dawn animal (R M F)

EPEIROGENY. Signifying broad and relatively widespread or continental uplift as compared with mountain building or **Orogeny.** (R M F)

EPHEDRA. Gymnosperms.

EPHEDRINE. Drugs and Alkaloids.

EPHEMERIDA. The may-flies, also known locally as shad-flies, salmon-flies, June bugs and Canadian soldiers The adults are sluggish insects with slender filaments at the caudal end of the body and large triangular front wings The hind legs are much smaller, in some species rudimentary The immature insect is aquatic and in most species feeds on decaying vegetable matter It may live for several years, while the adult stage lasts only a few days

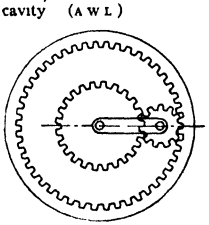
May-flies of one species emerge as adults in large numbers within a short period and are sometimes very abundant near favorable bodies of water They fly at twilight and can sometimes be seen in large gray clouds at a distance of more than a mile over the islands of Lake Erie, where they are especially abundant In the cities bordering the lake they are attracted to lights and their dead bodies are sometimes swept up in bushels after a heavy flight Under such conditions they are a nuisance but not a serious pest Their value as food for fishes more than offsets what little harm they do (A W L)

EPHEMERIS. Almanac.

EPHIPPIUM. The thickened covering of the **carapace** of certain **crustaceans** which is thrown off as a case for the winter eggs (A W L)

EPHYRA. A saucer shaped jelly-fish **larva** with deeply notched margin which is produced by the segmentation of the primary **scyphistoma** larva and develops directly into the adult **jelly-fish.** (A W L)

EPICARDIUM. The thin covering of the vertebrate **heart,** continuous with the lining of the pericardial cavity (A W L)



Epicyclic gear train.

EPICENTRUM. Earthquakes.

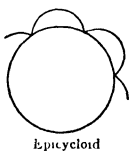
EPICYCLIC TRAIN. Combinations of **gears** having a motion resulting from rotation about an axis which, in itself, is in rotation, are known as epicyclic trains A simple epicyclic gear train, consisting of three gears and an arm, is shown in the figure Mechanism of this nature is sometimes used for speed reducers The ratios of speed of the driven and driving elements are found by the following simple rule consider, first, the gears locked and the arm turned, then the arm locked and the gears turned The algebraic sum of the separate motions thus determined will give the speed ratio (F T M)

EPICYCLOID. An epicycloid is a certain type form of mathematical curve, which may be defined as follows

If a circle of radius b rolls upon the exterior of a circle of radius a, a point on the first circle traces an epicycloid Its **parametric equations** are.

$$x = (a + b)\cos\theta - b\cos\left(\frac{a+b}{b}\theta\right),$$

$$y = (a + b)\sin\theta - b\sin\left(\frac{a+b}{b}\theta\right)$$



Epicycloid

This curve has been followed to some extent in the design of cycloidal gear teeth (L L S)

EPIDEMIC ENCEPHALITIS. This condition, which is also known as Encephalitis Lethargica or Epidemic Stupor, is an acute infectious disease of the **brain** and its coverings caused by an unknown **virus** The disease occurs in many forms with a marked diversity of symptoms so that few cases closely resemble each other The virus causing the disease may be similar in some respects to the virus of influenza, infantile paralysis and shingles (**herpes zoster**)

The disease was first generally known in the almost world-wide epidemic of 1916–17 But there is no question that some of the "mysterious diseases" as the sleeping sickness during the influenza epidemic in 1712 and at other times might have been a form of epidemic encephalitis

The onset is acute or gradual and varies markedly Usually the onset is marked by headache, malaise and fever, the triad common to the onset of many diseases Severe pain in the head, mental confusion, and delirium are often seen in the onset So many different symptoms may be present in any given case that it is difficult to distinguish this disease as a clinical entity from many other diseases

One form of the acute disease is characterized by somnolence, fever, and paralysis of the eye muscles In another form, slow rythmical recurring movements of the limb or muscular twitchings occur—all signs of an irritative disorder of the brain Psychotic forms occur with impairment of memory, alternating delirium and stupor Maniacal epileptic and cataleptic forms are seen If the symptoms or stages are permanent, the patient must remain in a mental institution

The mortality varies in the early acute stages Among frank, well-developed cases the mortality may be anywhere from ten to thirty per cent The tragedy of permanent defect of the central nervous system often occurs in those who survive the acute stage Relapses are prone to occur

There is no specific curative measure known Some workers report good results from serum from convalescent cases (R S M)

EPIDERMIS. In insects the outer layer of the noncellular cuticula, here the cellular layer is called the hypodermis In other invertebrates the cellular layer covering the body is called the epidermis In vertebrates, the epidermis is the outer cellular layer of skin The human epidermis consists of four layers, from without inward as follows —(1) a layer of horny flattened cells (2) a layer of transparent cells (3) layers of granular cells (4) a layer of rounded pigmented cells. (R S M, A.W.L)

EPIDIABASE. Epidiorite.

EPIDIORITE. A term applied to gabbros, **dolerites,** and **diabases,** the **augite** of which has been partly

altered to **hornblende,** thus approaching a diorite in mineral composition The term is derived from the Greek meaning upon, plus diorite (E S C S)

EPIDOTE. The mineral epidote is a basic orthosilicate of **calcium, aluminum** and **iron** whose formula may be written $HCa_2(Al,Fe)_3Si_3O_{13}$ The ratio of aluminum to iron ranges from 0 1 to 3 2 Epidote is found in prismatic **monoclinic** crystals, which may be acicular to fibrous Fine granular and compact masses are common The mineral displays one good cleavage, an uneven fracture, it is brittle, hardness, 6–7, specific gravity, 3 25–3 5, luster, vitreous to resinous, typical color, pistachio green, but may be yellowish to brownish green, sometimes red, yellow, gray, white or colorless Colorless to grayish streak, transparent to opaque The characteristic color of ordinary epidote makes it usually an easily identified mineral It occurs commonly in metamorphic rocks as gneisses and schists, however, it seems probable that under certain conditions it may appear as a primary mineral, for example in granitic rocks The Urals, Austria, Switzerland, Italy, France and Norway are known for their occurrences of fine epidote crystals In the United States epidote has been found in excellent specimens at Franconia and Warren, New Hampshire, Huntington, Massachusetts, Willimantic and Haddam, Connecticut, Chaffee County, Colorado and Riverside County, California The word epidote is derived from the Greek The name pistacite from the Greek word meaning, the pistachio nut, has been occasionally applied to this mineral It has been used as a gem stone but is in little demand for this purpose (E S C S)

EPIGENETIC A term used by **petrologists** to denote physical and chemical changes, particularly in **igneous** and **sedimentary rocks,** which are clearly secondary to (later in time) the conditions under which the rock originated This term is commonly used by the students of **ore** deposits to designate minerals formed after the enclosing wall rocks, in contrast to those minerals formed contemporaneously with the wall rocks The latter minerals are said to be syngenetic In the case of the sedimentary rocks the term is used to describe textures, structures and mineral aggregates, of non-metamorphic origin, which have originated during the post-lithification history of the formation Thus **flint, chert, concretions,** etc, may be described as being either epigenetic or syngenetic (R M F)

EPIGLOTTIS. A flap developed from the floor of the **pharynx** of terrestrial vertebrates which covers the opening to the **respiratory system** (glottis) while the animal swallows (A W L)

EPIGYNUM. A plate above the opening of the reproductive duct of the female **spider.** (A W L)

EPIGYNY. Fruit.

EPILEPSY. A symptom complex which may occur from many varieties of causative factors Many authorities class as epilepsy only those cases where convulsive seizures occur without known cause

In the great majority of epileptics physical and psychic developmental defects are present Fifteen to twenty per cent of feeble-minded individuals develop epilepsy in later life Glandular disturbances, especially of the **pituitary** type, are common

Convulsions in infancy, especially when severe, may predispose to epilepsy later in life **Migraine** is related to epilepsy—about ten per cent of patients afflicted with true migraine become epileptics at a later date Hereditary degeneracy is a common finding in the past history of many cases Mental deterioration occurs in those patients who have had epileptic attacks over many years Many of the victims become **alcoholics** or develop evidences of a psychopathic personality

The true epileptic seizure begins suddenly with a rapid loss of consciousness Half of the victims have warning signs before an attack Such premonitory signs are known as the aura and are really the first stage of the "fit" Aurae are sensory phenomena and may be optic, auditory, or olfactory in nature In about half the cases unconsciousness is preceded by a sinister cry No explanation has been given for this phenomenon With the onset of unconsciousness the fit follows a more or less general pattern Breathing temporarily stops, the subject becomes blue and rigidity of the entire body rapidly develops A second phase shortly follows marked by spasms and jerking of various muscle groups—the true convulsion Frothing at the mouth and a grunting, labored type of breathing are present This phase lasts four or five minutes and gradually subsides, leaving the subject in an exhausted state, or in a state of complete stupor

Rapid recurring epileptic seizures are known as *status epilepticus* and may lead to death

A severe convulsive seizure is termed grand mal Petit mal is a mild form characterized by a momentary loss of consciousness but may be accompanied by a variety of motor or sensory disturbances

Between attacks the epileptic exhibits a disagreeable personality He tires easily, is quarrelsome and is generally unbalanced emotionally

The principles involved in lessening the number of attacks involve hygiene, diet, and medical therapy Since the epileptic is improperly equipped mentally and emotionally to adjust himself to unfavorable conditions, such conditions must be avoided if possible By means of a certain diet it has been found that a produced state of acidosis has a beneficial effect on epileptics The principal medicinal drugs are of the sedative group and are of great value (R S M)

EPIPHARYNX. A fold on the inner surface of the upper lip (labrum) of the insect mouth (A W L)

EPIPHRAGM. A tough membrane of calcified mucus with which some **snails** close the aperture of the shell during periods of drought (A W L)

EPIPHYTES. A striking feature of tropical forests is the abundance of plants which grow attached to other plants These attached plants are called epiphytes, which means plants growing on other plants They are found both on the main trunk and on the branches, often far above the ground In many cases the epiphyte grows on the under side of a branch to which it is firmly fastened by its roots Epiphytes gain nothing but support, and a more favorable position of growth because of better light conditions and other environmental factors, they do not obtain any nutrients from the supporting plants, as parasites would. Particularly noteworthy among epiphytes are many **ferns, aroids** and especially **orchids.** Frequently as in the orchids, the **roots** of the plants are so modified as to absorb water directly from the atmosphere

In the strictest meaning of the word, many lower plants including **algae, fungi, lichens** and **mosses** are epiphytes, since they are often found growing on other plants, not only in tropical regions but in temperate regions as well (R M W)

EPIPODITE Biramous appendage. The epipodites of some **crustaceans** are filamentous or branching gills (A W L)

EPIPODIUM. A lateral ridge on the molluscan foot

EPISTASIS. The masking of one hereditary character by another which is genetically independent See **Heredity.** (A W L)

EPISTAXIS. Hemorrhage from the nose. Nose bleed (R S M)

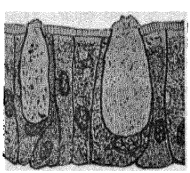
EPISTOME. A projection above the mouth of some **bryozoans.**

EPITHELIUM. Tissue which covers surfaces and lines hollow organs, and the derivatives of these tissues whether solid or hollow. All epithelial tissues are made up of closely associated cells with very little intercellular material and most of them have one surface free and the other connected with an underlying tissue.

Epithelia are classified according to the form of **cells,** the number of layers, and the embryonic origin and location. In flat, pavement, or squamous epithelium the cells are much thinner than their diameter. Cuboidal epithelium is made up of cells approximately as thick as their width. They are not strictly cuboidal but are polyhedral prisms. Columnar epithelium contains cells that are much higher than their diameter. Glandular epithelia are usually of the two latter forms. Any of these forms of cells may occur in more than one layer as a stratified epithelium, but flat epithelia are more often stratified and thicker cells usually form a single layer, or a simple epithelium. In some cases the epithelium is made up of cells of several forms in two or three layers, which change with movements of the part. Such a tissue is called transitional. Others appear to have several layers of cells but all are attached to the underlying tissue, rising to various heights. This is a pseudo-stratified epithelium.

Simple columnar epithelium from intestinal lining. (From Kimber and Gray, *Textbook of Anatomy and Physiology,* Macmillan & Co.)

According to origin and position three kinds of epithelia derived from the mesoderm are recognized. Of these endothelium lines the circulatory organs, mesothelium lines the body cavity, and mesenchymal epithelium lines the joint cavities. Other special types of epithelium are derived from each of the three germ layers. The free surfaces of some bear cilia.



Goblet cells from epithelium lining large intestine. (From Kimber and Gray, *Textbook of Anatomy and Physiology,* Macmillan & Co.)

The cells of many epithelia produce special secretions and in some cases these glandular layers are highly developed to form massive structures known as **glands.**

Most epithelia rest on a thin basement membrane or membrana propria derived from the connective tissues. (A.W.L.)

EPITOKE. The posterior sexual portion of the body in certain **annelids.** In one of the Pacific species this part of the worm breaks off when mature and rises to the surface. In this stage it is the palolo worm of the Pacific Islanders. The anterior asexual portion (atoke) remains in the burrow and produces another epitoke. (A.W.L.)

EPOCH. A subdivision of the geologic time scale which is divided as follows: Era, Period, Epoch and Age. (R.M.F.)

EPSOM SALTS. Magnesium sulfate.

EQUAL-ARM BALANCE. Balance.

EQUALITIES. An equality is a statement that two mathematical expressions are equal. Equalities are of two kinds: identical equalities or **identities,** and conditional equalities or **equations.** (L.L.S.)

EQUATION OF A LOCUS. The equation of a given locus is the **equation** which is satisfied by the **coordinates** of all points of this locus, and of only such points. (L.L.S.)

EQUATION OF TIME. Time.

EQUATIONS. An equation is an **equality** in which both members are equal for certain particular values of the symbols involved but not for all values. To emphasize this, an equation is sometimes called a conditional equality or a conditional equation.

An equation is indicated by putting the equality sign = between the two sides or members of the equation.

An equation with one unknown is an equality which holds for certain particular values of the unknown but not for all values of the unknown.

Equations are classified into many types. There are equations with one or more unknown **numbers** and equations with one or more unknown **functions.** Equations with one or more number unknowns are classified into **algebraic equations** and **transcendental equations;** each of these two classes is further subdivided into other sub-classes. Equations with functional unknowns are classified into **differential equations, integral equations, difference quations,** functional equations, etc.; each of these classes is also divided into subclasses. (L.L.S.)

EQUATIONS, CHEMICAL. Chemical Changes.

EQUATIONS OF MOTION. Kinematics.

EQUATOR. A plane perpendicular to the axis of rotation of the **earth** and passing through the center of the earth will intersect both the surface of the earth and also the **celestial sphere** in great circles. These great circles are known as the terrestrial and celestial equators. (W.K.G.)

EQUATORIAL COORDINATES. Equatorial coordinates are a system of **spherical coordinates** in which the origin may be the eye of the observer (in which we have the apparent system of coordinates), the center of the earth (geocentric system), or the center of the sun (heliocentric system). The fundamental line in this system is the line joining the poles of rotation of the earth which cuts the **celestial sphere** in its poles of rotation. The plane perpendicular to the fundamental line through the origin is the celestial **equator.** The fundamental direction in the plane may be either the point of intersection of the **local meridian** with the celestial equator, which is above the horizon, or the **Vernal equinox.**

To locate an object in this system of coordinates, a plane is passed through the object and the line joining the pole of rotation and this plane will cut out a great circle, known as an **hour circle,** on the celestial sphere perpendicular to the plane of the equator. The **declination** of an object is the angular distance of the object north (+) or south (—) of the celestial equator measured in the plane of the hour circle through the object. The **hour angle** of the object is the angular distance measured in the plane of the equator from the point of intersection of the meridian above the horizon to the point of intersection of the hour circle through the object in the direction of apparent rotation (west) of the celestial sphere. The right ascension of the object is the angular distance, measured in the plane of the equator from the vernal equinox to the point of intersection of the hour circle in a direction (east) contrary to the direction of apparent rotation of the celestial sphere. For purpose of convenience both right ascension and hour angle are frequently expressed in units of hour, minutes and seconds of time, rather than the more common angular notation of degrees, minutes, and seconds of arc.

Due to the fact that the local meridian remains fixed as the celestial sphere apparently rotates, the hour angle of an object is continually changing. Since both the

vernal equinox and the hour circle rotate with the celestial sphere both the right ascension and declination of the object remain fixed as the sphere rotates However, both right ascension and declination change slowly due to **precession** and **nutation** In tabulating these coordinates in **star catalogues** the values are given for the position of the equinox for some particular date and the corrections necessary to reduce the positions to the present date must be applied (W K G)

EQUATORIAL TELESCOPE. A **telescope** so mounted that it may be moved parallel to the **equatorial coordinates** of **hour angle** and **declination** is known as an equatorial telescope, or simply as an equatorial In this form of mounting one axis, know as the polar axis, is parallel to the axis of rotation of the earth, and the other axis, about which the telescope may be rotated, is perpendicular to the polar axis and known as the declination axis. From this arrangement of the axes, as the telescope itself is rotated about the declination axis it must move in a plane perpendicular to the **equator**, hence parallel to hour circle or in the direction of declination The rotation of the declination axis about the polar axis, with the telescope remaining fixed in declination, will cause the telescope to move parallel to the equator, hence in the coordinate of hour angle

The majority of equatorials are carried on a single pier This form of mounting has the difficulty that the telescope will frequently run into the pier when the hour angle is close to zero To avoid this several other methods of supporting the polar axis have been devised Perhaps the most common is the so-called English mounting, in which the two ends of the polar axis are supported on separate piers, with the telescope free to pass through zero hour angle

The most difficult adjustment of the equatorial is to get the polar axis strictly parallel to the axis of rotation of the earth When this has been accomplished the instrument is by far the most convenient of all forms of mounting If the instrument is rotated about the polar axis from east to west at exactly the same rate that the earth is rotating about its axis from west to east, the telescope lens will remain fixed relative to objects on the celestial sphere Hence once the instrument is set on a star, clock work may be devised to keep the telescope "following"

Many ingenious modifications of the equatorial mounting, such as the **Coudé**, have been devised Most such modifications have the comfort of the observer in mind and sacrifice both light and good definition to attain this end (W K G)

EQUIANGULAR SPIRAL. Logarithmic Spiral.

EQUIDAE. Pleistocene

EQUILATERAL HYPERBOLA. Hyperbola.

EQUILIBRIUM (Biological) The state of coordination which maintains an animal in normal posture

Equilibrium of aquatic animals such as the fishes is maintained by the resistance of the surrounding water in relation to specialized body form, by muscular movements of body and fins, and by the gas filled swim bladder The bodies of most fishes are heavier above, as is shown by their floating back downward when dead, but the combination of these factors maintains their erect position

Terrestrial animals maintain their posture by constant muscular adjustment in response to stimuli received by sensory organs in the soles of the feet and in the muscles and tendons A portion of the inner ear of vertebrates is also a center of equilibrium End organs in the semicircular canals of this organ are stimulated by movement in the liquid filling the canals when the animal moves. The three canals lie in the three planes of space so that at least one is activated by any movement The results of their reaction are transmitted to one of the lower brain centers, whence the proper impulses are relayed to the muscles.

Equilibrium in flight demands very delicate coordination of essentially the same type In insects and bats it is supposed to be accomplished partly through delicate sense organs located in the wings (A W L)

EQUILIBRIUM (Chemical). The fundamental law of chemical equilibrium is that enunciated by Le-Chatelier (1884), and may be stated as follows —If any stress or force is brought to bear upon a system in equilibrium, the equilibrium is displaced in a direction which tends to diminish the intensity of the stress or force This is equivalent to the "principle of least action" Its great value to the chemist is in that it enables him to predict the effect upon systems in equilibrium of changes in temperature, pressure, and concentration

The chemical system, **hydrogen-nitrogen-ammonia**, furnishes a notable example of the application of the principle

Nitrogen	+ Hydrogen	⇄ Ammonia	+ Heat
1 vol	3 vol	2 vol	12,000 calories per mol ammonia
4 vol			

At the temperature 700° C and pressure 1 atmosphere, the equilibrium percentage of ammonia is 0 03 in the above system, and at 100 atmospheres—2 5 Increase of pressure shifts the equilibrium towards the side of the smaller total volume, at a constant temperature Decrease of pressure shifts the equilibrium towards the side of the larger total volume, at a constant temperature Systems of the same initial and final volumes are unaffected, as to equilibrium amounts of materials, by change of pressure

At the pressure 100 atmospheres, and temperature 700° C, the equilibrium percentage of ammonia is 2 5 in the above system, at 600° C it is 5, at 500° C it is 10 Increase of temperature shifts the equilibrium in the direction which absorbs heat, at a constant pressure Decrease of temperature shifts the equilibrium in the direction which evolves heat (van 't Hoff's principle, 1884)

At constant pressure and temperature, the equilibrium is shifted away from the side subjected to an increase in concentration of any constituent, or towards the side subjected to a decrease in concentration of any constituent (See **Chemical Changes**) For the qualitative effect of temperature change, one may visualize the heat of an equilibrium reaction as material, and an increase of temperature (heat intensity) as operating to increase the concentration of "heat material" thus shifting the equilibrium away from the side of its increased concentration, and conversely It is possible, knowing the heat of reaction, Q, on the assumption that the heat of reaction is constant between two given (absolute) temperatures, T_1 and T_2, to calculate the equilibrium constant K_2 (at T_2) when the equilibrium constant K_1 (at T_1) and the gas constant, R (equals 2 calories per mol), are known, by the application of van 't Hoff's equation

$$\log_{10} K_2 - \log_{10} K_1 = \frac{Q}{2\,3 \times R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right).$$

In this way the quantitative effect of temperature change on the state of equilibrium may be calculated

In reactions of the ammonia synthesis type, to which **sulfur trioxide** from **sulfur dioxide** plus **oxygen** also belongs, the rate of reaction decreases with lowering of the temperature as the conversion is increased There is, in such types of reactions, a limit to the practicable lowering of the temperature The finding of a positive **catalyzer** for a given reaction of this sort permits the operation to gain the advantage of equilibrium conversion at the lower temperature as well as the increased rate of reaction at that temperature due to the presence of the catalyzer. (See **Chemical Changes.**) The time

yield of product is, therefore, very important, and, with a catalyzer, the space-time yield

Systems in equilibrium are divided into two great divisions, according to whether they are (A) homogeneous, that is, chemically and physically uniform throughout, or (B) heterogeneous, that is, not uniform throughout but consisting of two or more phases Each phase is a homogeneous, physically distinct, and mechanically séparable portion of a system For example, ice, water, water vapor are three different phases (solid, liquid, gas) of the substance water There can be only one gas phase of a system, and only one liquid phase where a *single* homogeneous solution is present But the number of liquid and of solid phases in general is limited by the number of components (not constituents) of a system The number of components is the least number of constituents, *independently* variable, and requisite to compose each and every phase For example, the system consisting of saturated solution in water (H_2O) of **sodium** sulfate (Na_2SO_4) plus solid sodium sulfate decahydrate ($Na_2SO_4\ 10H_2O$) plus water vapor consists of three phases (a) gas, (b) solution, (c) solid sodium decahydrate The *least* number of constituents, independently variable in amount *and* requisite to compose each and every phase is two, namely, Na_2SO_4 and H_2O These, therefore, are the two components of this system Since zero and negative as well as positive amounts of compounds are permitted in expressing the composition of each phase of any system, the three phases of this system are composed of the following components

(*a*) Gas phase, zero Na_2SO_4 plus H_2O
(*b*) Liquid phase, Na_2SO_4 plus H_2O
(*c*) Solid phase, Na_2SO_4 plus H_2O

The number of components in the ice-water-water vapor system is one, namely, H_2O

To systems in which equilibrium depends solely upon the following variables, namely, (1) composition of each and every phase, (2) temperature, and (3) pressure, the phase rule (Willard Gibbs, 1874) applies The number of variables, that is (1) the number of components, C, plus (2) temperature plus (3) pressure, above, equals the number of phases, P, plus the number of degrees of freedom, F The number of degrees of freedom of a system is the least number of the above variables which must be arbitrarily fixed in order to define the condition of the system.

$$C + 2 = P + F$$

The phase rule applies to true equilibrium systems, where the equilibrium can be reached from either side, and, furthermore, takes no account of the time involved to attain equilibrium The phase rule is a qualitative statement, whereas the law of mass action (concentration effect) is quantitatively applicable to those equilibrium systems where the reaction which occurs may be considered to take place in a homogeneous system, e g , gas phase, or solution phase (**Chemical Changes**)

In a one-component system, $P + F = 3$, and physical changes only occur When only one phase is present, for example, liquid water (no vapor, no solid) the system is bivariant, that is, two variables—temperature and pressure—may be independently changed over a range When a second phase, either vapor or solid appears through a sufficient change of temperature or pressure or both, or when two phases are originally present, the system is univariant, that is, one variable—either temperature or pressure—may be independently changed over a range When the third phase appears or when three phases are originally present, the system is invariant, that is, a change of either temperature or pressure destroys the equilibrium, and the disappearance of one of the phases occurs A system of one component in three phases is invariant and the conditions are represented by a point known as the triple point. The triple point for water is 0 007° C., 4 6 millimeters mercury pressure When the total pressure is one atmosphere (760 mm) the equilibrium temperature of water-ice is 0 000° C , and when the water vapor pressure is one atmosphere the equilibrium temperature of water-water vapor is 100 000° C

If, in dealing with any system, the gas phase or pressure may be neglected, on account of constancy or slightness of effect, the phase rule is simplified for practical purposes to $C + 1 = P + F$, and, if both may be neglected, to $C = P + F$

Many two- and three-component systems have been studied and recorded in detail The **iron-carbon** system is one that has attracted much attention and been of great value in iron metallurgy (R K S)

EQUILIBRIUM OF FORCES. A state of balance between or among forces The much used term equilibrium is here confined to its dynamical sense, such subjects as thermal equilibrium, radioactive equilibrium, etc , are treated in appropriate places elsewhere Unless otherwise specified, the term refers to that set of conditions to which a system of forces must be adjusted in order that a free body acted upon by them will experience no acceleration This is somewhat illogically termed "static equilibrium," to distinguish it from the "kinetic equilibrium" with which **D'Alembert's principle** is concerned

Two conditions are necessary for the equilibrium of a set of forces (1) The vector sum of the forces must be zero, then if they are resolved into rectangular components, the algebraic sums of the X, the Y, and the Z components must separately reduce to zero (2) The algebraic sum of the torques of the forces about each of any three mutually perpendicular axes must be zero; the body then has no tendency to rotate about any axis. (See **Statics** and **Graphical Statics**)

A body or a set of bodies under the action of forces may be in stable, unstable, or neutral equilibrium For any one of these, a very slight displacement or change of relative position may be regarded as taking place without change of energy, a fact known as the "principle of virtual work" If the energy is really constant, the equilibrium is neutral, if it is at a minimum, the equilibrium is stable (See **Least Energy Principle**), if it is at a maximum, the equilibrium is unstable The degree of stability in the second case may be expressed as the amount of energy which must be supplied to render the system unstable These various ideas may be illustrated by a body suspended by a string, a sphere resting on a horizontal plane, a pencil balanced on its point, and by blocks, pyramids, etc , on a table (L D W.)

EQUINOX The line of intersection of the plane of the earth's **equator** with the plane of the **ecliptic** (the **line of nodes** of the earth) intersects the **celestial sphere** in two diametrically opposite points known as the equinoxes As seen from the earth the sun apparently passes through each of the equinoxes once each year, passing through the vernal equinox on approximately March 21st and the autumnal equinox on approximately September 21st

The great circle passing about the **celestial sphere** through the equinoxes and the pole of the ecliptic is known as the equinoctial colure (W K G)

EQUIPARTITION OF ENERGY. If a great number of perfectly elastic, rapidly moving particles are turned into an enclosure together and are allowed time to mingle, darting about and striking or otherwise encountering each other, the kinetic energy which they possess becomes distributed in accordance with, the famous principle of equipartition of energy, or Maxwell-Boltzmann law, as enunciated by Boltzmann Each particle has a number of **degrees of freedom,** determined by its character (For the molecules of a diatomic gas, such as nitrogen, the effective number is five, plus some others not ordinarily concerned with thermal energy.)

The equipartition principle states that the average energy taken up by motions in each of the several degrees of freedom is the same (For a gas it is equal to one-half the product of the Boltzmann constant by the absolute temperature of the gas) Thus when heat energy is imparted to a pure diatomic gas, one-fifth of it goes into each degree of molecular freedom which heat can affect Three of these degrees of freedom are concerned with motions of translation, so that three-fifths of the energy takes this form And indeed, when we calculate the change in translational energy due to raising the temperature of one gram of the gas one degree (See **Kinetic Theory**), it is found to be almost exactly three-fifths of the specific heat as measured at constant volume, which represents the total imparted energy One of the strongest supports of the principle comes from quantitative observations on the **Brownian movement.** Many other examples occur in physics (L D W)

EQUISETALES Paleobotany

EQUIVALENT EQUATIONS Two equations in one unknown are said to be equivalent when they have the same **roots.**

An equation is changed to an equivalent equation by the following transformations

(1) when the same number or expression is added to or subtracted from each side of the equation,

(2) when both sides of the equation are multiplied or divided by the same number or expression, provided that number is not 0 and the expression does not contain the unknown (L L S)

EQUIVALENTS, CHEMICAL. Chemical Composition.

EQUUS Fossil Mammals.

ERA One of the five major subdivisions of the **geologic time-scale** The formations that belong in any one era are spoken of as a group (R M F)

ERBIUM. Symbol Er Atomic number 68 Atomic weight 167 2 Density 4 77 Type of compound Er_2O_3 Color of salts red Discovered by Mosander in 1842 A member of the **yttrium** sub-group of the rare earth metals (R K S)

EREPSIN. Enzymes.

ERG The c g s absolute unit of **work** and of **energy.** It is the centimeter-dyne, that is, the work done, or the energy transferred, when the continuous exertion of one dyne of force upon a body is accompanied by a displacement of one centimeter in the direction of the force The erg is so small that often a more convenient unit, called the joule, is used, 1 joule equals 10^7 ergs One foot-pound is approximately 1 355 joules (L D W)

ERGOMETER Power.

ERGOSTEROL. Alcohols and Ethers; also Vitamins.

ERGOT. A **fungus** which grows upon and replaces the grain or **rye.** (See **Diseases of Plants**) Ergot in the body contracts smaller arteries and smooth muscle fibers —especially that of the **uterus.**

Preparations of ergot are used medically to cause contraction of the uterus after childbirth to check hemorrhage It is also used on occasion to hasten labor During recent years a form of ergot has been used for the treatment of migraine

It is questionable whether it has any abortifacient properties in early pregnancy.

Continued use of ergot produces chronic spasm of the small arteries in the hands and feet producing gangrene In the past gangrene commonly occurred in certain European countries from eating bread made from ergot-infected rye (R S M)

ERGOTIMINE. Alkaloids.

ERGOTOXINE Alkaloids.

ERIOMETER Diffraction.

ERMINE. Mammalia, Carnivora The white winter phase of various species of **weasels** and the stoat of the Old World These animals turn white only in colder northern latitudes and always retain the black-tipped tail with which royal ermine is spotted The fur is fine but its value is less than is popularly supposed (A W L)

EROS. Of all of the more than 1300 **asteroids** which have been discovered up to the present time, Eros has probably attracted the most attention The interest in this object comes from the fact that when the object comes to **opposition** at the time of **perihelion** passage it is distant from the earth by only 13,840,000 miles, or is closer to the earth than any other member of the **solar system** whose orbit is accurately known, except the moon At the time of such close approach the **parallax** of Eros is nearly 60″ and is larger than that of any other member of the solar system Hence, observations made of this object when at close approach provide accurate determinations of its parallax, and, with the orbit of the planet accurately determined, **solar parallax** may be more accurately determined than from any other known object These favorable close oppositions of Eros come at rather widely separated intervals, those since discovery coming in 1901 and 1931 At both of these times many accurate observations, both visual and photographic, were made and from them a number of important astronomical constants have been determined

Because of the close approach of Eros to the earth the orbit of Eros suffers large **perturbations** from the earth A study of these perturbations provides data for the determination of the ratio of mass of the earth and the sun With this mass ratio determined the solar parallax may be accurately determined

Eros itself is a small object, between fifteen and twenty miles in diameter The light from it varies at times with a period of about five hours, and the regularity of the light variation can only be explained on the hypothesis that the object is in rotation with this period At the time of the close opposition of 1931 observations made in South Africa indicated that Eros is not spherical, but is "dumb-bell shaped"

Within the last few years two other asteroids have been discovered which apparently come closer to the earth than does Eros These objects are very minute, and at present the observational material is too meager to permit of accurate determination of their orbits (W K G)

EROSION The general term referring to the reduction of the land surface toward sea level by the various agencies of weathering, stream action, glacial action, wind action, etc A similar term is denudation The individual and combined processes of erosion are the primary surficial agencies in the sculpturing of topographic features and the development of scenery Erosion also provides the material from which are formed the bulk of the fragmental, or **clastic, sedimentary rocks.** (R M F)

ERRANTIA. A division of marine segmented **worms** including chiefly free-swimming species Sometimes ranked as an order and sometimes as a division of the order Polychaeta (A W I)

ERRATIC. In geology, an ice-carried **boulder** or block, sometimes weighing many tons, which because of its lack of similarity to the bed rock or formation on which it rests, and the peculiarity of its position, must have been transported to its present resting place by a glacier or an iceberg When erratics occur in sufficient quantity to form relatively pronounced topographic fea-

tures these are called moraines When erratics of similar or identical lithology show a well-defined lineal distribution from the parent outcrop they are called boulder trains (R M F)

ERRORS OF MEASUREMENT. Much of the routine work in any experimental research in the physical sciences is concerned with the eliminating, minimizing, or compensating for observational errors By the error of any measurement is meant the result of the individual measurement minus the true, or most probable, value of the quantity measured It may thus be either positive or negative Errors may be broadly classified into two types persistent or systematic errors, due to causes which endure throughout the whole series of observations and which, therefore, affect each individual observation alike, and accidental or chance errors, due to a combination of random influences which may be changed completely from observation to observation These two classes may be illustrated, respectively, by measurements of a length with a ruler which is too long or too short, and by measurements of an angle with a surveyor's **transit** which is being shaken by the wind Mistakes or blunders, due to the misreading of an instrument, etc, are not considered as errors of observation, but rather as errors of the observer

Various standard devices for dealing with persistent or systematic errors will be found discussed under **physical measurements** and **personal equation** The treatment of accidental errors is discussed briefly in the article on **least squares.** (L D W)

ERUPTION. A visible breaking out of the skin, marked by various degrees of redness, swelling, and elevation There are many types of eruption, some of which are characteristic of the disease which they accompany and are important in the diagnosis of these diseases Drug eruption is an eruption occurring after the use of a **drug** Plant eruption is an eruption occurring after exposure of a sensitive subject to an irritant substance found in certain plants Poison ivy is an example of such a plant (R S M)

ERUPTIVE. This term has the same general geological meaning as **effusive,** but is sometimes used in the much more general sense as synonymous with **igneous.** (R M F)

ERYOPS. Fossil amphibia.

ERYSIPELAS. An acute inflammation of the skin, caused by the *Streptococcus hemolyticus* It is accompanied by high fever and marked toxic reactions in the system Death from this disease is usually the result of a complication—either **pneumonia** or **septicemia.**

Infection takes place at the site of some injury—sometimes the break in the skin being too small to be visible. Lowered resistance for any reason is a predisposing cause Relapses are quite common Abscess formation at the site of infection is a quite common complication.

The most successful treatment is with the use of erysipelas antitoxin, the use of ultraviolet light irradiation over the involved areas, and the use of sulfanilamide preparations (R S M)

ERYTHRITE. The mineral erythrite is a rather rare mineral of secondary origin Chemically it is a hydrous **cobalt arsenate** corresponding to the formula $Co_3As_2O_8 \cdot 8H_2O$, the cobalt being replaced at times by **nickel, iron** or **calcium** It is found in **monoclinic** crystals, masses, and in crusts with other cobalt minerals It is a soft mineral, hardness, 1 5–2 5, specific gravity, 2 95; luster, adamantine to vitreous although massive varieties may be dull to earthy Color, red, occasionally gray, transparent to nearly opaque It is known from Bohemia, Saxony, Baden; Chalantes, France; Tunaberg, Sweden; Cornwall and Cumberland, England; Cobalt, Province of Ontario, Canada, and in the United States from Nevada and California Erythrite takes its name from the Greek meaning red (E S C S)

ERYTHROCYTE. Blood.

ERYTHROXYLON. Coca.

ESKER (OSE; plural, OSAR). Certain long, often winding, ridges formed of stratified sands and gravels, which occur within the glaciated regions of Europe and North America are called eskers These pronounced topographic features are frequently several miles in length and because of their peculiar and uniform shape somewhat resemble railway embankments Eskers represent the deposits of glacial streams which flowed within and under the mountain glaciers and continental ice sheets After the retaining ice walls melted away the stream deposits remained as long winding ridges (R M F)

ESOPHAGUS. The tube-like passage which connects the lower end of the **pharynx** with the stomach It is about ten inches long, lies in front of the spine as it descends through the chest, and passes through the **diaphragm** just before it enters the stomach. Its walls are made up of circular and straight muscle fibers which allow for wave-like contractions progressively from above downwards The inner surface contains many glands which secret mucus for lubrication of its walls The function of the esophagus is to mechanically pass food from the pharynx into the stomach The main disorders affecting the esophagus are **tumor** formation, diverticulum formation and stricture Stricture usually results from the swallowing of corrosive substances (R S M)

ESSENCES. Extracts.

ESSENTIAL OILS. Volatile oils.

ESSEXITE. Gabbro.

ESTABLISHMENT OF A FORT. Tides.

ESTERS, INCLUDING OILS, FATS, WAXES. An ester is a compound, which by reaction with **water, acid** or **alkali,** forms an **alcohol** plus an acid (a salt of the acid is formed when alkali is used) The reverse reaction, namely, reaction of an alcohol plus an acid, accompanied by the elimination of water, is the most important general method of formation of an ester Of the alcohols concerned with ester composition or formation, the most common are **methyl alcohol, ethyl alcohol, glycol, glycerol, cellulose** The range of acids important in the study of esters is wider than that of the alcohols, and the importance is determined largely by the point of view On the scientific side, esters of all acids are important in extending the knowledge of the acid, frequently important in the determination of unknown acids and some are individually important On the industrial side, esters of **nitric acid** are important in **explosives,** e g, glyceryl trinitrate (nitroglycerin, dynamite), cellulose hexanitrate (nitrocellulose, guncotton), glycol dinitrate, in **plastics** (pyroxylin and celluloid), **photographic** films, lacquers, **rayon,** and in collodion, esters of acetic, propionic, butyric acids in plastics, photographic films, rayon, lacquers, e g, cellulose acetate, ethyl butyrate; esters of **stearic, palmitic, oleic, linolic** acids, in vegetable and animal oils and fats for food, in paints and varnishes, for soaps, fatty acids, glycerol, esters of certain acids, e g, salicylic acid methyl ester (oil of **wintergreen**), in odoriferous substances and perfumes The esters of each acid are listed under the acid, as follows (1) carboxylic acids **acetic, benzoic, carbonic, citric, formic, lactic, malic, oleic, oxalic, palmitic, salicylic, stearic, tartaric,** (2) nitrogen acids· **nitric, nitrous, hydrocyanic, cyanic,** (3) sulfur acids· **sulfuric, sulfurous, thiocyanic,** (4) phosphorus acids. **phosphoric, hypophosphoric, phosphorous.** In addition, in the cases of those acids not discussed individually, the following esters are noted:

	Ester	Formula	Melting Point	Boiling Point
1	Methyl propionate	$C_2H_5COOCH_3$		80° C
2	Ethyl propionate	$C_2H_5COOC_2H_5$		99° C
3	Methyl normal-butyrate	$C_3H_7COOCH_3$		102° C
4	Ethyl normal-butyrate	$C_3H_7COOC_2H_5$		121° C
5	Methyl iso-butyrate	$(CH_3)_2CHCOOCH_3$		93° C
6	Ethyl iso-butyrate	$(CH_3)_2CHCOOC_2H_5$		112° C
7	Methyl normal-valerate	$C_4H_9COOCH_3$		127° C
8	Ethyl normal-valerate	$C_4H_9COOC_2H_5$		145° C
9	Methyl iso-valerate	$(CH_3)_2CHCH_2COOCH_3$		116° C
10	Ethyl iso-valerate	$(CH_3)_2CHCH_2COOC_2H_5$		135° C
11	Dimethyl malonate	$CH_2(COOCH_3)_2$		180° C
12	Diethyl malonate	$CH_2(COOOC_2H_5)_2$		199° C
13	Dimethyl succinate	$(CH_2COOCH_3)_2$	20° C	195° C
14	Diethyl succinate	$(CH_2COOC_2H_5)_2$		216° C
15	Methyl cinnamate	$C_6H_5CH\ CHCOOCH_3$	33° C	263° C
16	Ethyl cinnamate	$C_6H_5CH\ CHCOOC_2H_5$	12° C	271° C

Many esters are found in natural materials, and have uses Such esters are those found in animal fats, e g, beef fat for tallow, hog fat for lard, fish oils, and in vegetable oils, e g, olive oil, corn oil, cottonseed oil, linseed oil Fatty oils are stored in the plant mainly in the seed, e g, cottonseed, flax seed (linseed oil), or in a portion of the seed, e g, corn germ, coconut meat (copra when dried), and in the animal organism localized as such, e g, beef tallow, hog lard, or distributed in the flesh, in milk, e g, butter fat, or in liver, e g, cod liver oil In animal and vegetable oils and fats the predominating esters are glyceryl stearate, palmitate, oleate (an olefin acid), linoleate (a diolefin acid), linolenate (a triolefin acid), ricinoleate (a hydroxy-olefin acid) A few alcohols other than glycerol are found in the esters of animal waxes, e g, cetyl alcohol (as palmitate) in the head oil of the sperm whale, myricyl alcohol (as palmitate) in beeswax There are various methods of classification of oils, fats and waxes The following classification with a selected list of members, accompanied by selected physical and chemical constants is presented:

VEGETABLE AND ANIMAL OILS, FATS AND WAXES—A SELECTED CLASSIFIED LIST

			% Oil and Fat in the Seed	Solidification Point, °C	Specific Gravity	Index of Refraction n_D at °C	Saponification Number	Iodine Number	Titer Test, °C
A	Vegetable Oils								
	1 Drying	1 Linseed	40	−27	0 927–0 932	1 4725, 15°	188–195	170–190	19–21
		2. Chinawood *	55	− 3	0 936–0 943	1 51, 20°	190–195	150–175	37
		3 Perilla	30–40		0 932–0 937	1 483,	190–194	187–200	
		4 Walnut	65	−27	0 92–0 93	1 4808, 20°	192–197	142–146	16
		5 Soy bean	20–25	− 8	0 920–0 926	1 4673, 40°	185–195	128–135	21–24
		6 Rapeseed	35–40	−2 – +10	0 913–0 916	1 475,	170–179	94–105	11–13
	2 Semi-drying	7 Cottonseed	25–35		0 922–0 927	1 4643, 40°	193–195	105	33–38
		8 Corn	10	−10– −20	0 9105	1 4768, 15°	187	117	15–19
	3 Non-drying	9 Peanut (arachis, earthnut)	45	0	0 916–0 925	1 4612, 40°	185–196	85	28–29
		10 Olive	40–65	−6–+2	0 916–0 918	1 4698, 15°	185–196	79–90	17–21
		11 Olive kernel	15		0 92	1 468, 25°	181–184	86–87	
		12 Castor .	50	−10– −18	0 969	1 480, 15°	183–186	82–86	3
B	Vegetable Fats	13 Coconut	40–45	22	0 925	1 4488, 40°	233–253	7–10	20–22
		14 Palm	65–70	30–40	0 865–0 873	1 4503, 40°	196–205	11–83	42–45
		15 Palm kernel	45–50	23	0 912	1 4431, 60°	242–250	10–18	20–24
		16 Cacao butter .	45	22–27	0 950–0 970	1 457, 40°	192–198	3 5	48–50
C	Animal Oils								
	Marine								
	a Fish	17 Salmon			0 9258	1 478, 20°	182–188	160–190	
		18 Menhaden		−4	0 927–0 933	1 480, 15°	191–196	142–180	
		19 Herring			0 92–0 93	1 48,	180–194	140	
	b Liver	20 Cod-liver		0– −10	0 92–0 93	1 48, 15°	187–197	150–180	17–18
	c Blubber	21 Whale			0 871–0 878	1 46, 25°	122–144	80–93	22–24
		22 Seal		−2 – +3	0 924–0 926	1 474,	189–196	130–190	13–19
D	Animal Fats								
	Terrestrial								
	Non-drying								
	a Body fats	23 Beef tallow		27–35	0 943–0 952	1 451, 60°	193–200	35–46	43–45
		24 Hog lard		27–30	0 935	1 4539, 60°	195	52–77	36–39
	b Foot oils	25 Neat's foot oil		<0	0 92	1 469, 20°	194–199	58–70	20–26
	c Milk fats	26 Butter fat		19–24	0 926–0 940	1 4650, 60°	216–240	26–38	36–38
E	Animal Waxes	27 Spermaceti		42–47	0 945–0 960		123–135	4–7	
		28 Bee's wax		60–63	0 96–0 97	1 4439, 75°	88–98	8–12	

* Also known as Tung Oil

Saponification Number represents the number of milligrams of potassium hydroxide (KOH) required, under specified conditions, to saponify one gram of the sample

Iodine Number represents the number of grams of iodine absorbed, under specified conditions, by 100 grams of the sample Hubl solution contains iodine and mercuric chloride in absolute alcohol Wijs solution contains iodine monochloride in glacial acetic acid

Titer Test From the sample, the free fatty acids are made, and then cooled slowly, the temperature being observed by means of a thermometer whose bulb is immersed in the cooling liquid When turbidity appears in the liquid the temperature remains stationary or rises slightly The temperature of the top point of the rise is the titer of the sample

Reichert Meissl Number represents the number of milliliters of decinormal alkali required to neutralize the volatile fatty acid distillate, obtained, under specified conditions, from 5 grams of the sample For most oils and fats the number is small, of the order of 0 5, but in the case of butter fats is high, between 20 and 34 Coconut oil gives a value between 6 5 and 7 5, palm kernel oil between 5 and 7, and palm oil between 1 and 2

Drying oils are those which, upon exposure to the air, gradually form a permanent dry film Esters of linolic and linolenic acids are present in those oils, and the di-and triolefin acid radicals absorb oxygen from the air and produce this film Linseed and similar oils are used mainly in paints and varnishes Some fish oils, e g, salmon oil, also are used in the paint industry

Edible oils for food and cooking are mainly non-drying or semi-drying oils and fats The consumption in this field is the largest of all the outlets for oils, fats and waxes The edible natural fats, butter, lard, tallow, have been supplemented in recent years by processed materials, such as oleomargarine, supplement to butter, and vegetable shortening, supplement to lard Oleomargarine may be made by separation at a suitable temperature of liquid oleo oil from solid stearin of beef tallow, and then mixing oleo oil, coconut fat and cottonseed oil in the desired proportions and flavoring with butter fat or carefully ripened milk Vegetable shortening is made from the liquid oils, usually cottonseed, peanut, corn, soy bean, by reaction with **hydrogen** in the presence of finely divided nickel which is later removed at the proper temperature The gradual addition of hydrogen results in a product of less liquid and more solid, up to the limit of **hydrogenation**, when the product resembles closely beef tallow At the desired stage the process is terminated, and the product used as shortening or for frying

By reaction with water, acid or alkali, the oils and fats form glycerol plus fatty acids, which latter separate as salts when alkali is used Addition of sodium chloride aids in the separation These salts are soaps, and the ordinary hard soaps are sodium salts of stearic, palmitic, oleic acids Potassium salts are jelly-like, and are known as soft soaps Sodium and potassium soaps are soluble in water and yield a froth, known as lather or suds, when agitated in water Calcium soaps are insoluble in water, and yield no froth upon agitation When natural hard waters containing dissolved calcium or magnesium compounds, e g, the bicarbonate, chloride or sulfate, are used with sodium soaps in washing and cleansing, calcium soaps separate as insoluble precipitates in proportion to the amount of calcium and magnesium contained in the water This represents loss of soap for cleansing purposes as well as diminished froth and the accumulation of undesirable precipitate in the material being cleansed Aluminum soaps are also insoluble but are used in certain lubricants and greases Certain soaps of cobalt, manganese, lead, aluminum, are used as varnish dryers Glycerol is recovered by distillation under diminished pressure (vacuum distillation) of the water or sodium chloride solution portion, after separation of the sodium soaps.

When the sodium soaps are dissolved in water and dilute sulfuric or hydrochloric is added in slight excess, the free fatty acids of the soaps separate as an insoluble oily or fatty portion These fatty acids may be separated into fractions as desired by fractional crystallization and filtration, and by fractional distillation under diminished pressure The stearic acid portion is utilized in the manufacture of candles, when mixed with more or less paraffin wax to secure the desired consistency The oleic acid portion may be hydrogenated to stearic acid, or treated with concentrated sulfuric acid and naphthalene to form a reagent, known as Twitchell's reagent, for converting oils and fats into glycerol plus fatty acids While much of the soap which is made utilizes oils and fats that are in the edible class, inedible tallow and recovered greases are important sources

Other uses of oils and fats are for lubrication of machinery, ranging from light spindle oils to heavy greases, and in medicine, e g, castor oil, chaulmoogra oil, cod-liver oil

Oils and fats are recovered from seeds by pressing, cold or hot, or by extraction with a volatile solvent and then distilling off the solvent Butter fat is recovered from milk by centrifuging Tallow and lard are purified by heating to melting, the finer qualities being those recovered by less drastic heating and the lower qualities by more drastic heating

When oils and fats are exposed to air and light, or contain enzymes, rancidity is developed This is prevented by careful purification of the oil or fat and exclusion of air Rancidity is hastened in the presence of free fatty acids in the oil or fat (For further data on individual oils, see articles on **Cocoa, Castor, Coconut, Corn, Cotton, Olive, Palm, Peanut,** and **Soy Bean**) (R K S)

ESTRIN. Sex Hormones.

ETHANE. Ethane (C_2H_6 or CH_3 CH_3) is a colorless, odorless gas, boiling point —88° C, density 1 36 grams per liter at 0° C and 760 mm (specific gravity 1 05, air equal to 1 00), practically insoluble in water, moderately soluble in alcohol, burns when ignited in air with a pale faintly luminous flame, forms an explosive mixture with air over a moderate range, with excess air the products are **carbon dioxide** plus water, with deficiency of air carbon monoxide plus water Ethane is among the chemically less reactive organic substances It reacts, however, with **chlorine** (and with **bromine**) to form mixtures of chloro- (and bromo-) substitution compounds (one-half of the chlorine used forms hydrogen chloride) Ethane occurs, usually in small proportions, in natural gas The fuel value of ethane is very high, 1730 British thermal units per cubic foot Ethane may be prepared by reaction of magnesium ethyl iodide in anhydrous ether (**Grignard's reagent**) with water or alcohols Ethyl iodide (bromide, chloride) is preferably made by reaction of ethyl alcohol and **phosphorus** iodide (bromide, chloride) Important ethane derivatives, by successive oxidation, are (1) **ethyl alcohol** (C_2H_5OH or CH_3CH_2OH), (2) **acetaldehyde** (C_2H_4O or CH_3CHO), (3) **acetic acid** ($C_2H_4O_2$ or CH_3COOH). (R K S)

ETHER. This term is used, with entirely different meanings, in chemistry and in physics In chemistry it is used to designate a series of compounds which are discussed in this book under the heading **Alcohols and Ethers** Chemists also use the term ether to designate a particular member of the series, that is, diethyl ether ($(C_2H_5)_2O$) This compound is also known as sulfuric ether, and as ethoxyethane It is a colorless liquid, of characteristic odor, boiling point 35° C, inflammable and explosive with air when ignited by fire or electric spark Slightly soluble in water (1 volume ether in 10 volumes water) and slightly dissolves water (3 volumes water in 100 volumes ether), miscible in all proportions

with alcohol, dissolves **iodine** and many organic substances, e g, **oils** and **fats**, no reaction with ordinary acids or alkalis, with **sodium** or cold **phosphorus** pentachloride Ether is prepared by treatment of **ethyl alcohol** with concentrated **sulfuric acid** in excess at about 140° C. For use as an **anesthetic**, ether must be scrupulously pure Ether is used (1) as an anesthetic by inhalation of the vapor, (2) as a **solvent** in the preparation of explosives and of collodion, and in the extraction of **oils, fats, waxes, gums, resins, alkaloids.**

In physics, the concept of the ether had its origin in the necessity for explaining the propagation of light and the existence of electric, magnetic, and gravitational fields of force When it became evident that light is a wave phenomenon, the search for a medium became imperative While sound does not traverse a vacuum, light does so perfectly, and electric, magnetic, and gravitational attractions are not interrupted by removing the intervening air Yet all attempts to corral and examine portions of this supposed residual substance and to ascertain its properties by direct observation have totally failed If the ether is actually a wave-propagating medium, the speed of the waves is such as to imply an extraordinarily great rigidity coupled with a vanishingly small density (See **Vibrations and Waves**)

One mode of attack has been to seek for evidence of an "ether drift," that is, a relative motion of matter with respect to the ether through which it moves, just as one traveling through still air experiences a wind The results of such quests have proved ambiguous The **Michelson-Morley experiment** gave a completely negative result So did the Trouton-Noble experiment, which was an attempt to detect the electromagnetic effect of the motion of the electric charges in a condenser, as carried by the earth in its orbit On the other hand, Airy's experiment on the **aberration of light** might be interpreted as indicating that when a transparent substance moves, the ether is dragged along, not with the full speed of the moving matter, but with a fraction of that speed expressed by Fresnel's so-called "coefficient of drag" This fraction is equal to $\frac{n^2-1}{n^2}$, in which n is the refractive index of the transparent medium; and its validity was further attested by the experiments of Fizeau on the propagation of light in rapidly moving water The difficulties presented by such conflicting evidence have been avoided by Einstein, who in his theory of **relativity** dispenses with all assumptions as to the supposed stationary ether or motion with respect to it. (R K S, L D W)

ETHER DRIFT. Ether.

ETHYL ALCOHOL. Ethyl **alcohol**, ethanol, "grain alcohol" (C_2H_5OH or CH_3CH_2OH) is a colorless liquid, of pleasant odor, melting point —117° C, boiling point 78 5° C, constant minimum boiling point mixture—distillate—with water 78 15° C, 4 4% water 95 6% ethyl alcohol, miscible in all proportions with water or ether, soluble in **sodium** hydroxide solution, when ignited burns in air with a pale blue, transparent flame producing water plus carbon dioxide, the vapor forms an explosive mixture with air and may be used in **internal combustion engines** under high compression Ethyl alcohol reacts (1) with **sodium** metal forming sodium ethoxide, (C_2H_5ONa) plus hydrogen gas, (2) with **phosphorus** chloride, bromide, iodide, forming ethyl chloride, bromide, iodide, respectively, (3) with **sulfuric acid** concentrated, forming at 100° C ethyl hydrogen sulfate ($C_2H_5OSO_2OH$), at 140° C diethyl ether ($(C_2H_5)_2O$), at 200° C ethylene (CH_2 CH_2), (4) with organic **acids**, warmed in the presence of sulfuric acid, forming **esters**, e g, ethyl acetate ($CH_3COOC_2H_5$), ethyl benzoate ($C_6H_5COOC_2H_5$) (See various individual acids), (5) with magnesium methyl iodide in anhydrous ether (**Grignard's solution**) forming **methane** as in the case of primary alcohols, (6) with **calcium** chloride to form a solid addition compound ($4C_2H_5OH$ $CaCl_2$), which is decomposed by water, (7) with **oxygen**, using **sodium** dichromate solution and sulfuric acid, to form **acetaldehyde** (and **acetic acid**), using air, in the presence of acetic bacteria, to form vinegar (dilute acetic acid along with the substances present in the alcohol used, e g, wine, cider), (8) with **nitric acid** (a) concentrated, free from nitrogen tetroxide, to form ethyl nitrate, (b) dilute to form glycollic acid, (c) concentrated acid containing nitrogen tetroxide (fuming nitric acid) explosive reaction, (9) with **chlorine** (or **bromine**) to form chloral (CCl_3CHO) (or bromal)

The density of pure ethyl alcohol is 0 789, at 20° C, compared with water at 4° C (the corresponding figure for methyl alcohol is 0 792) and the percentage of ethyl alcohol present in an ethyl alcohol-water solution may be determined from the density of the sample Anhydrous ethyl alcohol, "absolute alcohol," may be obtained by removal of water by the reaction of the water with calcium oxide and then distilling the alcohol, or by distillation of ethyl alcohol-water with benzene

Ethyl alcohol is made (1) by **fermentation** of many **carbohydrates**, directly from dextrose or levulose of fruit juices, e g, grape, apple, and indirectly from sucrose, maltose, starch, cellulose after conversion of the latter group into the former When starch (usually from corn or potatoes) is used, the starch is changed to maltose by means of diastase of "malt," which is produced by the germination of **barley** Maltose from starch or sucrose of molasses is fermented by the addition of yeast which generates the **enzymes** maltase (converting maltose to glucose), invertase (converting sucrose to glucose plus levulose), zymase, effective in accomplishing the conversion of glucose to **ethyl alcohol** plus **carbon dioxide** (one-third of the sugar is changed to carbon dioxide) in dilute solution (not over 18% alcohol) When starch or cellulose of wood is treated with dilute acid heated, dextrose is formed (about 2% of fermentable sugars is present in the waste liquor from the sulfite process of making wood into paper pulp) and this may be fermented by yeast, (2) by absorption of ethylene of coal gas or petroleum gas, and subsequent reaction with water, (3) by reduction of acetaldehyde in the presence of a catalyzer From the solution, ethyl alcohol is separated, recovered and concentrated by fractional distillation "Proof spirit" is defined by the United States Government as one containing 50% by volume of ethyl alcohol and 50% water, that is, 42 47% by weight of ethyl alcohol and of density 0 930 at 20° C compared with water at 4° C

The intoxicating agent of alcoholic beverages is ethyl alcohol It is found in sherry, whiskey, brandy, wine, beer, ale, and all other alcoholic beverages Considerable knowledge has been acquired about the various effects of ethyl alcohol upon man, and they will be discussed briefly in this article

In the human body the principal action of ethyl alcohol is that of a mental depressant, not a stimulant, as is commonly believed However, in moderate doses, well-diluted alcohol stimulates the appetite, induces secretion of gastric juice and aids in the absorption of food When taken repeatedly in stronger forms it is an irritant to the mucous membrane lining of the stomach When excess acid is chronically present in the stomach, or an ulcer is present, any alcohol is harmful because of its irritant properties Alcohol is rapidly absorbed in the stomach and upper portion of the intestinal tract Since alcohol is a simple aliphatic hydroxy-compound, it is used by the body with little effort, furnishing energy and heat in a similar manner to **sugars** The **heat of combustion** of pure ethyl alcohol is seven calories per cubic centimeter It is as a substitute food that ethyl alcohol finds its main use in medicine

In moderation after severe exertion, exposure or strain, alcohol is of benefit because of this immediate food

value, its reflex stimulating effect, and its sedative action which gives a feeling of relaxation and rest.

Formerly ethyl alcohol was believed a stimulant to the circulation This is not now held to be true The only effect of small doses of ethyl alcohol is through its food value to the heart muscle, similar to any other simple sugar taken into the system, and through its dilating effect on the blood vessels, thereby lessening an increase in venous pressure which the heart could not accommodate. In sudden heart failure, or in angina pectoris, ethyl alcohol may aid in this way and also by lessening mental apprehension

Outside of its effect on the **nervous** and **digestive systems**, there is little evidence that ethyl alcohol in large doses is the specific or single cause of any known disease

When ethyl alcohol is taken to excess it is particularly toxic to the nervous system and is a direct and principal cause of several kinds of mental disease The damage to the nervous system is, for the most part, functional, since serious anatomical defects are seldom seen in autopsy

Acute or chronic alcoholism, or periodic alcoholism, is most commonly seen in those individuals who cannot tolerate unhappy or suppressed emotion in their consciousness In other words, it is a conscious or unconscious attempt to forget In another class of individuals, alcoholism is due to a mild attack of manic-depressive insanity brought on by strain, worry or overwork Treatment of periodic alcoholism is best carried on in the hands of a psychiatrist and in an institution An alcoholic will but rarely be cured unless he can recover his emotional or psychologic equilibrium

There are certain conditions that complicate or are frequently seen with chronic alcoholism (1) Delirium Tremens, a variety of acute insanity characterized by delirium and marked emotional excitement It is brought on by a temporary excess and subsequent withdrawal of alcohol, especially when an acute infection or injury occurs Hallucinations are the rule The patient is intensely ill Delirium tremens unaccompanied by injury, infection or acute illness, has a mortality of 15% Otherwise the mortality often averages 50% There is no specific treatment for this disorder Supportive and sedative measures are essential (2) Acute Alcoholic Hallucinations, a form of acute insanity marked by auditory hallucinations Unless guarded, suicidal or homicidal tendencies will follow as a sense of persecution by others is marked The treatment is the same as that for delirium tremens (3) Korsakoff's Psychosis, a chronic alcoholic delirium that develops in middle life, more often in women than in men The disease is accompanied by involvement of the nerves of the body as well as the central nervous system The neuritic symptoms are marked by disturbances in walking, some degree of paralysis, and even speech may be interfered with The psychosis that is part of this disease begins with delirium and with hallucinations, which are visual and tactial, different from the hallucinations of delirium tremens Loss of memory for recent and some past events causes the patient to have delusions and fictional experiences to compensate for memory loss The treatment is similar to the other alcoholic complications but the outlook is unfavorable (4) Alcoholic Wet Brain occurs when excessive fluid is present in and around the brain This often develops after delirium tremens, but may follow a heavy bout of drinking without delirium Usually coma or stupor follows the usual delirium. The patient may die in this state or develop a terminal **pneumonia** The mortality is high and those that do survive require several months for convalescence The treatment is similar to that of other alcoholic conditions (5) Alcoholic Neuritis In certain alcoholics, who substitute the nourishment of alcohol for a greater part of normal diet, a vitamin deficiency develops This in some cases is marked by nerve involvement with incoordination and disturbances in function. This may be in early cases in the form of an alcoholic neuritis In more severe cases it may resemble the spinal cord involvement seen in pernicious anemia The condition responds to concentrated **vitamin** B therapy given by intramuscular injection

Ethyl alcohol may be detected by the formation of iodoform, a treatment with alkali, potassium iodide, and iodine solution

Ethyl alcohol is used (1) as an important solvent of chemicals and pharmaceuticals, in varnishes, tinctures, perfumes, (2) as an **antiseptic** in surgery, (3) for the preservation of hospital and museum physiological and pathological specimens, (4) in the production of **ether, esters**, and the source of the ethyl group (C_2H_5—) and the ethoxy group (C_2H_5O—), in organic chemical reactions, (5) for the production of vinegar, e g , from wine, cider, (6) as a liquid **fuel**, clean and relatively safe, with possibility of extensive use in internal combustion engines, (7) in anti-freeze solutions (20% by volume ethyl alcohol, 80% water, freezing point 18° F , 36% alcohol, 64% water, — 2° F , 54% alcohol, 46% water, — 29° F) Stringent government regulations cover the manufacture, use and sale of ethyl alcohol in all forms Alcohol not for beverage but for industrial purposes is tax-free Tax-free industrial alcohol is either used under government supervision or, without such supervision, after being completely denatured by the addition of non-potable substances

Anhydrous ethyl alcohol is made from the constant boiling mixture with water (95 6% ethyl alcohol) (1) by heating with a substance such as **calcium** oxide, which reacts with water and not with alcohol, and then distilling, or (2) by distilling with a volatile liquid such as **benzene** (boiling point 70 6° C), which forms a constant low boiling mixture with water and alcohol (boiling point 64 9° C), so that water is removed from the main portion of the alcohol, after which alcohol plus benzene distills over (boiling point 68 3° C), and finally anhydrous ethyl alcohol (boiling point 78 5° C) Anhydrous ethyl alcohol is demanded for certain purposes as a solvent and reagent, among other applications is that of addition to gasoline or to benzene as motor fuel In the presence of water, separation into two layers takes place, and the following data apply

ALCOHOL-GASOLINE MIXTURES

Percent by Weight		Water Added per 100 Grams Mixture to Cause Separation	Percent Alcohol of Alcohol-Water Portion in Product
Alcohol	Gasoline		
10	90	0 46 g	95 6
20	80	1 09	94 8
30	70	1 85	94 2
40	60	2 78	93 5
50	50	3 75	93 0

ALCOHOL-BENZENE MIXTURE

Percent by Weight		Water Added per 100 Grams Mixture to Cause Separation	Percent Alcohol of Alcohol-Water Portion in Product
Alcohol	Benzene		
10	90	1 0 g	90 9
20	80	3 0	87 0
30	70	6 1	83 1
40	60	10 8	78 7
50	50	16 1	75 7

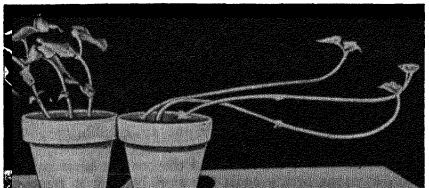
(R S M., R K S.)

ETHYL CHLORIDE. Chlorine; and Anesthesia.

ETHYLENE. Ethylene, ethene (C_2H_4 or $CH_2:CH_2$), is a colorless gas, of slight odor, and acts as an anesthetic when inhaled, boiling point —104° C., density 1.26 grams per liter at 0° C. and 760 mm. (specific gravity 0.97, air equal to 1.00), liquid at 10° C. and 50 atmospheres pressure, insoluble in water, burns when ignited in air with a luminous flame, its presence in coal gas is chiefly responsible for the luminosity of the latter, forms an explosive mixture with air, of high fuel value (1615 British thermal units per cubic foot). Ethylene reacts (1) with **chlorine (bromine, iodine)**, to form ethylene dichloride ($C_2H_4Cl_2$ or $CH_2Cl \cdot CH_2Cl$) (dibromide, diiodide), (2) with **hypochlorous acid (hypobromous acid)**, to form ethylene chlorohydrin ($CH_2Cl \cdot CH_2OH$), (bromohydrin), (3) with **hydrogen iodide** or **bromide** (not chloride) to form ethyl iodide (C_2H_5I) or ethyl bromide (C_2H_5Br), (4) with **hydrogen**, in the presence of a catalyzer, e.g., finely divided nickel at 150° C., to form ethane (C_2H_6 or $CH_3 \cdot CH_3$), (5) with concentrated **sulfuric acid** at 160° C. to form ethyl hydrogen sulfate ($C_2H_5HSO_4$) from which ethyl alcohol is readily made, (6) with **potassium** permanganate, to form ethylene **glycol** ($CH_2OH \cdot CHOH$), although glycol is made preferably from ethylene dichloride or chlorohydrin. Ethylene is made by the removal of water from ethyl alcohol, either by passing over heated bauxite, or by heating with concentrated sulfuric or **phosphoric acid**, and is recovered from gas mixtures in which it is present, e.g., oil-cracking gases where the olefin content may be as high as 35%. Ethylene is used (1) in the preparation of its derivatives, (2) as an **anesthetic**, (3) as a fuel with oxygen for high temperature flames, (4) as a coloring and ripening agent for citrus fruits and tomatoes. Ethylene chlorohydrin is used as an agent for decreasing the dormant period of seeds. Fuming sulfuric acid is used as a reagent for the absorption and estimation of ethylene in a mixture of gases. (R.K.S.)

ETIOLATION. This is the effect of darkness on a living plant. It is a matter of common observation that plants grown in dark contain little or no chlorophyll and so are nearly white. Green plants placed in darkness lose their chlorophyll. Eventually, when the food reserves are exhausted, the plant dies.

Besides the lack of chlorophyll, plants grown in the dark have other characteristics. In **dicotyledons**, the internodes of the stem become excessively elongated and very slender. The leaves are very long, wear **petioles** and small blades. In **monocotyledons** the leaves become very long and usually very narrow, but the stem shows little change. Etiolated plants never bear flowers, unless the flower buds are well developed before the plants are darkened.



Formative influence of light. Bean (Phaseolus) grown ten days in light (left), ten days in dark (right).

Internally the tissues are soft and lack strength, the cells being very large and having thin walls. Very little differentiation occurs, the conducting tissues being very much reduced. Leaves which form in darkness show very little of the structure characterizing a normal green leaf, but are almost entirely composed of loosely arranged **parenchymatous** cells.

The cause of the conditions observed in etiolated plants is not at all understood. The cessation of **photosynthesis** and the consequent inability of the plant to manufacture foodstuffs does not explain the phenomenon, since no etiolation effects are observed in experiments in which photosynthesis is entirely stopped by withholding **carbon dioxide** from a well-lighted plant.

This phenomenon is used to advantage in the growing of certain plants used for salads. French endives are grown in light until a food reserve is stored up, then held in storage, and later forced in darkened rooms. The bleaching of celery is a similar process, produced by covering the leaf petioles with earth or sheltering them with boards or paper. (R.M.W.)

ETIOLOGY. Knowledge of the cause of any disease or abnormal condition. (R.S.M.)

ETTINGSHAUSEN EFFECT. This phenomenon, discovered in 1887, is analogous to the **Hall effect** and appears to be closely related to it. If a strip of metal in which an electric current flows longitudinally is placed in a magnetic field with the plane of the strip perpendicular to the direction of the field, it is found that corresponding points on opposite edges come to different temperatures. If, to one looking along the strip in the direction of the current, and with the magnetic field downward, the decrease of temperature is toward the right, the effect is positive. This is the case with bismuth, in which the phenomenon was first observed by Ettingshausen. The same is true of antimony, nickel, and cobalt; but in iron the effect is negative. See also **Nernst** and **Righi-Leduc Effects.** (L.D.W.)

EUCALYPTUS OIL. Volatile oils.

EUCLASE. The mineral euclase is a **silicate** of **beryllium** and **aluminum** corresponding to the formula $Be(AlOH)SiO_4$ which crystallizes in the **monoclinic** system. It has a perfect prismatic cleavage; hardness, 7.5; specific gravity, 3.1; luster, vitreous; is colorless to sea-green or blue. It has been used to a very slight extent for jewelry as its transparent crystals somewhat resemble the aquamarine. Euclase occurs in the Minas Geraes region, Brazil, associated with **topaz** and **beryl**, and also in the Ural Mountains, where it is found in gold-bearing sands. The name euclase is derived from the Greek meaning easiness and fracture, in reference to its easily cleaved crystals. (E.S.C.S.)

EUGENICS. A division of biological science closely related to sociology. It is concerned with the study of human **heredity** and with methods of improving the heritage of human beings.

Sir Francis Galton, a student of human heredity, was a pioneer in suggesting the possibility of securing a better heritage for mankind by the deliberate control of human reproduction. It is evident now that man cannot extend to himself under his present social system the degree of control that he applies to his domestic animals, but a few measures have seemed possible Whether the possibility is more than theoretical is doubtful, but these measures are still advanced as the program of eugenics. They depend chiefly on the birth rate of different classes.

In the United States about 3.4 children per family is the average necessary for the maintenance of the population. This number is equaled only by the portion of the population at the lowest levels of mental development adequate for self-maintenance in society, while families of higher intelligence average far below it. Mental defectives who have to be confined in public institutions are not a serious source of concern, for many of them have no opportunity to reproduce, but at the level of the low-grade moron families average slightly more than four children. In the highest levels

of the population, too, there is little need for concern Families average slightly less than three children, but better opportunities probably offset this low figure The great mass of respectable, self-maintaining, ambitious human beings between these extremes, however, average scarcely a child per family and so are far from maintaining their lines of descent.

The purpose of eugenics to correct this discrepancy demands for its realization some practical means of leveling the birth rate by increase in the upper brackets of society and by decrease in the lower Sterilization has been suggested for the latter purpose and has been legalized by more than half of the states It can be applied as a legal compulsion, however, only to institutionalized criminals and defectives, and this application does not reach the parts of society most in need of restriction To increase the rate of reproduction in the higher middle classes is no easier Since economic problems are an important cause of the limitation of families, it has been suggested that state subsidies for the care of children would be an aid Unfortunately practical subsidization in the United States has been forthcoming only as charity and government aid, which have enabled the indigent to continue their overproduction at the expense of their more provident fellow citizens Education in the serious import of the unbalanced birth rate and in the responsibility of the family to society have also been suggested, but unfortunately the foundations of human existence involve a stronger sense of responsibility to family than to society

As a result of the lack of feasibility or of promise in the proposed measures of eugenics, the science is in the unenviable position of realizing the needs of mankind for the assurance of its future welfare and improvement, and of being impotent to accomplish any important gains toward the desirable end Until the individual can be more completely subordinated to society it will undoubtedly remain at this impasse (A W L)

EUGLENOIDIDA. An order of one-celled animals **Mastigophora.**

EULAMELLIBRANCHIATA In some classifications an order of **bivalve** mollusks containing the **oysters** (A W L)

EULERIAN COLUMN. **Column.**

EULER'S THEOREM ON THE EXPONENTIAL FUNCTION Euler's theorem is a remarkable mathematical result giving a relation between the **trigonometric functions** and the **exponential function** It may be expressed by the formula

$$\cos x + i \sin x = e^{ix} \qquad \text{(L L S)}$$

EULER'S THEOREM ON HOMOGENEOUS FUNCTIONS. This is a statement of a mathematical result concerning a certain type of function

If $u = f(x, y, z, \ldots)$ is a **homogeneous function** of two or more variables which has continuous first **partial derivatives**, then

$$x\frac{\partial u}{\partial x} + y\frac{\partial u}{\partial y} + z\frac{\partial u}{\partial z} + \cdots = nu \qquad \text{(L L S)}$$

EUPHAUSIACEA. A small order of marine **crustaceans.**

EUPHORIA. This term describes a feeling of well-being which may not be justified by the physical condition of the patient It is seen in certain mental disturbances and especially in the terminal stages of **peritonitis** (R S M)

EUROPEAN CORN BORER. Insecta, Lepidoptera A small **moth**, *Pyrausta nubilalis*, whose **larva** bores in the stems of plants, especially Indian corn The species is closely related to certain North American moths and was first noticed as a pest in the eastern part of the United States about 1920 Since then it has spread halfway across the continent (A W L)

EUROPIUM. Symbol Eu Atomic number 63. Atomic weight 152 0 Type of compound Eu_2O_3 Color of salts Rose Discovered by Demarçay in 1906. A member of the **cerium** sub-group of the rare earth metals (R K S)

EURYALAE Ophiuroidea.

EURYPTERID. **Invertebrate paleontology.**

EUSTACHIAN TUBE A slender canal between the **pharynx** and the middle **ear** of **vertebrates** It permits the equalization of pressure on the two surfaces of the ear drum (A W L)

EUTAXIC. A term proposed by Keyes in 1901 for obviously stratified **sedimentary** ore deposits as contrasted with those which are unstratified The latter he designated as **ataxic** (R M F)

EUTECTIC. This term is applied by **petrologists** to a discrete mixture of two or more minerals, in definite proportions, which have simultaneously crystallized from the mutual solution of their constituents The eutectic point is the lowest temperature at any given pressure at which the above physical-chemical process may take place The eutectic ratio is the ratio by weight of two minerals which originate by the above process

The term eutectic is used in metallurgy in reference to that particular mixture, of a definite composition, of two or more given substances which has the lowest freezing point The solid which separates at this temperature has the same composition as the liquid (R M F, F T M)

EUTHANASIA. Easy or painless death brought on to end a lingering, hopeless, painful, disease (R S M)

EUTHERIA Mammalia

EVAPORATION The evaporation of a liquid consists in the escape from the main body of the liquid of those **molecules** which, in their thermal agitation, are moving with a sufficient speed to break through the **surface tension**, that is, whose **kinetic energy** exceeds the **work function** of cohesion at the surface Since only a small proportion of the molecules are at any instant located near enough to the surface and are moving in the proper direction to escape, the rate of the evaporation is limited It is easy to see why it proceeds more rapidly with higher temperature, and why liquids of low surface tension are relatively volatile Also, as the faster moving molecules emerge, those left behind have less average energy, and the temperature of the liquid is thereby lowered If the evaporation takes place in a closed vessel, the escaping molecules accumulate as a **vapor** above the liquid Many of them return to the liquid, such returns being more frequent, the greater the density and pressure of the vapor Presently the processes of escape and return come to equilibrium, the vapor is then said to be "saturated," its density and pressure no longer increase, and the cooling effect ceases. Even a warm breeze cools the skin because it removes the evaporating perspiration and prevents saturation See **Hygrometer, Distillation,** and **Heat of Vaporization** (L D W)

EVAPORATOR. Evaporators are used, (1) to concentrate a solution by volatilization of water it contains, (as discussed in the article on **Distillation**), and (2) to produce pure water from sea water, or other impure source of supply

An evaporator system may be single effect, in which the steam is produced from one evaporator, or multiple effect, in which the steam is produced from several evaporators in series In a multiple effect system the

vapor from one evaporator becomes the heating steam in the succeeding Unusual conditions met in industrial or steam heating plants may require so large a fraction of make-up as to warrant double, triple, or quadruple effect evaporators The central generating station ordinarily employs single effect and rarely requires more than a double effect system The ratio $\frac{\text{vapor produced}}{\text{steam used}}$ is about 0 8 for the single effect, 1 5 for the double effect, and 2 5 for the triple effect system Evaporator feed is sometimes preheated to increase evaporator capacity In power plant design the evaporator system should be considered a vital part of the heat balance, the larger the per cent make-up the greater its importance

Evaporators are classed as film, flash, or submerged tube types The first and last are steam-tube types, in the former the raw water trickles over the hot tubes, in the latter the tubes are entirely surrounded by the water being evaporated The flash type produces steam by dropping the pressure on water at the saturation temperature The excess heat flashes part of the water into steam, then the remainder is drawn off, reheated, and again flashed (F T M)

EVERGREEN. Conifers.

EVOLUTE OF A PLANE CURVE. The evolute of a curve is the locus of the center of curvature of the given curve

The **normal** to a curve at a point P is **tangent** to its evolute at a corresponding point Q, so that the **envelope** of the system of normals to a given curve is the evolute of that curve (L L S)

EVOLUTION. In astronomy, for the evolution of the planets, see **Solar System**, for that of stars or the sun, see **Stars** In mathematics, evolution is the operation of raising a number to a given positive integral **power** (i e, of multiplying a number by itself a certain number of times) is sometimes called evolution Its two **inverse operations** are involution and taking **logarithms**

In biology, evolution is a process of gradual transformation In application to living things, it is the process by which their hereditary characteristics are modified through a series of generations, resulting ultimately in the production of new subspecific units and species differing in various degrees from the ancestral stock

The idea of gradual change in living things as a normal part of their vital processes, and the idea of origin of species through these changes, were expressed in a crude form by the philosophers of ancient Greece, but it was not until 1859, when Charles Darwin published his famous book, the *Origin of Species,* that they were so firmly established as to be a permanent part of science The idea of evolution now permeates all fields of science In biology organic evolution, as opposed to special creation of species by a divine power, is regarded as an established principle, although it is still referred to as the theory of evolution

The evidences of evolution are derived from two sharply contrasted fields, biology and **paleontology** In the former the subsidiary anatomical sciences, **embryology** and **physiology**, reveal countless details of relationship among living things All are related in their cellular and protoplasmic structure and in taxonomic groups within the animal kingdom the resemblance becomes more and more detailed as the lower divisions are approached Thus all animals resemble each other in metabolic processes, in contrast with plants Within the kingdom a fairly sharp division into the one-celled **Protozoa**, the loosely integrated multicellular **Parazoa** containing only the sponges, and the numerous phyla of **Metazoa**, is evident Among the Metazoa **diploblastic** and **triploblastic** structure, **coelomate** and **acoelomate**, and metameric and unsegmented, mark other progressive divisions. The classification of the entire kingdom expresses all details of relationship (**Anatomy, classification, tree of life**)

The interpolation of these relations varies To the person who is satisfied with the idea of special creation it is no more difficult to believe in the creation of related forms than of unrelated, but several types of evidence lead the biologist to entirely different conclusions The existence of structurally similar organs (**homology**) adapted to widely different environmental conditions is among these evidences An example is the group of appendages, including the human arm, the flipper of the whale, and the wing of a bird All are based on the **pentadactyl appendage** although they differ so widely that they are superficially unlike each other Structures of similar uses but very different structure (**analogy**), such as the wings of birds and insects, indicate that animals may be adapted to a given environment in different ways, hence the many examples of homologous organs such as those mentioned above are strongly suggestive to the scientist that animals have been able gradually to become adjusted to environments different from those of their ancestors through structural modification The vestigial organs recorded by anatomy, such as the human appendix and wisdom teeth, are additional evidence Structures of no value to the individual and sometimes even harmful can most satisfactorily be explained as persisting remnants of things once useful in an ancestral stage

Only one biological science, embryology, reveals an actual transition in structure This transition is the foundation of the recapitulation theory or biogenetic law which postulates that the individual during its development passes through steps representative of ancestral stages in its evolution The idea must be used with caution, for no embryonic stage can be regarded as precisely like a preceding ancestral form and such conditions as **cenogenesis** are accompanied by correspondingly great modifications in individual development In some structures, however, a transition occurs that is too closely like the sequence of structures in related groups of animals to be wholly insignificant The circulatory system of the vertebrates is a particularly good illustration In an embryonic bird or mammal it is first like that of a fish in many details, then like that of an amphibian, then it resembles the reptilian system, and at last it attains the distinctive development of its own class This transition involves the formation and destruction of many parts and the remodeling of a structural plan fitted for a gill-breathing animal to form that of a lung-breathing type Such preliminary stages cannot be explained as necessary to the ultimate pattern of the organic system in all cases They are much more logically interpreted as remnants of ancestral stages, pointing to the origin of existing forms by evolution from ancestors in which they were definitive adult structures

Paleontology adds to this evidence a fragmentary record of extinct inhabitants of the world in the form of fossils These remains are in many cases associated with strata of sedimentary rocks that have enabled geologists to determine a sequence of past ages extending through many millions of years In the chronology thus established the fossil remains appear also as a sequence, extending from the simplest forms in the oldest fossil-bearing rocks to man in the most recent periods, with a dominance of various forms of gradually increasing complexity between In this sequence only invertebrate remains appear in the earlier deposits Later primitive fishes are found, and still later an age of fishes in which the group gained high development The succeeding periods are an age of amphibians, an age of reptiles, and finally an age of mammals

In many cases abundant fossils have made it possible to arrange series of forms leading by very gradual stages from some remote ancestor to an existing species One

of the most famous of these ancestral series is that of the horse Beginning with a small browsing animal, *Eohippus*, with four toes on the front feet and three on the hind, it passes through the gradual loss of all but one toe on each foot, accompanied by increase in size and by the modification of the teeth for grazing Sequences of this kind, and the many fossils of animals unlike the present fauna, leave no doubt that the population of the world has undergone tremendous changes, and no reasonable doubt that the changes have been based on the gradual modification of living things

Accepting the occurrence of evolution, biological science is particularly interested in knowing how such changes have come about Various theories have been proposed but exact knowledge of the nature of evolutionary change is still lacking

Two schools of thought were emphasized in the earlier works on evolution following Darwin's contribution, one based on the ideas of the French biologist, Lamarck, and the other on those of Darwin Lamarck emphasized the reaction of the individual to its environment through the use or disuse of inherited potentialities as a source of modifications The results of such reaction in the individual body are commonly called acquired characteristics Lamarck regarded them as the foundation of evolutionary changes through a succession of generations Darwin's theory of natural selection, on the other hand, emphasized the great variation of heritable characteristics as the basis of evolution through the selective action of the environment He pointed out that overproduction is a general tendency among living things Assuming that variation within species results in some individuals being better equipped than others to meet environmental conditions, he concluded that these well-adapted individuals would have a better chance of surviving and perpetuating their inherited characteristics He added that these characters would continue a progressive development in succeeding generations, to the ultimate production of new species This theory is also known as the survival of the fittest

Many objections have been proposed to both of these theories Lamarck's idea that change occurs in the individual through reaction to the environment, or by use and disuse, is abundantly supported We have no reason to believe that such changes are inherited, but whether or not they have some influence on the development of the following generation is less clear Darwin erred chiefly in assuming the progressive development of selected characters Apparently natural selection alone can result only in the splitting up of a species or in the contraction of its range of variation, but not in change beyond existing limits of variation An even more serious objection is that the destruction of surplus individuals is largely accidental, offering no opportunity for the preservation of any particular hereditary characteristics

One early result of this controversial approach was a futile attempt to establish some influence of body structures on reproductive tissues The modern approach to this problem accepts the unity of the body and the close coordination of all of its parts, reproductive tissues included, but is still at a loss to prove that reactions of the body to environmental factors during the life of the individual have an effect on succeeding generations

An important modern contribution is the mutation theory of De Vries, a Dutch botanist Mutations are abrupt changes from the ancestral range of variation, which breed true, barring further change of the same kind Mutations have been observed in many plants and animals, including the evening primroses with which De Vries worked and the fruit fly, **Drosophila**, which has been so important in the study of **heredity** The recognition of such changes provides a foundation for effective evolutionary change by natural selection, if only it can be demonstrated that some mutations are useful to the individual Unfortunately most of those that have been observed are of no evident value. Even with the assumption that mutation plus selection may be an adequate explanation of evolution, we are faced with the difficulty of explaining the production of mutations, for they are only a recognized phenomenon of unknown source at present They have been produced by the action of penetrating rays, such as x-rays and radium emanations, and in some cases by the effect of temperature on the parent animal Here the problem returns to the interaction of the individual with its environment, and in the normal association of these factors the solution may yet be found

Selective forces, including natural selection, **isolation** of limited stocks, and the deliberate control of reproduction by human interference (**selection**), may well bring about changes in the complex population of the world, and when associated with hybridization their potentialities are greatly increased This type of evolutionary change does not, however, explain the initial appearance of diversity, as any adequate theory of evolution must

Modern investigation of evolutionary processes is closely linked with the science of genetics In this science many of the observed chromosomal irregularities associated with reproduction account for hereditary changes in organisms, to be classed with those mentioned above Our ultimate explanation of evolutionary change may well come from studies of correlated environmental and hereditary changes in this field of study (A W L)

EXACT DIFFERENTIAL EQUATIONS. Ordinary Differential Equations of First Order and First Degree.

EXCESS AIR. The theoretical quantity of air which should supply just that amount of **oxygen** required for chemical union with the molecules of a **fuel** is insufficient for combustion under actual conditions This is because of the dynamic conditions attending the combustion of fuel in a furnace In the relatively short time that the fuel and air are together in a region of high temperature, the imperfection of mixing methods, and the presence of the fuel in lumps and large particles, rather than separated molecules, combine to promote incomplete combustion unless there is an excess of oxygen over that which is actually needed The excess air is ordinarily given as a percentage of the theoretical requirement, and the amount employed is determined by the degree of technological control of combustion practiced, the surface exposure of the fuel, i e , whether the fuel is gaseous, atomized, powdered, or lump, and the perfection of design of the furnace and firing equipment Excess air is shown by the presence of oxygen in the products of combustion When no more than a trace of **carbon monoxide** is present in the flue gas, the excess air may be found by the following formula

$$\text{Excess air} = \frac{20\,9R}{CO_2(R+3)} - \frac{R+2\,37}{R+3}.$$

In this formula the symbol R is employed to denote the "fuel ratio" of the coal, this being the ratio of carbon burned to hydrogen burned with oxygen from the air The carbon is the total revealed by the ultimate analysis, less any fraction left unconsumed in the refuse The hydrogen part of the ratio is ordinarily the free hydrogen, but if much sulfur is contained, the hydrogen should be corrected as follows

$$H = \text{total hydrogen} - \frac{(\text{total oxygen} - \text{sulfur})}{8}$$

R is generally from 50 to 25 for anthracite, 20 to 16 for semi-bituminous, and 16 to 12 for bituminous coals

Fuels ranging from the hard and nearly smokeless anthracite through intervening ranks down to the brown and woody lignite have their combustible elements combined in many different ways but, strangely enough, the air required to produce a thousand heat units from

any coal is very nearly a constant amount. This fact may be turned to good account in rapid determination of the air needed for combustion if the calorific value of the coal is known Trial computations show that a pound of combustion air is theoretically required for each 1340 B T U produced in complete combustion, for any coal chosen

The excess air requirements vary widely with the type of installation Lump coal, fired by stokers, will usually be completely burned with the use of 50% of excess air, whereas in the hand-fired stokers, up to 100% may be necessary, and undoubtedly a great deal of domestic coal firing, unaided by technological information or experience, is carried out with from 150% excess air upwards Pulverized coal and fuel oil may be satisfactorily fired with 5 to 15% excess air, and gaseous fuels fired with the aid of well designed burners may be so effectively mixed with air that no excess air is needed (F T M)

EXCITATION. Excitation of the field windings of a **dynamo** machine produces the magnetic field needed for induction The synchronous generation of **alternating current** by the induction process is based upon a **direct current** field excitation The synchronous electric motor also must be furnished with direct field current, whereas other types of alternating current motors have an alternating field current The direct current generator furnishing field excitation is known as the exciter Depending upon the size of an alternator, its exciter will have a capacity of from one-half of one per cent to five per cent that of the **alternator** The dynamo employed as the exciter is a shunt wound generator, slightly compounded to prevent reverse polarity after a short circuit

The term excitation is also used in reference to other electrical equipment, for example, the excitation of broadcasting antennae

In physics, excitation usually refers to the process of putting an atom or a molecule into a condition in which the total energy of its interior mechanism is greater than it is in the normal or "ground" state (This does not refer to energy of translatory motion of the particle as a whole) According to the **quantum theory**, the energy required to accomplish such a change must be supplied in certain definite amounts or quanta A less amount than this "excitation limit" apparently cannot be received by the atom or molecule The necessary energy may be supplied by a **collision** with another atom or with an electron (as a cathode particle), or by the advent of a radiation quantum In the former case the impinging atom or electron must have at least a certain speed (See **Critical Potential**), in the latter, the frequency of the radiation must be sufficient to give its quanta the necessary energy (See **Planck's Law**)

Upon returning to the normal state, or to a state of lower excitation, the atom or molecule yields up this extra energy, ordinarily by emitting a radiation quantum of this amount and of corresponding frequency, as in the emission of light or x-rays, by imparting the energy, in a "second-class" collision, to another atom or molecule, or by hurling off particles of itself, as in induced radioactivity Familiar examples of excitation are the production of incandescence by heating, and the glowing of phosphorescent substances after exposure to light or **X-rays.** (F T M, L D W)

EXCRETION. The removal of the waste products resulting from the chemical transformation of materials in the body

The **oxidation** of materials derived from foods for the release of energy may produce carbon dioxide and water whether the compound oxidized is a **protein, a carbohydrate,** or a **fat,** but since proteins contain **nitrogen** and other elements in addition to **carbon, hydrogen,** and **oxygen,** they also give rise to more complex waste products The chief nitrogenous wastes of animals are **urea** and **uric acid** The elimination of all of these compounds and other substances of like derivation is excretion

Many small animals, including both protozoans (**Protozoa**) and more complex forms, apparently discharge these wastes from the surface of the body generally, while in others a special **excretory system** occurs Even in those forms which have a complex excretory system, any moist surface directly or indirectly exposed to the medium surrounding the animal is favorable for the diffusion of materials into or out of the body, and so may carry on excretion The wastes passed out in this manner are largely carbon dioxide and water, although the discharge of water may also take out dissolved solids Thus the lungs of a terrestrial vertebrate eliminate carbon dioxide and the sweat glands of the skin of some animals discharge water with other materials, including nitrogenous wastes, in solution By far the greater part of the complex wastes is eliminated by the **excretory system**

In complex animals other organs than those directly involved in the elimination of wastes may play an important intermediary role The circulatory system of the **vertebrate,** for example, transports all wastes from the tissues where they are formed to organs which act upon them and finally to the centers which remove them from the body The liver removes some substances, including complex organic compounds resulting from the destruction of old red blood cells, and discharges them in the **bile** by way of the intestine It also transforms **ammonia** and **amino acids** resulting from the oxidation of proteins into urea which is returned to the blood to be removed by the **kidneys.**

Wastes are stored in the body during embryonic life and immature stages of some animals to be discarded with the tissues containing them at birth or transformation The **allantois** of bird embryos serves as a reservoir for wastes and the **fat body** of insect larvae serves a similar purpose according to some observers (A W L)

EXCRETORY SYSTEM An organic system whose principal or only function is the removal of complex wastes from the animal body.

Some animals lack an organized excretory system, discharging wastes from the surface of the body generally, but others, even among the one-celled animals, have special excretory structures The **contractile vacuoles** of protozoans are supposed to carry out this function

In the flatworms a special excretory system based on the flame cell appears Flame cells are large and hollow, with a group of cilia projecting into the cavity whose movement drives out the liquid discharged by the cell The cavity of each flame cell joins a small duct and these ducts converge to form larger ducts which ultimately open at the surface of the body. Flame cells emptying by ducts into a vesicle connected with the caudal end of the alimentary tract also occur in **rotifers**

Roundworms have two slender excretory canals along the sides of the body which unite to empty by a single pore near the anterior end.

In the segmented worms the body cavity becomes involved in excretion Two forms of tubes, the coelomoducts and nephridia, open from the **coelom** to the exterior in these worms These organs are segmentally arranged ciliated tubes with a funnel shaped inner end and a minute opening externally They are variously associated in the excretory organs of different species and in some do not open into the coelom but are provided with cells much like flame cells which are called solenocytes

Arthropods of different classes have special excretory structures including the coxal glands of **scorpions,** said to be derived from coelomoducts, and the Malpighian

tubules of insects The latter are slender tubules opening into the alimentary tract at the caudal end of the stomach and blind at their other end

The occurrence of **solenocytes** in the lancelets of the phylum **Chordata** is unusual in this phylum, since in the true vertebrates a pair of kidneys are the chief excretory structures They are developed from intermediate mesoderm (**Embryology**) The excretory unit in these organs is a minute tubule which has in its primitive form a ciliated funnel leading from the coelom At their lateral ends the series of tubules unite to form a duct which grows back to empty into the **cloaca.** The tubule is associated with a knot of blood vessels near the coelomic opening (the nephrostome) In a more advanced stage of development excretory tubules lack the nephrostome and have the wall expanded to form Bowman's capsule, embracing the knot of blood vessels which is called a glomerulus This unit, known as a renal corpuscle, is found in the kidneys of most vertebrates The tubule leading from it is also specialized for the removal of wastes from the blood

Three pairs of kidneys are found in different vertebrates and appear in succession in the embryos of the higher classes, the reptiles, birds, and mammals In cyclostomes and embryos of fishes and amphibians the kidneys are pronephroi, lying well forward in the body and made up of tubules of the primitive type The pronephroi are vestigial in embryonic reptiles, birds and mammals Functional kidneys in these embryos and in the adults of cyclostomes fishes and amphibia are the mesonephroi, lying behind the pronephroi and made up of closed tubules As they develop these tubules connect with the duct formed by the pronephroi, this duct is then called the mesonephric or Wolffian duct In adult reptiles, birds and mammals the mesonephroi are replaced by the metanephroi, lying still farther back Their tubules develop in a mass of tissue surrounding a blind diverticulum of the mesonephric duct

The connection of the excretory ducts with the cloaca persists in many vertebrates but in the true mammals this passage splits to form a dorsal rectum and a ventral urogenital sinus which receives the Wolffian duct An expanded reservoir, the urinary bladder, developed ventrally in connection with the cloaca, ultimately receives the ducts of the metanephroi, while the remainder of the mesonephric duct persists in the male as the main duct of the testis The relations of all these parts differ greatly in animals of different groups In all animals with metanephroi the ducts leading from the kidneys are called the ureters and a separate duct from the urinary bladder to the exterior is the urethra

The association of excretory and reproductive passages is considered under the **urogenital system** (A W L)

EXOCYCLOIDA. An order of sea urchins **Echinoidea**

EXOGENTIC. A general term designating all surficial, or near surficial, geologic processes such as **erosion,** deposition, **secondary enrichment** of ore bodies, etc Not particularly applicable to volcanism (R M F)

EXOPHTHALMIC GOITRE. Thyroid Gland.

EXOPHTHALMOS An abnormal protrusion of the eyeball most often seen in **Grave's disease** or certain forms of hyperthyroidism (See **Thyroid Gland**) (R S M)

EXOPODITE. Biramous appendage.

EXOPTERYGOTA. Insects whose wings appear in the immature stages as external flaps These insects have gradual or incomplete metamorphosis, hence the term embraces the **Paurometabola** and **Hemimetabola** of some writers (A W L)

EXOSKELETON. Skeletal system.

EXOTHERMAL CHANGE. Thermochemistry.

EXPANDING UNIVERSE. Spirals.

EXPANSION. The term expansion refers commonly to a process in which a constant mass of a substance undergoes an increase in volume In thermal expansion this is brought about by the application of heat to the substance Expansion processes are of great importance in engineering Thus, the power derived from steam engines and turbines, and internal combustion engines is produced as a result of expansion of gases and vapors Expansion of metals with increase of temperature is the operating principle of **thermometers, thermostats,** and many other useful devices On the other hand the increase in size of pipes as they are heated creates a problem in engineering design. (See **Expansion Joint**)

Each molecule of a body of matter in any state appears to monopolize a certain amount of space which, while it cannot be accurately called the volume of the molecule, does represent the contribution of that molecule to the volume of the whole body The molecules are in a state of agitation, and it is to be expected that the space which any molecule monopolizes, or keeps clear for itself, will be larger, the greater the amplitude of its oscillations (just as one may make a post-hole larger by working the post to and fro in different directions) We have here the fundamental reason for the expansion of bodies with rise of temperature (See **Heat**)

The rate of expansion of a substance with temperature has been expressed by several different "expansion coefficients" The one now usually employed, as regards change of volume, may be defined as the rate of change of the volume of a body of the substance with respect to temperature, divided by its volume at the zero of temperature

$$X_v = \frac{dv}{dt}/v_0 \qquad (1)$$

Thus for iron at ordinary temperatures, X_v is about 0 000036 per Centigrade degree While not strictly constant, it is nearly enough so for ordinary purposes By interpretation of (1) the volume at any temperature t is

$$v = v_0(1 + X_v t) \qquad (2)$$

These statements apply alike to solids, liquids, and gases The fact that the coefficient X_v is nearly the same for all gases is expressed by **Charles's law**

For solids we may also define a linear expansion coefficient, relating to the change in any one dimension l, thus

$$X_l = \frac{dl}{dt}/l_0, \qquad (3)$$

from which the value of that dimension at any temperature t is

$$l = l_0(1 + X_l t) \qquad (4)$$

Since for an isotropic solid the volume at a given temperature is proportional to the cube of any dimension, it is easy to show that

$$X_v = 3\left(\frac{l}{l_0}\right)^3 X_l \qquad (5)$$

But for moderate temperatures l and l_0 are nearly equal, hence, practically, the volume coefficient is three times the linear Thus the linear coefficient for iron is about 0 000012 per degree Centigrade

If from the known thermal capacity of a solid we deduct the calculated energy corresponding to change of thermal agitation in all the atomic degrees of freedom, and also the energy expended in expansion against the external pressure, the remainder may be taken as

representing the work of expansion against cohesion, and hence used as a means of calculating the "internal pressure" arising therefrom (See **Adhesion and Cohesion**)

Much progress has been made in the preparation of substances having expansion coefficients of desired value Thus "platinite" (54% iron, 46% nickel) has practically the same coefficient as glass and may therefore be used for lead-wires in vacuum tubes, while "invar" (64% iron, 36% nickel) has a linear coefficient of only 0 0000008 per degree centrigrade, and is therefore suitable for clock pendulums (L D W, F T M)

EXPANSION JOINT. Metals constituting pipes have the property possessed by all materials of expanding with increase of temperature Were they constrained to a fixed length, a reaction equivalent to the force required to compress the pipe through a **deformation** equal to the prevented expansion would be set up For all but very short steam lines this force is too large to incorporate in the piping system The same force would be present, theoretically, in the short line, but the supports would have enough elasticity to take the small expansion In long lines the expansion is permitted by the use of suitable joints and bends

Both packed and packless expansion joints are used for saturated steam at pressures up to 250 pounds per square inch High temperature has a deteriorating effect on packing, however, packed joints have been designed for high temperature by protecting the packing by air-cooled sleeves Expansion joints take up expansion at one point by allowing relative motion of the two sections of pipe connected by the joint Usually one pipe end is anchored by a rigid connection to the body of the joint but occasionally the double slip joint in which both pipe ends are free to move in the joint is used

When expansion is to be taken by the flexibility of the pipe itself various forms of pipe bends are used This way of caring for expansion is free of the temperature-pressure limitations of the expansion joints and also of any maintenance work such as the repacking of joints Consequently, it has been the standard for boiler and turbine leads and for long runs of high-pressure piping of all sorts Its principal drawbacks are the added friction losses, the expense of fabrication (most bends are special jobs), and the space required (F T M)

EXPANSION OF DETERMINANTS BY MINORS. Determinants

EXPANSION OF FUNCTIONS IN SERIES In many mathematical investigations it is desirable to express a given function in a certain special form of representation known as an infinite series One important use of such representation is for the calculation of numerical values of functions, as, for instance, in the preparation of mathematical tables

Taylor's formula with a remainder for a **function** of one variable is

$$f(a+h) = f(a) + hf'(a) + \frac{h^2}{2!}f''(a) + \frac{h^3}{3!}f'''(a) + \cdots + \frac{h^{n-1}}{(n-1)!}f^{(n-1)}(a) + R_n.$$

Various formulas have been given for R_n, some of which will be given presently

If $f^{(n)}(x)$ is finite in an interval (a, b) for all values of n and if $R_n \to 0$ when $n \to \infty$, then the formula gives a **convergent infinite series (power series)** for the function $f(x)$

Lagrange's form of the remainder is.

$$R_n = \frac{h^n}{n!}f^{(n)}(a+\theta h) \quad \text{where} \quad 0 < \theta < 1$$

Cauchy's form of the remainder is

$$R_n = \frac{h^n(1-\theta)^{n-1}}{(n-1)!}f^{(n)}(a+\theta h), \quad 0 < \theta < 1$$

Let $|f^{(n)}(x)| \leqq M$ in the interval to be considered, then

$$|R_n| \leqq \frac{|h|^n}{n!} M$$

When $a = 0$, Taylor's formula becomes Maclaurin's formula

$$f(h) = f(0) + hf'(0) + \frac{h^2}{2!}f''(0) + \cdots + \frac{h^{n-1}}{(n-1)!}f^{(n-1)}(0) + R_n$$

If $R_n \to 0$ as $n \to \infty$, we obtain a power series expansion for $f(h)$ in powers of h

Some important expansions of elementary functions in power series are

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \cdots,$$

convergent for all values of x,

$$\log_e(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots,$$

convergent for $-1 < x \leqq 1$,

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots,$$

where x is in radian measure, convergent for all values of x,

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \quad ,$$

(x in radian measure), convergent for all values of x,

$$(1+x)^m = 1 + mx + \frac{m(m-1)}{2!}x^2 + \frac{m(m-1)(m-2)}{3!}x^3 + \cdots,$$

convergent for $-1 < x < 1$, when m is not a positive integer

Taylor's formula with remainder for a function of two variables is

$$f(a+h, b+k) = f(a,b) + hf_x(a,b) + kf_y(a,b) + \frac{1}{2!}[h^2f_{xx}(a,b) + 2hkf_{xy}(a,b) + k^2f_{yy}(a,b)] + \cdots + R_n,$$

or in symbolic form

$$f(a+h, b+k) = f(a,b) + \left(h\frac{\partial}{\partial x} + k\frac{\partial}{\partial y}\right)f(a,b) + \frac{1}{2!}\left(h\frac{\partial}{\partial x} + k\frac{\partial}{\partial y}\right)^{(2)}f(a,b) + \frac{1}{3!}\left(h\frac{\partial}{\partial x} + k\frac{\partial}{\partial y}\right)^{(3)}f(a,b) + \cdots + \frac{1}{(n-1)!}\left(h\frac{\partial}{\partial x} + k\frac{\partial}{\partial y}\right)^{(n-1)}f(a,b) + R_n,$$

where

$$R_n = \frac{1}{n!}\left(h\frac{\partial}{\partial x} + k\frac{\partial}{\partial y}\right)^{(n)}f(a+\theta h, b+\theta k), 0 < \theta < 1$$

(L L S)

EXPLICIT FUNCTION. If a **function** is defined by a relation between the **variables** giving an **equation** expressing one variable directly in terms of the other without the necessity of solving the equation, the function so defined is called an explicit function (L L S)

EXPLOSIVES. Explosives are substances that, either pure or with admixture of other substances, react rapidly with the production of local high temperature and the generation of large volumes of gases The power from the expansion of the gases is utilized for propelling charges or for **blasting** objects, usually for military or industrial purposes Gunpowder was the first explosive to be used Not until 1865, when Abel perfected a process for washing nitrocellulose, "guncotton" (cellulose hexanitrate) thus making it safe to store and use, and in 1867, when Nobel discovered that nitro-

glycerine (glyceryl trinitrate) could be rendered safe by absorption in a porous material such as kieselguhr, were safe explosives available In 1886, Nobel gelatinized these two explosives, nitrocellulose with nitroglycerine, and at the British government laboratory these were gelatinized with **acetone** Such an explosive is in very general use as a propellant

Black powder (gunpowder) consists of an intimate mixture of finely divided solids, 75% **potassium** nitrate, 15% **carbon**, 10% **sulfur**. Powders for sporting guns contain a slightly larger percentage of potassium nitrate (75 to 78%), smaller percentage of carbon (15 to 12%), and a variation in sulfur from 9 to 12% Mining or blasting powders, where large volumes of gas are desired may have 14 to 21% carbon and 13 to 18% sulfur When ignited, potassium nitrate supplies oxygen for the combustion of explosives, of carbon to carbon dioxide and of sulfur to sulfur dioxide One gram of powder yields 250 to 300 milliliters of gas measured at 0° C and 760 millimeters pressure The heat evolved per gram is 500 to 700 calories, and the temperature of the explosion is estimated at 2700° C

In explosives of the smokeless powder type, that is, composed of nitrocellulose-nitroglycerine-trinitrotoluene, the material composing the explosive furnishes oxygen for its own combustion when exploded One volume of nitroglycerin produces by explosion 1300 volumes of gas, measured under ordinary conditions or 10,000 volumes at the temperature of explosion The speed of the explosive wave in various explosives is as follows

Explosive	Speed of Explosive Wave Meters per Second
Nitroglycerin	1300
Dynamite	2700
Hydrogen plus oxygen	2800
Nitrocellulose	3800 to 5400
Picric acid	6500
Ethyl nitrate	
(*a*) In rubber tube covered with cloth	1600
(*b*) In glass tube	2500
For comparison	
	Speed of Sound Wave
Hydrogen plus oxygen	515

Nitrocellulose is soluble in **acetone**, ethyl acetate (See **Esters**), **nitrobenzene** or **benzene**, insoluble in water, alcohol, ether, **acetic acid**, or nitroglycerin, when treated with **iodine** dissolved in **potassium** iodide solution followed by **sulfuric acid**, turns yellow (**cellulose** similarly treated turns blue), when treated with sodium **sulfide** solution or **ferrous** chloride solution, decomposes and is thus treated when it is desired to destroy the explosive When carefully washed, nitrocellulose may be transported in the wet condition in wooden boxes placed inside zinc boxes, which are then hermetically sealed. Nitrocellulose may be ignited and burned in the open air without explosion The ignition temperature of various explosives is as follows

Explosive	Ignition Temperature
Nitrocellulose (not compressed)	220 to 250° C
Nitroglycerine (explosive at 240° to 250°) . .	218
Black powder	288
Mercury fulminate	200

In order to produce an explosion it is usually necessary that a **detonator**, such as mercury fulminate, be used to set up the explosive wave The explosive wave may be transmitted through a solid body with which portions of the explosive are in contact, as is shown by setting up a row of dynamite cartridges from 30 to 70 cm apart When the end cartridge is detonated the others are successively exploded by transmission of the explosive wave through the solid support

Nitrocellulose is made by reaction of **cotton** with concentrated **nitric acid** in the presence of concentrated **sulfuric acid** (so-called "mixed" acid) The product is carefully washed free from acid with soda, and in composition is an **ester** (not a nitro-compound) cellulose hexanitrate, containing 13 per cent of **nitrogen** and 85 per cent insoluble in ether-alcohol mixture Less highly nitrated celluloses, soluble in ether-alcohol mixture, are made and used for other purposes, for example, in plastics, collodion and photographic films

Nitroglycerin is made by reaction of **glycerol** with nitric acid and sulfuric acid, in a process similar to that for nitrocellulose The product is also an ester, glyceryl trinitrate, a colorless to yellow liquid, 23 4 per cent nitrogen, freezing point 13° C, very sensitive to shock and dangerous to handle Nitroglycerin is used as dynamite by absorbing in a porous material, such as kieselguhr, which is chemically inert, or wood pulp, which reacts in the explosion Dynamite is safely handled and transported, and the explosive power of the contained nitroglycerin is practically unchanged upon detonation

Composition of Various Dynamites

1	Nitroglycerin	72–75%
	Kieselguhr	24 5
	Sodium carbonate	0 5
2	Nitroglycerin	40%
	Sodium nitrate	45
	Wood pulp	14
	Magnesium carbonate	1
3	Nitroglycerin	20%
	Sodium nitrate	36
	Ammonium nitrate	25
	Roasted flour	18 5
	Sodium carbonate	0 5

Safety explosives, used in coal mining, are designed to diminish the danger of igniting the mine gases, These are made of such materials that the rise in temperature upon explosion is relatively small, and the safety in use is thereby increased

Composition of Various Safety Explosives

1	Ammonium nitrate	37%
	Potassium nitrate	34
	Nitrobenzene	29
2	Ammonium nitrate	82%
	Dinitrobenzene	18
3	Ammonium nitrate	92%
	Trinitrotoluene	4
	Flour	4

High explosives are used for blasting purposes and in bombs, shells, and mines, where great shattering effect is desired

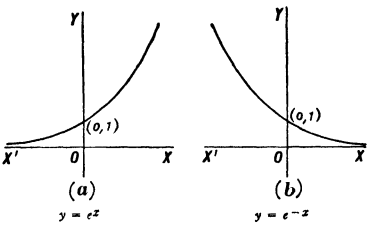
Composition of Various High Explosives

1	Dynamite	
2	Nitroglycerin	90 6%
	Nitrocellulose	8 8
	Calcium carbonate	0 6
3.	Trinitrotoluene	
4	Trinitrophenol (picric acid)	(R K S)

EXPONENTIAL CURVE. This is a very important type of mathematical curve, which is of use in many diverse kinds of problems, as in pure mathematics and in applied mathematical investigations in physics, chemistry, biology, finance, etc

The exponential curve, whose equation is $y = e^x$, is

shown in the accompanying figure It crosses the Y-axis at the point $(0,1)$, is **asymptotic** to the X-axis on the left, and rises more and more steeply on the



Exponential curve

right The graph of $y = a^x$ $(a > 1)$ will be similar to that of $y = e^x$, except of different steepness

The exponential curve, whose equation is $y = e^{-x}$, is also shown in the figure It is the same as the preceding, except reversed in position

The graph of $y = ae^{bx}$ or $y = a\ c^x$ will be similar to that of $y = e^x$, except that it will cross the X-axis at (o, a), and will have a different steepness (slope) (L L S)

EXPONENTIAL EQUATIONS. An equation in which the unknown is involved as an **exponent** is called an exponential equation

Simple exponential equations can be solved by taking **logarithms** of both members and equating them, and solving the resulting **algebraic equation** (L L S)

EXPONENTIAL FUNCTION. An exponential function is a **transcendental function** of the form $y = a\ b^x$, where a and b are **constants** $(b \neq o \text{ or } 1)$, and x is the **variable**, it has a constant base and a variable **exponent**

It is often represented in the standard form $y = ae^{cx}$, where e is the Napierian base, and a and c are constants (L L S)

EXPONENTS. Powers and Exponents.

EXTRACTION Extraction is the process of separation of a desired constituent from the other constituents of a mass The term, as generally applied, refers to (1) Mechanical extraction or expression, in such cases as the expression of vegetable oils from seeds by the application of high pressure The material to be pressed is sometimes placed in layers between cloths which are folded at the edges to prevent expulsion of solid material during compression, and sometimes the material is fed to the annular space between a pair of interfitting slightly tapered compression rolls The oil and press cake residue are collected separately (2) **Solvent** extraction, in such cases as the recovery of oils from oil-bearing material The material is placed in a porous container and subjected to treatment with solvent The solvent containing some dissolved material passes through the porous membrane leaving the undissolved residue in the container The principle of counter-current (See **Dissolving**) extraction may be utilized in consecutive containers, or the solvent may be vaporized from the solution, condensed onto the material, and, by means of a syphon in the apparatus, withdrawn periodically to the solution compartment below, as in the Soxlet type of apparatus When a third substance is of different solubility in two non-miscible liquids, this substance may be separated from the solution of lower concentration by shaking with the more powerful solvent, and then separating the two liquid layers The desired substance may be recovered from the solution by evaporation of the solvent The effectiveness of separation is increased by the use of a given amount of extracting solvent in successive smaller portions rather than by a single extraction with the total amount

Example Upon shaking one volume of liquid A plus one volume of liquid B, suppose a concentration ratio of $\frac{1}{10}\frac{(\text{conc in } B)}{(\text{conc in } A)}$ of the third substance C

Concentration Ratio $\frac{B}{A}$	Volume Ratio $\frac{B}{A}$	Amount of C in B	Amount of C in A	Fraction of C in B	Fraction of C in A
10	1	$10 \times 1 = 10$	$1 \times 1 = 1$	$\frac{10}{11} = 0\ 91$	$\frac{1}{11} = 0\ 09$

Upon shaking one volume of liquid A plus one-half volume of liquid B, and, after separation, shaking one volume of liquid A (containing the residue of C) plus one-half volume of liquid B

	Concentration Ratio $\frac{B}{A}$	Volume Ratio $\frac{B}{A}$	Amount of C in B	Amount of C in A	Fraction of C in B	Fraction of C in A
First Extraction	10	0 5	$10 \times 0\ 5 = 5$	$1 \times 1 = 1$	$\frac{5}{6} = 0\ 83$	$\frac{1}{6} = 0\ 17$
Second Extraction	10	0 5	$0\ 17 \times 0\ 83$	0 03	0 14	0 03
Combined					0 97	0 03

A single equal-volume extraction would, therefore, remove 91 percent of C from A, whereas a double half-volume extraction would remove 97 percent

$\frac{\text{Concentration of solute in liquid } A}{\text{Concentration of solute in liquid } B}$ = Approximately Constant at a given temperature

Example Distribution of Salicylic Acid at 25° C between

A Water and Diethyl Ether

Concentration of Salicylic Acid in Water Layer C_1	Concentration of Salicylic Acid in Ether Layer C_2	$\frac{C_2}{C_1}$
0 0666 millimol per liter	1 3975 millimols per liter	21 0
0 0850 " " "	2 415 " " "	28 4
0 125 " " "	3 855 " " "	30 8
0 195 " " "	7 645 " " "	39 2
0 295 " " "	14 825 " " "	50 3

B Water and Chloroform

Concentration of Salicylic Acid in Water Layer C_1	Concentration of Salicylic Acid in Chloroform Layer C_2	$\frac{C_2}{C_1}$
0 575 millimol per liter	0 625 millimol per liter	1 09
0 850 " " "	1 180 " " "	1 39
1 138 " " "	1 862 " " "	1 64
1 425 " " "	2 625 " " "	1 84
2 625 " " "	6 575 " " "	2 50

(R K S)

EXTRACTION CYCLE Extraction cycle refers to any arrangement whereby steam is bled from a turbine at one or more pressures for any purpose whatsoever, i e, feed-water heating, process steam, heating steam, etc The terms "bled steam" and "extracted steam" may be used synonymously, as may also "bleeder point" and "extraction point"

There are two types of extraction, i e, extraction at constant steam pressure, and extraction at whatever pressure exists in the turbine at the extraction point Extraction at constant pressure requires that an extraction valve gear be provided to regulate the opening through which steam flows into the extraction line

This is necessary because, not only would the extraction pressure vary with different amounts of extracted steam demanded, but varying loads on the turbine would cause the casing pressure at the extraction nozzle to vary. The extraction valve gear is often complicated by the use of a control or pilot valve to operate the main extraction valve. Turbines equipped with extraction valve gear are naturally more expensive than the simpler forms which have no pressure governing on the extraction lines. Industrial use of extracted steam often requires that the pressure of the bled steam be kept constant. Also, industrial use of the extraction turbine differs from central station practice in that frequently a large portion of the total flow is extracted, whereas in the power plant only a small fraction of the total is used for feed-water heating. (F.T.M.)

EXTRACTS. Extracts, or essences, are solutions of flavoring substances, mostly **volatile oils**, dissolved in alcohol or in water. (R.M.W.)

EXTRAEMBRYONIC MEMBRANES. A series of structures developed in connection with the embryos of vertebrates but not as parts of the body itself. They relate the embryo to its environment in several ways. These membranes are the **allantois, amnion, chorion, serosa,** and **yolk sac.** (A.W.L.)

EXTRANEOUS ROOT OF AN EQUATION. In the process of the **solution of equations,** they are often transformed into other derived equations, and one of the derived equations may be readily solved. It sometimes happens that one or more **roots** of the derived equation will satisfy the original equation and also that one or more roots of the derived equation will not satisfy the original equation.

An extraneous root of an equation is a value which satisfies a derived equation but does not satisfy the original equation.

Extraneous roots are liable to occur in solutions of **fractional equations** or **radical equations,** or in **trigonometric equations.** (L.L.S.)

EXTRATHECAL ZONE. The projecting tissue about the base of a **coral polyp,** from which young polyps develop. (A.W.L.)

EXTRA-UTERINE PREGNANCY. Ectopic pregnancy.

EXTRUSIVE ROCK. Effusive.

EXUMBRELLA. The upper or convex surface of the body of a **jelly-fish** or other **medusa.** (A.W.L.)

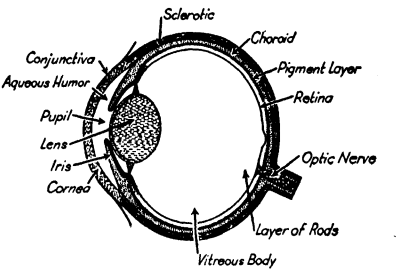
EYE. A sensory organ which is stimulated by light, particularly an organ whose stimulation results in the formation of a mental image of the objects from which the light is reflected or radiated.

Although most eyes enable the animal to form visual images, that is to see in the usual sense of the word, some light-sensitive organs are capable only of perceiving light and the direction from which it comes. Pigment spots in some of the one-celled animals are supposed to be light-sensitive and in flatworms and a few insects the eyes are formed of a group of sensitive cells partially isolated by pigment. The structure of these eyes shows no possibility of their forming images.

Eyes of reasonable complexity are found in some of the segmented worms and three types of complex eyes occur in the phyla **Mollusca, Arthropoda,** and **Chordata.** These three forms of eyes have been extensively studied and are known in detail.

Arthropod eyes are of two kinds, simple and compound, of which one or both may occur in a single individual. The sensory end organ in both forms is the retinula, a group of visual cells surrounding a central optical rod or rhabdom. In many simple eyes a portion of the cuticula is thickened to form a biconvex lens opposite to a group of retinulae. Compound eyes are made up of many ommatidia, each consisting of a similar lens forming a facet of the cornea of the entire eye, and an underlying retinula, with intervening crystalline cells and in some species other structures.

Both mollusks and vertebrates, including, of course, man, have camera eyes, although their development and structure differ. All camera eyes have a lens suspended before a chamber lined with a sensory layer, the retina. In front of the lens is another chamber and in front of that a transparent cornea which acts as a lens in



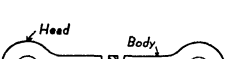
The vertebrate eye.

terrestrial animals. The eye is insulated by a heavily pigmented layer which surrounds it except where the lens is suspended and extends in front of the lens as the iris. The iris, activated by muscles, controls the size of its central opening, the pupil, through which light enters the eye. Light passing through the lens is focused on the retina in a sharp image and the varied stimuli acting on nerve endings result in a definite mental picture. Such eyes are provided with muscles which direct them toward objects to be observed. They also have muscular focusing devices which move the lens in relation to the retina or vice versa, or control the curvature of the lens as in the human eye.

The action of the different kinds of eyes results in different kinds of **vision.** (A.W.L.)

EYE BAR. The eye bar is a heat treated tension member formed from a single piece of steel. The finished eye bar consists of a body having a rectangular cross-section and two circular heads containing holes for **pins,** which are used to connect the eye bar when it forms part of a structure.

In the fabrication of an eye bar the ends of a steel plate, of the correct cross-sectional area and length, are heated and **upset** to form the heads. The heads are next rolled to remove any unevenness resulting from the upsetting operation. While the ends are still hot, holes are punched out which are smaller in diameter than the finished pin holes. The bars are then subjected to special heat treatment which produces a high tensile strength. After cooling, the pin holes are bored to exact size simultaneously.



Eye bar.

Eye bars make excellent tension members since the heat treatment enables them to carry higher tensile loads than the ordinary built-up steel members. As the eye bar is a very slender member it cannot be used where there is a possibility that it will have to carry compressive **stress.** These members are used in the cable anchorages of suspension bridges as well as for tension members of trusses. Eye bar chains have been used in preference to wire cable for suspension bridges.

The tension members of cantilever **bridges** are often composed of eye bars. (C.W.C.)

EYELID. A fold of skin which can be drawn over the eye in **vertebrates** above the fishes. Three eyelids are the maximum. These are an upper and lower lid and a third eyelid or nictitating membrane which passes between the others and the eyeball from the inner to the outer margin of the eye The eyelids contain glands whose secretion lubricates the apposed surfaces of the lids and eyeball, and in the mammals bears a row of stiff hairs, the cilia or eyelashes (A.W L.)

EYEPIECE. The lens, or system of lenses, which is closest to the eye in an optical instrument such as a **telescope** or a **microscope** is known as the eyepiece or ocular. The eyepiece is usually a magnifying device used for the purpose of detailed examination of the real image formed by the objective of the instrument. It is usually designed to act as a collimator to the light from the objective so that the light from each point of the image formed by the objective emerges in parallel or nearly parallel rays Hence in using a telescope or microscope in proper adjustment, the eye should be focused as though looking at a distant object.

The simplest type of eyepiece is either a simple convex or concave lens, of relatively short focus, so placed as to serve as a magnifier for the image formed by the objective. The use of such simple eyepieces is shown in the diagrams in connection with the article on telescopes. Because of the **spherical** and **chromatic** aberrations of the simple lens of short focus, a combination of lenses is usually employed as an eyepiece The two most common types of compound eyepieces are the

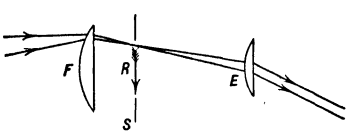


Figure 1. Eyepiece

Huygens (Figure 1) and the Ramsden (Figure 2) In these eyepieces the lens *F* is known as the field lens and the lens *E* as the eye lens. The Huygens eyepiece is placed slightly inside the focus of the objective and the field lens of the eyepiece forms a real image *R* in the plane *S* from which the rays emerge parallel

Figure 2. Eyepiece.

from *E*. In the Ramsden type the field and eye lenses combine to render the light from the real image *R*, formed in the plane *S* by the objective, parallel upon emergence from the eyepiece. Since the Huygens type eyepiece is placed inside of the principal focus of the objective, a **reticle** or **filar micrometer** cannot be used, although a reticle may be placed inside the eyepiece itself in the plane *S* The Ramsden type, on the other hand, is focused directly upon the plane of the real image from the objective and a reticle or micrometer may be placed in this plane. Eyepieces of the Ramsden type, which are simple magnifiers focused upon the real image from the objective, are known as positive eyepieces, while eyepieces placed inside the principal focus of the objective, as in the case of the Huygens type, are known as negative eyepieces. There are many other types of positive and negative eyepieces which will be found discussed in treatises on optical instruments

Both the positive and negative eyepieces give a view of the image from the objective in the same orientation as that image is formed This means that the observer will see the image of a distant object inverted. While this is no disadvantage in microscopes and in astronomical telescopes, it is intolerable in a telescope or field glass to be used for observation of distant terrestrial objects The simple concave lens, as used in the so-called Galilean telescope or opera glass, gives an erect image of a distant object. To avoid the aberrations of the simple concave lens various "erecting systems" are used in terrestrial telescopes. Some of these erecting systems employ prisms, as in the case of binoculars, or complicated systems of lenses. (W.K.G.)

EYRA. **Cat.**

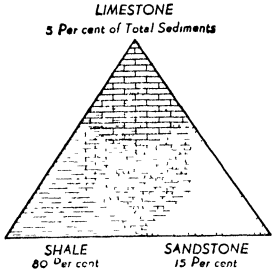
F

FABRIC. In geology, the term proposed by Cross, Iddings, Pirsson and Washington, in 1902, for the shapes and arrangement of **crystals** in an **igneous** rock. (Compare with **texture** and **structure**). (R.M.F.)

FABRICATION. Fabrication is the action of constructing or forming a **structure** composed of a number of separate elements which must be joined together in one way or another, according to a definite plan. The common methods of engineering fabrication include fusion methods, such as **welding**, **adhesion**, exemplified by gluing and **soldering**, and pinned connections, illustrated by bolting, riveting, and doweling. Fabrication will also include those operations necessary upon the several elements in order to fit them for assembly; also such trimming, polishing, or adjusting operations as will put the complete structure in its final shape. Included in this category are operations like **drilling**, **shearing**, **milling**, polishing, plating, etc. (F.T.M.)

FACE. The anterior and ventral part of the head, bearing the mouth, eyes, and in vertebrates the nose. (A.W.L.)

FACIES. In geology, the sum total of the inorganic and organic characteristics of a sedimentary formation. Obviously, different facies of a **sedimentary** formation (sedimentary time unit) are of the same age;



Illustrating the relative abundance of the three principle types of sedimentary rocks and their intergradations, or facies. (Field, *Outline*, Barnes & Noble.)

but similar sedimentary facies may represent different formations. Fossils may be useful in determining the age of a facies, provided the types of organisms have not changed with the change in habitat, which, in the case of marine sediments (such as **limestones** or **shale**) they usually do. The term facies is also used to designate gradational types of **igneous** rocks which are supposed to have been differentiated from a parent **magma**. (R.M.F.)

FACTORIAL NOTATION. **Binomial Formula.**

FACTORING. To factor a **polynomial** means to find polynomials of lower degree than the given one whose **product** is the given polynomial.

By reversing the special **product formulas**, we obtain methods for factoring.

A polynomial with a common monomial factor may be factored by use of the formula

$$ax + bx + cx = x(a + b + c).$$

The difference of two squares may be factored by use of

$$x^2 - y^2 = (x + y)(x - y).$$

Trinomials which are perfect squares may be factored by use of

$$x^2 + 2xy + y^2 = (x + y)^2, \quad x^2 - 2xy + y^2 = (x - y)^2.$$

Trinomials of the form $x^2 + qx + r$ may be factored by use of

$$x^2 + (a + b)x + ab = (x + a)(x + b).$$

Trinomials of the form $px^2 + qx + r$ may be factored by use of

$$acx^2 + (ad + bc)x + bd = (ax + b)(cx + d).$$

The sum or difference of two cubes may be factored by use of

$$x^3 + y^3 = (x + y)(x^2 - xy + y^2),$$
$$x^3 - y^3 = (x - y)(x^2 + xy + y^2).$$

Polynomials may often be factored by grouping of terms and applying the preceding methods

The process of **synthetic division** is often useful in factoring (L.L.S.)

FACTOR OF SAFETY. The factor of safety is a number expressing the relation between the utmost endurance of a structural part, or of a complete structure, to the maximum actual demand that may be expected ever to be made upon it But the factor of safety is not merely some ratio to allow for inaccuracies, lack of knowledge, or absence of confidence Indeed, it has a very definite rational basis which becomes more apparent as the conditions which govern the factor of safety become known Factor of safety has many different forms, a few of which will be given below. It represents a combination of the allowances necessary to be made in the use of practical data The factor of safety will often include a factor which is not so much one of safety, but one of making due allowance for factors known to be present, but not definitely computable. If the engineer could definitely specify the usage and the care to which his product would be put, a large element of the so-called factor of safety would not be necessary. It must include allowance for unavoidable shocks or jars which might be expected during the working life of the structure The material used may not be homogeneous in character, or uniform in all deliveries. Then there is always the desire to be well on the safe side when, due to failure of some part, life will be endangered Usually, the factor of safety, at least for machine parts and structures, is taken as the ratio of the **ultimate strength** claimed or accepted for the material, to the working stress used for design, and presumably reached under maximum design loading.

Factors of safety do not always bear this name; for example, the safety of a masonry **dam** against overturning is contained in a computed ratio of the overturning moment due to water pressure, divided by the stabilizing moment of the masonry weight. Safety in aircraft design is contained in a carefully and scientifically determined "load factor" made up in accordance with certain rules promulgated by a governmental bureau. (F.T.M.)

FACTOR THEOREM OF ALGEBRA. If $x - r$ is a factor of a **polynomial** $P(x)$, then $x = r$ is a **zero** of the **polynomial function** $P(x)$, and $x = r$ is a **root** of the **polynomial equation** $P(x) = 0$; conversely, if $x = r$ is a zero of the polynomial $P(x)$, or is a root of

the equation $P(x) = 0$, then $x - r$ is a factor of $P(x)$ (L L S)

FACULAE. Sun.

FAHLBAND. A Scandinavian term used by miners to describe **metamorphic** rocks containing richly disseminated ore minerals (R M F)

FAHRENHEIT SCALE. Temperature Scales.

FAILURE. The inability of a **structure** or a structural member to perform its proper function causes a condition known as failure. This condition may be the result of sudden fracture as in the case of brittle materials or the excessive **deformation** of ductile materials Another cause of failure is a lack of equilibrium between the external **loads** and resisting forces such as exists in structures which fail by sliding or overturning (C W C)

FAIRED. An object is said to be faired if it is constructed to streamline shape, or has attached to it supplementary bodies which cause it to assume a shape of some degree of excellence of streamlining The term has its major usefulness in aircraft nomenclature where many instances of fairing of parts in the exposed windstreams are present Fairing of exposed struts, wheels, cabins, etc, has done much to reduce wind drag and increase performance Sometimes the part is actually built in a streamline shape, and sometimes the streamline shape is obtained by enclosing the part in a streamlined case, or by attaching to it a shaped piece of some light material, such as balsa wood The best faired object is one whose shape approaches that of a tear drop, having a ratio of length to width of approximately 3 5 (F T M)

FALCON Aves, Falconiformes Large birds (**Aves**) of prey closely related to the hawks and eagles and like them in appearance They are found throughout the world

One species of the Old World is called the windhover, *Falco tinnunculus*, or, in common with other species, kestrel Another is the merlin, *F gesalon* The peregrine falcon, *F peregrinus*, has been widely used for catching game and other birds

Several species of falcons and merlins occur in North America, among them the duck hawk, *F anatum*, pigeon hawk, *F columbanus*, and the little sparrow hawk, *F sparverius* (A W L)

FALCONIFORMES An order of birds of prey containing the **vultures, falcons, eagles,** and **hawks** They have strong hooked beaks and, with the exception of the vultures, large curved claws used for grasping prey The eyes are directed laterally, unlike those of the owls which have similar beaks and claws (A W L)

FALLFISH Pisces, Teleostei A **chub**, *Leucosomus corporalis*, of the eastern states It lives in lakes and rapid streams and is a food and game fish of moderate worth (A W L)

FALLOPIAN TUBES (UTERINE TUBES, OVIDUCTS) The two fallopian tubes in the female are situated lateral to each side of the **uterus**, extending from its upper angle outward to the side of the pelvis, ending near the **ovary** on each side The end of each tube is surrounded by fringe-like processes This portion of the tube is called the fimbria It is partly by means of these processes that the **ovum**, after discharge into the abdominal cavity, gains access into the tube through which it passes to reach the cavity of the uterus

It is believed that fertilization by the male sperm cell takes place along the course of the tube

When the tubes are subject to chronic disease they may be surgically removed Inflammation of the Fallopian tubes is called salpingitis and is most frequently caused by **gonorrhea** It is the most common cause of sterility (For a general zoological discussion of this term, see **Reproductive System.**) (R S M)

FALSE BEDDING. Cross Bedding.

FALSE CLEAVAGE. This is also called strain-slip **cleavage** by the British geologists It differs from the typical slaty cleavage in that it is obviously associated with incipent **foliation** of **metamorphic rocks** (R M F)

FALSE SCORPION. Pseudoscorpion **Arachnida.**

FAMILY. 1 A group of animals consisting primarily of two parents and their offspring, sometimes with other related individuals 2 A taxonomic subdivision of an order Family names are formed of the stem of the type genus with the ending -idae Thus *Homo*, the genus to which man belongs, has the stem Homin- and forms the family name Hominidae. See **Taxonomy.** (A W L)

FAN CHARACTERISTIC. A fan characteristic is a curve showing the relation between pressure and delivery It is important because a fan operates entirely at the conditions depicted by the characteristic curve Hence, it is a basis for fan selection The characteristic is determined by the shape of the blades Blades curved forward in the direction of rotation have what is known as a rising characteristic—pressure increases with volume delivered This characteristic is productive of low tip speed but fans having it can overload their drives if ignorantly handled Backward curved blades have a drooping characteristic

The centrifugal fan compresses the air or gas but slightly In modern fan theory the work of compression is neglected and the action is assumed to be similar to a reversed **hydraulic turbine** or a **centrifugal pump** (F T M)

FANGLOMERATE. The term proposed by Lawson in 1913 for the coarser **clastic** sediments deposited at the head of **alluvial fans** (R M F)

FANS. Draft Fans.

FARAD. Capacitance; Electric and Magnetic Units.

FARADAY EFFECT Magneto-Optical Rotation,

FARADAY'S LAWS. The well-known Laws of Faraday, in electrochemistry, may be stated briefly as follows 1 The amount of chemical action is proportional to the amount of electricity which has passed through the **electrolyte.** 2 Ions liberated by the same quantity of electricity are in the proportions of their chemical **equivalents.** (Taylor) (See **Electrochemistry.**) (R K S)

FASCIA. Layers of connective tissue composed largely of regularly arranged fibers They cover muscles Also marks in the form of bands (A W L)

FASTENINGS. Two or more pieces of a **structure** or machine may be joined together by methods varying with the degree of permanency of the fastening These methods range from such relatively permanent methods of joining as **welding** or **brazing,** to fastenings as easily separated as those yielded by pinning or lashing **Rivets, screws, bolts, pins,** and **keys** form a particular class of fastening of great importance, since they are used for so great a variety of purposes, and in so much of the machinery of today

The rivet is generally used for relatively permanent junctions The junction may be parted with damage only to the rivet itself. The rivet is a short, metallic

rod having a head which is usually either hemispherical or conical. In use, the parts to be riveted are punched or drilled with holes slightly larger than the shank of the rivet. The holes are located concentrically, and the rivets are passed through them until the shank projects. The projecting portion is then deformed into a head, thus solidly fastening the pieces together. Iron and steel rivets are generally heated to a cherry red heat before having the shank upset. Non-ferrous rivets are frequently driven cold. For structural iron work, steel rivets are employed. In other work, we find iron, copper, duraluminum, and a variety of metals comprising the materials from which rivets are made. The most common rivet is that having a button head. A smooth-surfaced riveted construction is possible when an inverted conical head is used on the rivet, and the hole is reamed or **countersunk** so that the head fits flush with the surface.

Another class of fastenings is that great group including all forms which depend for holding power upon screw threads. Included in this category are bolts, nuts, screws, and pipe threads. The screw thread is a continuous helix formed on the surface of a cylinder of the proper size. The most common form of this screw thread is that of a helical groove having the sides sloping at 60° to each other. The thread, illustrated in Figure 1, is derived from a 60° V shape by slightly cutting the crests and filling the grooves. The pitch of a screw thread is the distance p between adjacent peaks.

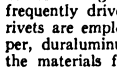
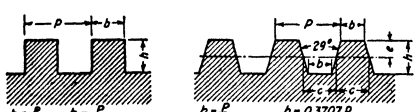


Figure 1. V-thread.

The ordinary **bolt** depends upon friction to prevent the nut unscrewing. The V type thread is excellent in this respect. Cap screws, set screws, and other special screw fastenings have similar forms of threads. Instances where low value of friction in a smooth running fit between nut and thread are to be found is in jack screws and lead screws. For these, either the square thread, or the Acme thread (Figure 2) is preferable to the V thread. Bolts are distinguished from screws by passing entirely through the parts to be connected, and being fastened on the end with a nut. Screws, unlike bolts, do not require the nut, but seat directly into one of the parts being joined. This seat may be drilled and threaded internally, as in cap screws for joining metal parts, or the screw may form its own threads in the manner of the ordinary wood screw. Wood screws are made of iron or brass, and have V threads tapered to a point. The heads are either hemispherical or conical, slotted to receive a screw driver. Large wood screws, which would be difficult to force into the wood with the screw driver, are made with square or hexagonal heads so that a wrench may be applied for turning. These are known as lag screws. Adjacent sections of **pipe** may be joined by screw threads, as well as by caulking, by flanges, and by welding. The most common way of making a screwed joint is with malleable or wrought iron couplings. All fittings for screwed pipe are threaded to conform to the Briggs standard gage and taper, which is the American standard for pipe threads. This tapered thread allows all joints to be set up tightly by screwing, even though the size of thread may vary somewhat from standard.



Square thread. Acme thread.

Figure 2.

A type of fastening not relying on screw threads for holding power, but on the tightening action of a tapered pin or wedge, is illustrated by pins, cotters, and keys. (See **Cotter.**) A method of fastening relatively unimportant parts cheaply is offered by the taper pin, which is driven tightly into a taper hole. This is used to fasten small gears or pulleys to hubs. Often a pin may be used for a relatively important fastening, which does not need the tightening action of a bolt and nut, by retaining the pin with another pin or cotter passed through a hole drilled near its end.

A key is the most common device for fastening a hub to a shaft. In the simplest form, it consists of a simple rectangular prism of metal so shaped as to fit tightly into a similar rectangular space formed by grooves cut on the outside of the shaft and the inside of the hub. Improved keys are superior in that some may be self-tightening, some may be able to resist heavy driving loads in one direction, and some may not require a slot to be cut on the shaft. The Woodruff key, illustrated in Figure 3, is a patented form of key made in the shape of a segment of a disk. The keyway in the shaft is circular in shape, permitting the key to adjust itself for even bearing on the hub during the tightening process. (F.T.M.)

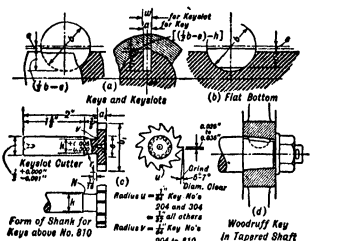


Figure 3. Woodruff keys.

FAT BODY. 1. A large mass of fatty tissue found in **insects.** It serves for the storage of food during larval life, since it is much smaller in the adult, and is apparently a reservoir for nitrogenous wastes since it contains deposits of **uric acid.** 2. A mass of fatty tissue located near the **gonads** in **Amphibia.** (A.W.L.)

FATHEAD. Pisces, Teleostei. A small **minnow,** *Pimephales promelas,* found throughout the United States in sluggish streams. (A.W.L.)

FATIGUE. When a metal is subjected to repeated reversals of **stress,** it undergoes a progressive failure which arises from the non-homogeneous character of materials in general. The ultimate failure in fatigue is that of cracking, initially started along the planes of the crystalline structure of the metal. The presence of certain external features, such as square shoulders, scratches, or tooling marks, promotes early failure in fatigue. The maximum strength of a material which can be used to resist the action of repeated reversals of stress is known as the fatigue or endurance limit. In the case of steel, this is about one-half of the **ultimate strength.** (F.T.M.)

FATS. Esters.

FAUCES. 1. The exposed portion of the cavity of a **snail** shell. 2. The opening of the throat of a **vertebrate,** flanked by the tonsils. (A.W.L.)

FAULT. A fault is a great fracture in the crust of the earth along which movement has taken place with the result that the crustal blocks are displaced relative to one another. This movement is in most cases probably intermittent and the actual individual displace-

ments may be very small, but by accumulation may reach tens, hundreds, or rarely thousands of feet The fractures themselves may often be traced for many miles The San Andreas fault, horizontal movement along a portion of which caused the earthquake that so severely damaged San Francisco, California, in 1906, has been traced for about 600 miles

In describing faults, certain terms have been adopted Those in most common use are given herewith the fault plane is the plane of the fracture and may be vertical or at an angle, the angle between the fault plane and the horizontal is called the angle of dip of the fault plane The angle between the vertical and the fault plane is spoken of as the angle of hade or simply as the hade of the fault The surfaces of the fault plane are called the walls of the fault If the fault plane dips, the uppermost wall is called the hanging wall, the lower wall the foot wall These terms are applied irrespective of whether the fault is normal,

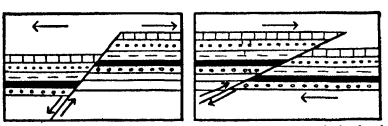


Figure 1. Structure sections of a simple normal fault (on left) and of a simple thrust fault (on right)

with the hanging wall slipping down the dip of the fault plane, or whether it is a reversed fault with the hanging wall apparently pushed up the dip of the fault plane A normal fault is sometimes spoken of as a gravity fault The displacement measured down the dip of the fault plane is designated as the slip, the displacement measured vertically is called the throw, the displacement measured at right angles to the plane of the involved stratum is called the stratigraphic throw The amount of horizontal displacement between the ends of a broken stratum measured at right angles to the direction of strike of the fault plane, is called the heave The visible evidence of the trace of a fault plane at the earth's surface is called the fault trace The block of the earth's crust which has moved downward, relatively speaking, to the other is called the downthrown block or referred to as the downthrow side of the fault The other block is called the upthrown block or the upthrow side of the fault If the strike of the fault plane is essentially at right angles to that of the **bedding** it is called a dip fault A strike fault is one in which the movement has been

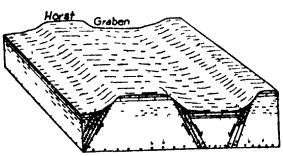


Figure 2 Block diagram of one type of scenery produced by "normal" or block faulting It may also be assumed that the graben has been pushed down, and the horst has been pushed up Neither structure is necessarily entirely the result of tension Note that the stratigraphic (vertical) order of the formations has not been duplicated or reversed (Field, *Laboratory Manual,* Princeton University Press)

parallel to the strike of the strata involved A compound fault involving several parallel displacements, dipping in the same direction resulting in a step-like arrangement is referred to as a step fault The term graben or trough fault refers to a down thrown area bounded on each side by two or perhaps more faults A horst is an uplifted area bounded by two or more faults (ESCS)

FAULT BRECCIA. Autoclastic.

FAULT SCARP. Scarp.

FAULT TRACE. Fault.

FAUNA. The animal population of a region (FTM)

FEATHER. The structure characteristic of the vestiture of birds (**Aves**) The development of a feather indicates that it is a modified scale, like those of reptiles and birds

A feather consists of a central axis or rachis continuous with the hollow quill which is attached to the body The rachis bears the flat vane of the feather which is made up of many slender barbs bearing barbules along each side The barbules of adjacent barbs interlock to form the continuous surface of flight feathers and the similar contour feathers of the body. Down feathers are of generally soft structure and lack barbules, and filoplumes are slender feathers with few barbs (AWL)

FEATHER-BACK. Pisces, Teleostei A fish (**Pisces**) of peculiar form found in Africa and the Oriental region. (AWL)

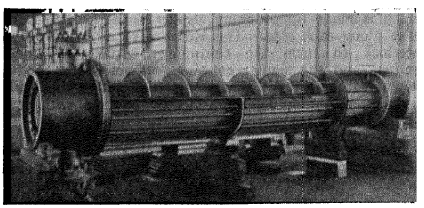
FEATHERING. An object of flat plate shape in a fluid stream has maximum resistance to relative motion if its largest area be placed in an attitude perpendicular to the fluid stream, and minimum when the smallest area is so placed Conditions occasionally arise when it is desirable to have a maximum resistance at one point of a cycle of events, and minimum at another For example, during the cycle of a rowing stroke, the blade of the oar should have maximum resistance to motion in the water, whereas during the return stroke it should have minimum air resistance Certain experimental types of lifting planes or **airfoils** have been built involving this same action The act of first presenting the surface of maximum resistance, followed by the surface of minimum resistance on a return stroke, is known as feathering. (FTM.)

FEATHER STAR. Crinoidea.

FEED WATER. Feed water is water properly prepared for entering a **boiler** to take the place of that which is evaporated in the generation of steam Although the instantaneous flow of feed water is not necessarily equal to the rate at which steam is boiled off, the total amount fed over a considerable period of time must equal the evaporation plus such loss as blow-down and steam released through the safety valve The nearer a boiler design approaches the flash type, the nearer must the instantaneous flow of feed water be to the rate of evaporation To be suitable for the service, feed water should be at a pressure enough above that of the boiler contents, so that it flows readily into the boiler when the feed valve is opened It should have chemical purity to the required degree, and be heated to a temperature as near that at which the boiler operates as is economically feasible (FTM)

FEEDWATER HEATER. The purpose of heating feed water is threefold First, if the water is heated by heat which would otherwise entirely or partially go to waste the heating represents a saving of fuel Second, the thermal stress induced in the **boiler** plate by contact with a stream of cold feed water is reduced, possibly eliminated Third, the nearer the feed to saturation temperature the less the heat to be added in the boiler itself and the more the steam raising capacity of each square foot of heat transfer surface This becomes of increasing importance at higher boiler pressures For instance, of the 1186 6 BTU total heat at 100 pounds per square inch, 25% is in the heat of the liquid, and 75% in the latent heat, at 400 pounds per square inch the division is 35% to 65%, at 1400 pounds per square inch, it is 51 5% to 48 5%

So, feed water heating results in increased efficiency and increased boiler capacity. The cost of the heating equipment is opposed to the lowered fixed and energy elements of cost, and when the balance is on the side of decreased cost of producing energy the heating equipment is justified. Some amount of heating is almost always justified. The efficient **regenerative** cycle is built around the heating of feed water in stages. While the fundamental plan of the **Rankine** vapor cycle is independent of feed heating, the practice of heating the feed in open heaters is universal.



Feedwater heater. (Courtesy of *Foster Wheeler Co.*)

Feed water heaters are divided into two classes, the contact and the surface heaters. Economizer surface and a portion of the boiler surface are actual water heating surface; however, it is customary to refer only to equipment obtaining heat from steam as feed water heaters.

The open heater is ordinarily built up in rectangular form, but heaters for other than near-atmospheric pressure are constructed in cylindrical form of cast iron or steel plate. The open heater is provided with tiers of trays, properly perforated and inclined to break up the flow of water, delivered by gravity from a distributing trough, into a multitude of small cascading streams which present a large surface to the steam. It is possible to heat water to the temperature of saturated steam entering the heater if there are no non-condensible vapors. Heating is by direct conduction from steam to water so the effectiveness as a heater is not adversely affected by scale accumulation. A float-regulated valve admits the cold water required to supplement the returns in drips, condensate, and other uncontrolled feed supply.

The surface heaters are divided into steam tube and water tube types. Steam tubes are ordinarily used in evaporators, but most extraction heaters are of the water tube type. These heaters can also be divided into straight tube and bent tube (U tubes and steam coils), and into single or multi-pass. The surface heater is used when water is to be heated under pressure without direct contact with the steam. Non-condensible gases are vented from the heater to the condenser through a small vent line. Sometimes, to avoid all possible load on the air removal apparatus, the heaters supplied with steam above atmospheric pressure are vented to atmosphere through a small vent condenser which condenses the vapor escaping with the gas.

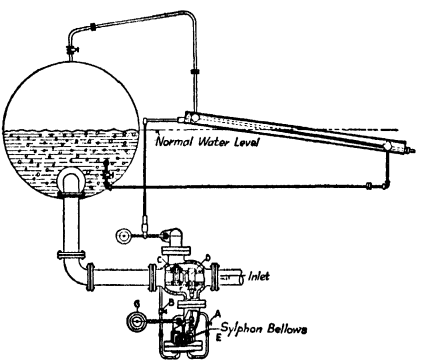
The ordinary closed heater is housed in a cylindrical shell of steel or cast iron, depending on the heater pressure. Brass, Admiralty, or other copper alloy tubes are rolled into tube sheets, one of which is fixed, the other floating. This construction is possible only in multi-pass heaters; however, most closed heaters are multi-pass. The floating tube sheet allows free expansion and contraction and permits the use of interchangeable tubes. The vertical hairpin tube type of surface heater is coming into wide use on account of its low cost, accessibility, and low economic terminal difference (F.T.M.)

FEEDWATER REGULATOR. Air, fuel, and water are the three variables entering into the production of steam "as wanted." The feedwater regulator is the governor of the **feed water** supplied to the boiler.

Soon after steam **boilers** came into use it was discovered that a disastrous explosion resulted if they boiled dry; also that the engine might be wrecked by water passing over with the steam. Naturally great care was taken to prevent the water level in the boiler from passing below or above the safe limits.

Under modern conditions it is necessary for feed water to flow into the boiler almost as rapidly as the steam flows out—and since boilers are approaching the flash type, it is plain that the feed water regulation should be automatic, purely a machine function. It cannot be done successfully by hand.

There are several makes of feedwater regulators on the market; most of them either thermostatically or float operated. Continuous regulators have become the standard type. In order to take advantage of the thermal storage contained in boiler drums between high and low water level, the regulator should gradually increase or decrease the feed on slowly increasing or decreasing steam demands, but it should decrease the feed during rapid increase of steam demand and increase it when the demand decreases rapidly, for in that way the fluctuation of boiler water level can offset the time lag of combustion response to changing steam



Feedwater regulator.

requirements. For illustration, suppose that the regulator shown in the accompanying figure is regulating the water level at middle gage. The expansion tube is half full of water and half full of steam, giving normal valve opening which produces a normal feed. There is a sudden increase in steam demand, and rapid withdrawal of stored steam is followed by a rapid drop in pressure and bubbling up of escaping steam at a rapid rate. This raises the water level and contracts the tube which decreases the valve opening. The decrease of cold feed input allows the boiler to steam at maximum rate. A continued heavy steam demand gradually lowers the water level in the boiler and tube, expanding the tube and opening the control valve wide enough to pass the required flow. (F.T.M.)

FEEDWATER TREATMENT. The purpose of a **feedwater** treatment system is to maintain the surfaces of the **boiler** in the same or approximately the same condition as when new. After entering the boiler, feed water is first heated to the saturation temperature, then evaporated in contact with the hot tube surface. Unless the concentration of soluble salts and suspended particles in the boiler water is very great the steam will be free of all impurities the feed water might have contained except dissolved gases. The impurities are left behind in the boiler water whose concentration,

as a result, increases The point of evaporation being at the tube surface, there is every opportunity offered the impurities to deposit themselves on these surfaces as a scale When untreated feed water produces enough scale on the boiler surfaces to interfere with heat transfer, or when it contains elements which either corrode or alter the strength of the boiler metal, feedwater treatment is necessary

The higher the rate of heat transfer per square foot of surface, the more important it becomes to keep that surface scale-free, because the scale can both reduce the steaming capacity and cause overheating of the tubes

Natural waters usually contain dissolved salts and gases, also some organic and inorganic material in suspension They rarely are neutral in reaction The dissolved salts are chiefly the carbonates, sulfates, and chlorides of **calcium, sodium,** and **magnesium**; and occasionally some **iron, aluminum,** or **silica** salts **Oxygen** and **carbon dioxide** are the gases The suspended matter is usually alumina and silica in the form of mud and silt, or, if organic, sewage and industrial wastes

The troubles caused by the feeding of water of undesirable quality are scaling, corrosion, foaming and priming, and **embrittlement.**

Boiler scale is due, mainly, to the cementing action of salts of calcium and magnesium Calcium is the worst offender, particularly in the sulfate form The formation of scale is caused by the dissolved salts in the boiler water reaching a concentration beyond which they are no longer soluble at the boiler temperature At average boiler temperatures the sodium salts have solubilities running to thousands of grains per gallon Magnesium sulfate is quite soluble in hot water and the chlorides are sufficiently soluble not to cause scale trouble But calcium sulfate is less soluble in hot water than in cold Its solubility varies between 150 grains per gallon in cold water to 5 grains in hot water, which explains why it is so troublesome a substance Calcium and magnesium carbonates have solubilities so low at 212° F that water containing them is treated merely by boiling and filtering The reactions are

$$Ca(HCO_3)_2 + \text{heat} \rightarrow CaCO_3 + CO_2 + H_2O$$
$$Mg(HCO_3)_2 + \text{heat} \rightarrow MgCO_3 + CO_2 + H_2O.$$

Scaling may take place in boiler drums or tubes, heater tubes, and feedwater piping Its effect on the piping system is to choke the flow, requiring an increase of pressure to maintain water delivery Its effect on heat transfer surfaces is to decrease the transfer Treatment for scale consists of removing the scale-forming elements or replacing them with extremely soluble salts

Corrosion is the destructive conversion of boiler metal into oxides or iron salts Corrosion may occur at any place in the feedwater cycle, but it is found principally in boilers, heaters, and piping It is due either to an acid condition of the water or to dissolved oxygen From the standpoint of corrosion, scale is a protective agent The corrosion may be a general loss of metal over the whole tube surface or a localized action The latter is the more serious as it produces pitting To prevent corrosion the boiler water is maintained alkaline and, if necessary, the feed water is deaerated to reduce the oxygen content to a suitable value

Foaming refers to that condition of boiler operation where a stable foam is produced It may or may not be accompanied by priming, which is the production of wet steam or, in the aggravated case, slugs of water. Priming can be produced by other causes than foaming, for instance, carrying too high a water level, insufficient disengagement area, or a pulsating steam demand that overtaxes the boiler steam storage Foaming results also from saponification of the boiler water through mixture of oil or grease with the alkali Floating organic matter is another source of foam When foaming is due to concentration of salts in the water the condition is relieved by altering the treatment or by blowing down more of the concentrated water

Chemical treatment is classed as external or internal, depending on whether the reactions are completed before the water enters the boiler or in the boiler. Internal treatment, if scientifically designed and controlled, is an effective method and is the best system where the proper treatment for the boiler might prove injurious to the steel tube economizers

External water softeners are of two types, precipitation and base exchange A precipitation softener embodies the principle of using calculated quantities of soluble reagents to react with the hardness in the raw water Two treating tanks are used in the intermittent system, one supplying treated water to feed service, while the other is receiving its charge of chemicals and water or maintaining a quiescent condition so that the precipitate may settle out Water flows continuously from inlet to outlet in the continuous type of softener Reagents are added at the inlet and what precipitate does not settle out in the reaction tank is removed by filtration

A base exchange softener removes the hardness by a simple filtration of the water through a bed of active material which exchanges its sodium base for the magnesium and calcium in the water Natural and artificial **zeolites** are used as the active material Natural zeolite is hard and dense, artificially prepared silicates such as permutit ($Na_2(Al_2Si_2O_8)$) are porous, thereby exposing a much greater surface to react with the water (F T M)

FEHLING'S SOLUTION. This is an alkaline solution of copper hydroxide and sodium **tartrate** used either as a mild oxidizing agent or as a test for easily oxidizable groups such as **aldehyde** groups (See **Carbohydrates**) (R K S)

FELDSPAR. Feldspar is the name of a group which includes the most important of the rock forming minerals, making up perhaps as much as 60% of the earth's crust

This group of minerals consists of three **silicates:** a **potassium aluminum silicate,** a **sodium** aluminum silicate, and a **calcium** aluminum silicate ($KAlSi_3O_8$ $NaAlSi_3O_8$, and $CaAl_2Si_2O_8$) and their **isomorphous** mixtures

The various members of the feldspar group show many characteristics in common Crystallizing in the **monoclinic** and **triclinic** systems, they show similarity of crystal habit, cleavage and other physical properties as well as similar chemical relationships

Orthoclase, $KAlSi_3O_8$, derives its name from the Greek words meaning right or straight, and fracture, because its two cleavages are at right angles to each other It crystallizes in the monoclinic system and its crystals are usually prismatic, it occurs also in coarsely cleavable masses Hardness, 6, specific gravity, 2 56–2 58, luster, vitreous to pearly, colorless to white, gray, yellow or red, rarely green Twin crystals not uncommon

Orthoclase is a common constituent of many igneous rocks and is often found in huge masses in pegmatite veins Localities for orthoclase are so numerous as to prohibit a complete list Adularia (from Adular) is essentially a pure potassium silicate, when pearly and opalescent it is called moonstone and frequently used for jewelry These opalescent varieties are known to be an intergrowth of orthoclase and albite A glassy kind of orthoclase, sanidine, is found in the trachytes of the Drachenfels, Germany Beautiful moonstones come from Ceylon and Switzerland, in the United States from California and Virginia

Orthoclase is found in the New England **pegmatites,** in New York, Pennsylvania, Virginia, North Carolina, Arkansas, Texas, Colorado, California and elsewhere Its commercial use is in the manufacture of porcelain, and as a constituent in scouring powders

Microcline, $KAlSi_3O_8$, is chemically the same as orthoclase, but belongs to the **triclinic** system, the prism angle being slightly less than a right angle ($89°30'$), hence the name microcline from the Greek meaning small, and to slope Microcline is like orthoclase in all physical properties and can be distinguished from it surely only by optical examination Under the polarizing microscope microcline displays a minute multiple twinning which results in a grating like structure that is unmistakable It is probable that much orthoclase would, upon proper examination, prove to be microcline Amazon stone or amazonite is a beautiful green microcline occurring in the Ilmen Mountains in the Urals, Italy, Norway, Madagascar, and in the United States in the Pikes Peak region, Colorado, Virginia, North Carolina and sparingly in the pegmatites of New England

The name amazon stone is derived from the application of this term to some green mineral found by the Spaniards among the aborigines of the Amazon Valley in South America As no microcline is known to occur in the region there must have been some confusion with another green colored substance

A soda microcline, anorthoclase, is known, which is probably an isomorphous mixture of $KAlSi_3O_8$ and $NaAlSi_3O_8$, the sodium aluminum silicate being in the greater proportion The soda feldspar albite, $NaAlSi_3O_8$ and the calcium feldspar anorthite, $CaAl_2Si_2O_8$ form an isomorphous series from pure albite at one end to pure anorthite at the other, the two molecules appearing to be completely miscible one with the other The members of this series are spoken of as the soda-lime (or lime-soda) feldspars, and as a group are called the plagioclase feldspars from the Greek meaning *oblique* and *fracture*, referring to the two cleavages at an angle that differs slightly from a right angle Nearly always present are the striations, fine parallel lines, resulting from minute multiple **twinning**, which, never seen on orthoclase or microcline, are therefore an important diagnostic feature

More or less arbitrarily, four intermediate **plagioclase** feldspars are recognized between albite and anorthite, these are listed below together with the approximate percentage of each molcule present

	Percentage of $NaAlSi_3O_8$	Percentage of $CaAl_2Si_2O_8$
Albite	100 to 90	0 to 10
Oligoclase	90 to 70	10 to 30
Andesine	70 to 50	30 to 50
Labradorite	50 to 30	50 to 70
Bytownite	30 to 10	70 to 90
Anorthite	10 to 0	90 to 100

Albite is so called from the Latin, *albus*, in reference to its usual pure white color It is a sodium aluminum silicate corresponding to the formula $NaAlSi_3O_8$ It crystallizes in the triclinic system commonly in tabular crystals Twinning is very common, thin twinning lamellae producing a series of fine striations on certain crystal faces. There are two good cleavages at an angle of $86° 24'$ to each other Hardness, 6, specific gravity, 2 62; luster, vitreous to pearly It may be colorless to white or gray and transparent to opaque

Albite is a relatively common and important rock-making mineral associated with the more acid rock types and in **pegmatite** dikes, often with rarer minerals like **tourmaline** and **beryl** There are many famous localities in Europe in the Swiss and Austrian Alps, the Urals, the Harz Mountains, in Italy, France and Norway Brazil has yielded fine specimens In the United States notable localities are Paris and Auburn, Maine; Chesterfield, Mass; Haddam, Conn; Amelia County, Va; and the Pike's Peak region of Colorado. It is used in the ceramic industries and also in the manufacture of artificial teeth.

Anorthite was named by Rose in 1823 from the Greek meaning oblique, referring to its triclinic crystallization The physical properties are essentially the same as for albite, except that the specific gravity of anorthite is somewhat greater, 2 74 – 2 76 Anorthite is characteristic of the basic igneous rocks such as gabbro and basalt Anorthite is found in the lavas of Vesuvius and Monte Somma, Italy, in Finland, Japan, and in Sussex County, N J

The intermediate members of the plagioclase group are all very similar and with the exception of certain labradorites, cannot be distinguished from each other ordinarily save by optical means Oligoclase is a common mineral in such rocks as **granites, syenites, diorites**, their extrusive equivalents and many **gneisses**. It is a frequent associate of orthoclase The word oligoclase is derived from the Greek meaning little, and fracture, in reference to the fact that its cleavage angle differs slightly from 90° Sunstone is mainly oligoclase (sometimes albite) spangled with flakes of hematite

Andesine is a characteristic mineral of rocks such as diorites which contain a moderate amount of silica and related extrusives, such as andesites Because of its occurrence in these latter andesine derives its name from them as well as from the Andes Mountains

Labradorite is the characteristic feldspar of the more **basic** rock types like diorite, **gabbro, andesite** or **basalt** and it is usually associated with some one of the **pyroxenes** or **amphiboles** Labradorite frequently shows a beautiful play of iridescent colors due to minute inclusions of another mineral The classic locality for this mineral is of course Labrador, whence its name It is a constituent there of the rock **anorthosite** and is found in the anorthosites of the Provinces of Quebec and Ontario and in the Adirondack region in New York State

Bytownite, named from Bytown the former name for Ottawa, Canada, is a rare mineral occasionally found in the more basic rocks

The feldspars crystallize from the **magma** in both extrusive and intrusive rocks, they occur as contact minerals, in veins and are developed in many sorts of **metamorphic** rocks, e g, albite **schists.** They may also be found as mechanical deposits in various sedimentary rocks (E S C S)

FELSITE Felsites are defined by American geologists as dense, fine-grained, light-colored rocks rich in silica, hence classified with the **rhyolites**, from which some of them have been formed by **devitrification** Felsites may occur as intrusive dikes but in general are found as **extrusive** rocks They frequently occur interbedded with volcanic ash, tuff or breccia According to American usage any light-colored lava whose ground mass or matrix is so fine-grained that the individual minerals cannot be distinguished by the naked eye (macroscopically) may be roughly classified as felsite, hence the prevalence of the term felsitic texture When felsites show **phenocrysts** they are called felsite porphyries The term felsite was first applied by Gerhard in 1814 to the fine ground mass (matrix) of **porphyries**, and is therefore one of the oldest, commonly used, petrological terms (R M F)

FEMALE. Sex.

FEMIC. This term is used by petrologists to designate the more common ferromagnesian (See **Iron; and Magnesium**) minerals such as **pyroxene** and **olivine.** Rocks which are relatively rich in femic minerals are said to be urafic. (R M F)

FENNEC. Mammalia, Carnivora Animals of two species which resemble foxes with enormous ears. One, *Vulpes zerda*, occurs in northern Africa, and the other, *V. famelicus*, in Syria and adjacent regions. (A.W.L)

FENNEL. Carrot Family.

FERBERITE. Wolframite.

FER-DE-LANCE. Reptilia, Sauria. A large poisonous **snake**, *Lachesis lanceolatus*, of tropical America. It reaches a length of seven feet and is active at night. A **pit viper.** (A.W.L.)

FERMAT'S PRINCIPLE. This is a law of optics recognized nearly three hundred years ago by Fermat. It states that when light proceeds by any path from a point *A* to another point *B*, the time required in its passage is either a minimum or a maximum as compared to other, arbitrarily chosen, adjacent paths. If the light is reflected from *A* to *B* by a plane surface, or is refracted at a plane surface on its way from *A* to *B*, the time is a minimum. For a curved reflecting surface, the time is a minimum if the surface has less curvature than the "aplanatic" surface osculating with it at the same point (i.e., the surface which gives rise to no **spherical aberration**); and this holds true also for a curved refracting surface. In these cases the law is known as the "principle of least time." But if the reflecting or refracting surface has greater curvature than the aplanatic surface at the same point, the time for the actual path is a maximum; that is, if the light could be made to follow a path through any other point of the curved surface than the one it actually passes through, it would do so in less time. For all points on a given aplanatic surface, the time is the same, and the light, if unobstructed, actually does follow paths through all of them. (L.D.W.)

FERMENTATION. While in recent literature there has been a tendency to extend the use of this term to include many **biochemical** reactions catalyzed by enzymes, this term applies strictly to the chemical conversion of **glucose** into **ethyl alcohol** under the influence of the enzyme **zymase.** (See **Carbohydrates.**) (R.K.S.)

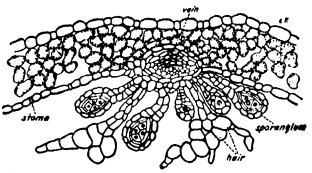
FERNS. Pteridophytes. The ferns and their allies form the third division of the plant kingdom. This is a small division comprising only about 4500 species of plants, few of which are very large. But in past times, and especially in the **Carboniferous** period, plants of this division were more numerous and many of them of very large size.

At the present time the ferns are found in nearly all

Tree ferns in African forest. (Courtesy of *American Museum of Natural History.*)

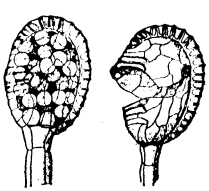
parts of the world, especially in regions where there is plenty of moisture. They are particularly numerous in the tropics. There also the largest of the ferns, called tree ferns, are found. These tree ferns have an erect usually unbranched trunk bearing at its top a crown of much dissected leaves of large size. Tree ferns are from ten to thirty feet in height; a few may reach a height of fifty feet.

In nearly all ferns the stem is a slender structure. In many species it grows underground as a creeping horizontal **rhizome**; in other species it is shorter and erect, but seldom rises much above the surface of the ground. From the stem numerous fine wiry roots extend into the ground. The leaves of ferns having creeping rhizomes are borne singly at the nodes; those of erect-stemmed ferns are borne in a group which forms a close crown. In many ferns the leaf, often called a frond, is pinnately compound, and the individual **pinnae** themselves compound. Other ferns have entire leaves. Young leaves are circinnately coiled, the tip of the leaf being in the center of a tight coil, which unrolls from the base upward. Often these young leaves are covered with a mass of dense brown hairs. On the lower surface of the frond reproductive bodies are formed. In many ferns these are found on all pinnae; in others they occur only on special pinnae which are commonly very much modified in size. These reproductive bodies are commonly borne in compact groups called sori, which are often covered by a protective structure, the indusium.



Section through leaf and sorus of *Polypodium* showing sporangia in various stages of development.

The reproductive bodies are stalked sporangia containing **spores**, which are freed by the action of certain special cells of the **sporangium.** These cells have thick inner walls and in many ferns form a distinct row called the annulus. When the atmosphere is dry the cells of the annulus of a mature sporangium lose water and gradually contract. As a result, a considerable strain is exerted by the thin outer wall of these cells, so that the annulus is pulled backwards, a break occurring in a group of thin-walled cells known as the **stomium.** Finally the tension becomes too great and the annulus snaps back violently, catapulting the spores out of the sporangium.

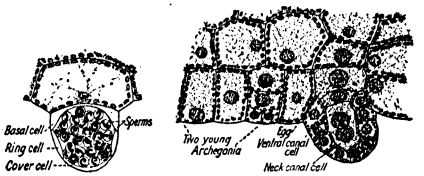


1. 2.

Fern sporangia. 1, Unopened sporangium filled with spores; 2, The empty sporangium after the annulus has returned to its first position.

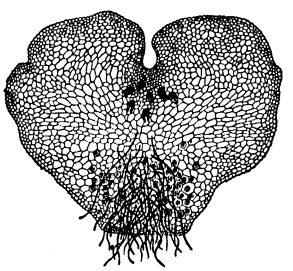
These spores, carried by air currents to a region where moisture is sufficient, germinate. They do not, however, form a new fern plant. Instead they develop a small delicate green plant called the prothallus. In many ferns this is a heart-shaped body one cell thick. In others it is a branched object resembling certain species of algae, and in still other ferns it is a small tuberous body. From the lower surface of the prothallus numerous short **rhizoids** grow down and anchor it firmly in the substratum. On the lower surface also, reproductive bodies are formed. These consist of two kinds, commonly found on the same prothallus. One, usually in the basal portion of the prothallus, is the **antheridium.** An antheridium is a small multicellular object in which are formed many small sperms. Fern sperms are spirally coiled cells, each having a group of **cilia** at the tip. The female sex organ is the **archegonium.** These are commonly found near the notch of the prothallus. Each archegonium is a small body consisting of a basal layer of cells surrounding the single large egg cell and a short tube surrounding a row of cells known as the neck cells. These break down, forming the neck canal, through which the sperm swing to unite with the egg. The

fertilized egg or **zygote** immediately starts dividing and gives rise to a new fern plant. The prothallus of the



1, Mature antheridium of fern. 2, Two young archegonia of fern and one mature one. (From Chamberlain's *Elements of Plant Science*, McGraw-Hill Company, Inc.)

fern is the **gametophyte** generation. It is green and very much smaller than the sporophyte, of which it is

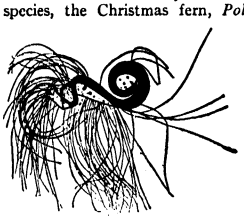


Fern prothallium. View of the under side showing archegonia near the apical notch and antheridia among the rhizoids near the base. (From Sinnott's *Principles and Problems*, McGraw-Hill Company, Inc.)

entirely independent. Water is absolutely necessary for the prothallus to give rise to a new sporophyte.

Fern embryo sporophyte still attached to its parent (the gametophyte) but differentiated into its parts and making its own food. Left, as seen from above; right, seen from below.

The ferns are of very little importance to man. One species, the Christmas fern, *Polystichum acrostichoides*, has thick evergreen leaves which are often used for decorative purposes. This fern grows wild in open woods of the north temperate region. Another fern, the maidenhair, *Adiantum pedatum*, and related species, is frequently grown as a decorative plant because of its delicate fronds. However, the fronds wilt too quickly to be of much use if cut from the plant. Species of *Osmunda*, including the Cinnamon fern, the interrupted fern, and the royal fern, are often planted in shady places for ornament. From these ferns is obtained a coarse fiber used as a potting substance on which to grow epiphytic orchids.



A single fern microgamete, killed and stained so that the parts of the cell are visible. (After Steil.)

Sometimes planted as a curiosity, *Camptosorus rhizophyllus*, the walking fern, gets its name because the tips of the fronds bend down to the ground and take root. New plants are formed at these points. This is a special

Plants of the walking fern, *Camptosorus rhizophyllus*.

form of vegetative reproduction. Several ferns propagate themselves by forming small bulbils on the surface of the fronds. Eventually these drop off and take root, giving rise to new plants. *Cystopteris bulbifera* is a fern propagating in this way. One of the commonest and best known ferns is the common brake, *Pteridium equilinum*, which grows on dry hillsides and in open woods.

The Pteridophytes include not only the ferns or Filicales, but also the **Horsetails**, **Club-Mosses**, and the **quillworts**. These three groups are called the fern allies. (See also **Paleobotany**.) (R.M.W.)

FERRATES. Iron.

FERRET. Mammalia, Carnivora. 1. A plains species which preys chiefly on prairie dogs. Found from western Dakota to Montana and Texas. The black-footed ferret, *Mustela nigripes*. 2. The domestic ferret, a descendant of the European polecat, used to catch rats and mice and sometimes to pursue other animals into their burrows. (A.W.L.)

FERRET-BADGER. Mammalia, Carnivora. Animals of several species found in the forests of the Oriental region. They are intermediate in form between the slender carnivores of which the ferret is an example and the more stocky badgers. (A.W.L.)

FERRIC. Iron.

FERRITE. Iron.

FERROMAGNETISM. Magnetism.

FERROUS. Iron.

FERRUM. Iron.

FERTILIZATION. The union of reproductive cells of the two sexes to form a new individual.

In many species of animals germ cells of the male are transferred to the genital passages of the female in the process of **insemination** prior to fertilization and in others both sexes discharge their **germ cells** into the water. In either case the **spermatozoa** swim about in

the liquid surrounding them until they meet the ova. When a spermatozoon meets an **ovum** either the entire male cell penetrates the surface and lodges in the cytoplasm of the egg or the tail alone is left outside After entering, the head rotates so that the basal part is toward the interior of the ovum At this point a mitotic figure develops The nuclei of both eggs and sperm may enter the resting state as male and female pronuclei prior to their union Whether this step occurs or not, the **chromosomes** derived from the two nuclei enter the mitotic figure and the first **cleavage** division results Since each germ cell has only one chromosome of a kind as a result of **meiosis**, the diploid number characteristic of the species is restored by this union

The ovum reacts to the entry of the sperm head with peripheral changes which prevent the entrance of other male cells A fertilization membrane separates from the surface of the egg and in some species a redistribution of cytoplasmic materials takes place

a tabulated report of the constituents of the ashes of certain kinds of crops helps to make these points clear. Nitrogen does not appear in the ash, but must be supplied from the soil **Silicon, magnesium, iron, chloride** are usually available in sufficient amounts The constituents of plant ash vary with the kind of crops, and the weight of a given crop varies with the soil and its physical and chemical treatment, and with the season

The content of each of the three chemical fertilizer elements is usually expressed in a characteristic manner, thus, for illustration, "4–8–2," which signifies that the percentage composition of the dry fertilizer is 4% **nitrogen** (N) element, 8% **phosphorus** pentoxide (P_2O_5), spoken of as "phosphoric acid," and 2% **potash** (K_2O). This expresses the composition of a "mixed" fertilizer, and on the same basis of expression "sulfate of ammonia" ($(NH_4)_2SO_4$) would be "21–0–0," "nitrate of soda" ($NaNO_3$) "16–0–0," "superphosphate of lime"

CONSTITUENTS OF ASH OF NORMAL CROPS

POUNDS OF CONSTITUENTS PER ACRE OF GROUND

	Silica	Potash	Soda	Magnesia	Lime	Ferric Oxide	Chloride	Sulfate	Phosphate
Grain	15	14	7	2	8	1	0	0	36
Straw	233	33	1	28	12	6	4	13	11
Roots	27	143	17	46	18	4	12	46	26
Tops	3	89	17	72	10	3	50	39	29
Hay	78	38	12	45	7	1	4	9	15

Although some eggs develop normally without fertilization (**parthenogenesis**) and others may be stimulated artificially to do so, fertilization is the normal cause of development in most species It is also important for the combination of hereditary qualities (See **Heredity**) of two individuals (A W L)

FERTILIZERS. In connection with the effective use of soils and the economic yield of crops, it is requisite that the exhaustion of soils by the removal of chemical elements of the crops be compensated by the addition of such elements as may not be spontaneously supplied by the soil It has been found that the primary needs in this respect may be met by the addition of so-called fertilizers containing one or more of the three elements, **nitrogen, phosphorus, potassium.** Secondary needs require in some cases **sulfur, calcium.** Examination of

($Ca(H_2PO_4)_2$ $CaSO_4$) "0–35–0," "sulfate of potash" (K_2SO_4) "0–0–54," "muriate of potash" (KCl) "0–0–63"

Common nitrogen fertilizers are **ammonium** sulfate, **sodium** nitrate, calcium **cyanamide,** organic substances, such as packing house recovered wastes, tankage, fish scrap, cotton seed meal, treated garbage and sewage, manure, **phosphorus** fertilizers are **calcium** dihydrogen phosphate, either as "superphosphate" or "treble superphosphate," **calcium** phosphate of "phosphate rock" or of bones, **potassium** fertilizers are potassium chloride or sulfate Sulfur is supplied in two of the above, namely, "superphosphate" and "sulfate of potash," or may be used as gypsum or sulfur, calcium is also supplied in "superphosphate" and "treble superphosphate," or may be used as gypsum or limestone

The following are typical analyses of phosphate rocks and bones

ANALYSES OF PHOSPHATE ROCK

Source	Phosphorus Pentoxide	Fluorine	Calcium Oxide	Carbon Dioxide	Aluminum Oxide	Ferric Oxide	Silicon Oxide
Florida	31–35%	3 6%	46–50%	2–3%	1%	1–2%	5–10%
Tennessee	32–37	3 6	48–50	2	1–2	1–4	2–12
South Carolina	26	3 4	42	4	1	1 5	13
Idaho	34	3 4	48	2	0 7	0 5	4
Montana	29	3 0	40	1	1 7	1 5	22
Wyoming	31	3 5	48	4	0 4	1	5
Quebec	39	3 0	54	1	0 4	0 4	1
Morocco	35	4 0	53	4	0 3	0 3	1
Bone ash	40	0 1	54	1	0 0	0 2	0 5
Steamed bone meal	35	0 1	48				

In making superphosphate about equal weights of Florida phosphate rock and sulfuric acid are used (R K S)

FEVER. This term is used to describe abnormal elevation of the body temperature Fevers are often described as low, high, or very high They may also be described according to the constancy with which the elevated temperature is maintained. Thus, a continuous fever is one that is maintained at a fairly constant level for several days When there are moderate fluctuations, the temperature is said to be remittent If the temperature approaches or reaches normal during some part of the day. but rises considerably at other times, the fever

is said to be intermittent Rises in temperature may be gradual or very sudden and accompanied by chilly sensations or shaking chills Fever may terminate slowly by lysis or suddenly by crisis

The unusual rises of temperature seen in patients with fever are due to an unstable condition of the heat-regulating centers in the brain (See **Temperature**) This may be caused by infections, by injections of foreign protein or certain chemical substances, by excessive loss of water from the body, and by hemorrhage or tumor formation in that region of the brain where the heat-regulating centers are located The fever produced by infections is closely related to that produced by the injection of foreign proteins The organisms growing in the body during an infectious process are liberating a continual supply of toxic substances to which the body is not accustomed

The question is often debated as to whether fever is beneficial during an infectious disease, or should attempts be made to reduce it In general, with fever of moderately high degree, it is known that the body finds it easier to produce protective **antibodies** to fight infection, and, furthermore, the increased temperature is harmful to micro-organisms, making it more difficult for them to grow and increase within the body Excessively high fevers in certain instances demand active measures toward their reduction, as it indicates that the heat centers of the brain are probably temporarily overwhelmed and unable to cope with the emergency (R S M)

FIARD. Fiord.

FIBERS. Stem Fibers are long, usually slender, thick-walled **sclerenchyma** cells Usually they have pointed ends and lignified (**lignin**) walls In most cases the central cavity of the fiber is very small, due to the thickness of the wall Fibers are found in many parts of a plant, but are most frequent in the cortex and in the vascular cylinder The name bast fibers is given to fibers occurring in the **cortex** and in the **phloem** region Fibers may occur as single cells or in compact groups forming extensive masses, giving to the part of the plant in which they occur considerable tensile strength Masses of bast fibers of this sort give us **flax, hemp, jute, ramie** and **sisal.**

The single-celled outgrowths which surround the seeds of the **cotton**-plant are often called fibers They are slender hollow cells of almost pure **cellulose,** and strictly are hairs, as are also the cells of **kapok.** (R M W)

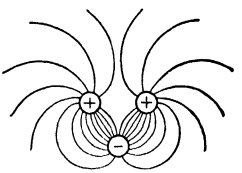
FIBRIL. A minute threadlike structure in a **cell,** also the smaller components of the intercellular white fibers of connective tissue

Fibrils occur near the surface of smooth muscle cells and connective tissue cells (border or myoglia fibrils and fibroglia fibrils respectively) and in fully differentiated muscle and nerve cells (myofibrils and neurofibrils respectively) (A W L)

FIBROID. A **tumor** composed of fibrous or connective tissue They are usually benign and are removed surgically because of their size, bleeding, or interference with function Fibroid tumors may occur in various parts of the body but are very commonly found in the uterus They are the most common cause for removal of the uterus (hysterectomy). (R S M)

FIBROLITE. Sillimanite.

FIELDS OF FORCE. A field of force is commonly recognized by the fact that an appropriate test object placed therein gives evidence of a force acting upon it Thus a stone in the earth's gravity field has weight, a charged pith ball near an electrified glass rod is urged toward or away from the rod, etc The concept of such regions of space in which there is a condition of stress analogous to elastic tension or compression is due primarily to Michael Faraday He initiated the "field theory" as a substitute for the older "action-at-a-distance" concept, and explained the observed behavior of appropriate objects in the neighborhood of magnets, electric charges, or gravitating masses as due to stresses along definite stress lines or "lines of force" Every student of physics is familiar with the experiment of mapping a **magnetic field** by means of iron filings sprinkled upon a card placed over a magnet. In this experiment, attention is first called to the direction of the lines as indicating the direction of the magnetic stress, later the student learns to interpret the closeness with which the lines are packed as corresponding to the intensity of the field The lines are, of course, pure conventions, but they are nevertheless useful both qualitatively and quantitatively in discussions of field theory Analogous concepts are applied in the case of electric and gravitational fields, and are useful in the theory of the **electromagnetic field,** so ably developed by Maxwell In recent years Einstein has undertaken to identify these different fields of force as components or aspects of a more general entity, and has developed his unified field theory as a feature of general **relativity** (L D W)



Typical electric field between charged conductors, mapped by lines of force.

FIELDFARE. Aves, Passeriformes A common **thrush,** *Turdus pilaris,* of northern Europe. (A W L)

FIG. *Ficus carica* Moraceae Figs are the fruit of a shrub or small tree probably native to southwestern Asia They have been cultivated since earliest recorded times, being widely used by the Hebrews, greatly improved by the Greeks, and highly valued by the Romans The fig tree is now grown in cultivation in nearly all tropical countries and many subtropical regions, in the United States it is grown to some extent in the southwestern states, notably in California

The plants have alternate leaves which are rather thick and rough surfaced above, but soft-hairy beneath The leaves are deeply lobed in the cultivated varieties The minute flowers are borne on the inside of the hollow receptacle, which develops into a pear-shaped body with a minute opening at its apex The fruit developing from this is a synconium, composed of many small fruits inserted in the inner wall of a hollow fleshy receptable The narrow passage into this is partly closed by numerous small **bracts.**

There are four kinds of flowers in the fig Staminate flowers, each having four pollen-bearing **stamens,** occur in the wild "caprifig" A few cultivated forms have staminate flowers **Pollination** is brought about by using pollen from caprifigs, and called caprification Pistillate flowers, each having a single **pistil** which if pollinated produces a seed These flowers are short-stalked The third flower type is the gall-flower, so-called because a small wasp, *Blastophaga grossorum,* lays its **eggs** in them The developing **larvae** causes the **ovaries** to become swollen **galls,** incapable of developing seeds This type of flower occurs only in caprifigs, in the basal portion of the synconium Lastly, in varieties of cultivated figs there are found sterile flowers, which will neither produce seeds nor become galls, these are called mule flowers Caprifigs contain the first three types of flowers If pollen is needed to insure fruit development, caprifigs must be planted, since they alone have pollen-bearing flowers So among Smyrna fig trees, the fruits of which fail to develop unless pollinated, caprifigs must be planted

In Mediterranean countries, where figs are grown in abundance, three crops are produced each year The first fruits, known as profichi, are formed in the spring In the pistillate flowers of these the female wasp lays her eggs, so that galls are formed in the profichi When the young wasps emerge, these profichi are gathered and hung among Smyrna figs Wasps escaping have to crawl past the staminate flowers near the aperture of the synconium and so are dusted with pollen The wasp then enters and pollinates a flower of the second crop, thus insuring fruit development This second crop is known as mammoni The third crop, the mammae, remain on the trees It is in these that the wasp passes the winter.

Fig fruits are gathered and sometimes eaten fresh, but more frequently dried in the sun, then pressed together and shipped Smyrna figs are often enlarged by pulling during drying The fruits produce a mild laxative effect, and so are sometimes prescribed in cases of chronic constipation From them a wine is sometimes made, and alcohol produced The wood of the fig tree is occasionally used in cabinet work

Propagation is usually by stem cuttings, but sometimes by budding or **grafting.**

Other species of *Ficus* are of some importance In southern Asia the Sacred Fig, also called Peepul or Bo-tree, occurs This is a large tree with deltoid leaves, the apex of each leaf tapering into a long point Any water falling during a tropical rain runs off rapidly from this point, so that the leaf surface does not long remain wet The tree is held sacred by the Hindus

There are many species of *Ficus* native in the American tropics, known as Strangling Figs The seeds of these frequently germinate on the branches of other trees, sending aerial roots downward and developing slender stems which grow about the supporting plant Eventually the roots enter the ground and become established there. The stems, enlarging and often anastomosing, grow tightly around the supporting plant, which is often strangled and killed

All these plants have a milky juice which may be made into **rubber.** The juice of the India Rubber Tree, *Ficus elastica,* is used in this way

The **Banyan** tree is another species of *Ficus* (R M W)

FIG INSECT. Chalcid fly.

FIGWORT FAMILY. Scrophulariaceae This family contains some 2500 species, most of which are herbs or shrubs Its members are numerous in temperate regions, where many of them are common plants, as for example mullein, "butter-and-eggs," speedwell, and lousewort Annuals, biennials and perennials are found in the family

The flowers are zygomorphic, or bilaterally symmetrical, with the **calyx** and **corolla** both tubular and each composed of four or five lobes In many plants of this family the corolla is distinctly two-lipped, as in the Snapdragon Usually there are four **stamens,** which are inserted on the corolla tube The **ovary,** composed of two united **carpels,** becomes a dry capsule containing many small seeds The flowers of this family are mostly pollinated by insects, such as bees, wasps, and flies, which seek the nectar secreted in a disk at the base of the ovary

Many members of this family show a tendency towards parasitism. In these, the seed on germinating sends out a root which comes in contact with the roots of another plant, commonly a grass On making this contact, the root sends into the grass root absorptive organs or haustoria, which take from the host certain materials in solution The parasite grows into an ordinary green-leaved plant capable of carrying on **photosynthesis,** but with a root development insufficient for its own needs Such plants are only partially parasitic

In this family are found many plants grown by man as ornamentals Some, such as Foxglove (*Digitalis*) and Veronica are hardy biennials or perennials, others, like Snapdragon (*Antirrhinum*) are not hardy, while *Calceolaria,* a native of South America and Mexico, is a hot-house plant grown for its bizarre sac-like flowers of brilliant color Drugs of medicinal value are also found in several plants of this family, the most important being **digitalin,** from species of foxglove In early days many species were used as a source for home-made brews. Others are poisonous herbs (R M W)

FILARIASIS. A parasitic disease of the tropics caused by various species of *Filaria,* a genus of **nematode** or thread worms

Both anopheline and culicine **mosquitoes** serve as intermediate hosts for the parasites The adult forms develop in the human body after larval forms are transmitted by the bite of the infected mosquito

The parasites are commonly found in tropical countries but cases of infection have been reported in the Southern states

Symptoms depend on the degree of infestation and the parts of the body involved The parasites show a predilection for the lymphatic structures High fever, **lymphangitis** and swelling of the **lymph glands** are common

After repeated attacks permanent thickening of tissue occurs accompanied at times by great swelling of the affected parts The swelling is caused by blockage of the lymph channels by the parasites obstructing the flow of lymph

When the legs are involved the condition is called elephantiasis, as the legs become tremendously swollen with thickened, fissured skin The external genitals may be similarly involved

The disease is difficult to treat Some of the newer **arsenicals** have given promising results. (R S M)

FILAR MICROMETER. The filar micrometer is an instrument for measuring small distances in the field of an **eyepiece.** It consists fundamentally of two parallel wires, one of which is fixed and the other capable of motion in the direction perpendicular to its length by means of an accurately cut screw The pitch of the screw is carefully determined for various temperature conditions and the head of the screw is graduated so that whole revolutions and fractions thereof may be read

For astronomical purposes the filar micrometer has some modifications from the instrument as used for ordinary measuring purposes In the accompanying figure we have *AB* a plate of brass carrying two wires *H* and *F* which are accurately perpendicular to each other This plate may be rotated about an axis and the index *I* sweeps over a circle graduated in degrees, with a vernier reading fractions of a degree A second plate *CD* may be moved over the surface of the first plate by means of the accurately calibrated screw *S* with the graduated head *P* This plate carries on its lower surface, so that it will be practically in the same plane as *F,* a wire *M* which is set accurately parallel to *F*

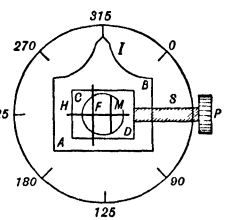


Diagram of filar micrometer

This instrument is so mounted that *F* and *M* are in the focal plane of the objective of a **telescope** with the optic axis of the instrument passing through the center of the opening in *AB* When so mounted the filar micrometer is one of the most valuable instruments for measurement of small angular distance

For the study of **double stars** the first adjustment of the instrument is to point the telescope at a star, prefer-

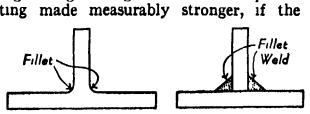
ably near the equator, and rotate the instrument until the star will move, due to the rotation of the earth, along the wire H H, being now parallel to the equator, the reading (R_1) of the index is taken. Next the wires M and F are placed in coincidence and the head reading (D_0) taken. The telescope is then directed at the double star under investigation and rotated until H passes through both stars and the reading (R_2) of I is taken Then holding one component of the pair of stars on F the screw is turned until M passes through the other star. The reading (D_1) of the head is taken, account being taken of the number of whole revolutions in the process. R_2-R_1 is defined as the **position angle** of the double star, and D_1-D_0 (when converted into angular units) is the distance.

The filar micrometer may also be used to determine the position of one astronomical body relative to another close object whose **spherical coordinates** are known. For this purpose the wire H is first held at setting (R_1), (i e, parallel to the **celestial equator**), the wire F held on one of the two objects and the wire M set on the other. The distance thus measured is parallel to the equator (i e, is proportional to difference in **right ascension** of the two objects) The instrument is then rotated through 90° and the difference in **declination** may be measured (W K G)

FILIBRANCHIATA. Lamellibranchiata.

FILICALES. Paleobotany.

FILLET. Fillet is the term employed to describe a concave section of a body which is used to reinforce a re-entrant angle formed by the intersection of two plane surfaces It is purposely incorporated in patterns from which **castings** are to be made, since lines of stress radiating from sharp edges and corners are set up in the casting during cooling These will be prevented, and the casting made measurably stronger, if the outside



edges are rounded, and the inside filleted Filleting is also employed to improve the appearance of a corner, or hide a crack, and for the purpose of replacing an angularity with a smoothly rounded surface. An aircraft wing is faired into the fuselage by fillets The junction of two parts, such as plates at right angles to each other, is often made with a weld of the fillet type, in which a small fillet of welding metal is laid down in the angle created by the intersection of the surfaces of the plates (F T M)

FILTER. A light filter is a substance or device which changes the color or intensity of the transmitted light. It is widely used in the field of photography, spectroscopy, and microscopy Light filters, once the adjunct of trained photographers only, are now in widespread use by amateur photographers who understand that atmospheric conditions, type of object to be photographed, and distance to be included, call for careful selection of light filter for best photographic results.

Gas filters are used to separate solid or liquid particles from gases An important application is the purification of air for human use Although the physiological advantages secured in the breathing of clean, filtered air have long been known, only recently has the general public been able to experience the pleasure of this addition to the standard of living, through the increasing use of **air conditioning** systems, all of which involve filtration Especially are benefits to be gained where the air is abnormally polluted, as in passenger trains drawn by steam locomotives, in cities, or in the proximity of factories discharging a dusty waste Many types of filters are used in the air conditioning of trains, homes, theaters, and stores, some of which are of the wet spray types, others dry, containing mineral wool or felted pads through which the air is caused to pass, while others have oily surfaces to catch the dust Filters are also to be found for cleaning the dust from air used in internal combustion engines, and for purifying dust or ash-laden gases from industries, and in the laboratory.

Liquid filters are used for separating solid particles from the liquid They are used extensively in many chemical industries (See **Filtration**). In some cases the solids may be impurities, in others, they may be the product sought It is often necessary to purify raw water by treating it chemically to precipitate the salts it may contain, or to coagulate impurities carried in suspension Public water supply offers numerous examples of large scale filters A liquid filter may be made of paper, a porous membrane, or a layer of a porous material such as charcoal, coke, or sand Two systems of large scale filtration of raw water are practiced,—one known as the slow sand filter, the other the rapid sand filter. The slow sand filter is simply a large water-tight basin containing graded sand to the depth of three or four feet, overlaid with three to five feet of water Water percolates downward through the sand bed, being removed by an underground system consisting of tile laid with open joints After an extended period of time the effectiveness of the filter is reduced by accumulation of dirt on the filter bed, and cleaning is necessary Then the filter is unwatered, and the top layer of sand and dirt removed for cleaning and renewal A rapid sand filter employs a thinner filter bed, and is arranged for backwashing the bed to remove dirt This cleaning action must be performed much more frequently than in the slow sand filter, because the rate of percolation through the bed is considerably faster The usual arrangement of the rapid sand filter embodies a channel into which water from a sedimentation or coagulation basin flows From this channel a number of lateral distributing gutters lead off at right angles These distribute the water over the filter bed Ordinarily, the filter bed will be about three or four feet thick, and will be submerged to a depth of two or three feet The under drain system is much more complete and effective than in the slow sand filter, and consists of a series of parallel water channels which discharge into parallel pipes, all of which are connected to a common filtered water header Some amount of suction, or negative head, on the drain system, is permissible

Radio telephony equipment frequently uses apparatus known as filters These are found in several different forms, a few of which are low-pass filters, wave filters, band filters Low-pass filters have a continuously rising curve of impedance, as frequency increases These filters are used to give direct current from rectified alternating current Ordinarily, the low-pass filter consists of three filter condensers and three choke coils The wave filter is one designed to transmit currents in a desired band of frequencies, and to suppress, as nearly as possible, all other frequencies Wave filters are composed of impedances The band pass filter is employed in transmitting circuits to pass band of frequencies about ten kilocycles in width at any point over the broadcast range to which it may be tuned (See **Electric Oscillations and Waves**) (F T M)

FILTRATION, SEDIMENTATION, CENTRIFUGING, CLARIFICATION. These processes all involve the principles of separation of solids and liquids in the same system from each other Filtration accomplishes this end by means of interposing a porous medium, usually of paper or cloth of the desired porosity, but sometimes of sand or woven metal in such a way that the solid or precipitate is retained by the membrane while the liquid filtrate passes through the pores of the membrane. In some cases both precipitate and filtrate are recovered, whereas in other cases either precipitate or filtrate is desired and recovered and the other dis-

carded. The separation of precipitate and filtrate may be made more complete by washing the precipitate while on the filter or by repeated sedimentation before filtering. In sedimentation the solid material settles in the liquid at a rate depending upon the diameter of the particles (assuming these to be spherical), the difference in densities between the solid and liquid, and the viscosity of the liquid. This relation was expressed mathematically by Stokes, thus, where g is the acceleration due to gravity:

$$\text{Rate of fall of particle} = \frac{2g}{9} \times \frac{(\text{Radius of particle})}{\text{Coefficient of viscosity}} \times \text{Difference in densities of solid and liquid.}$$

It is evident, therefore, that, in a given case (1) the larger particles of solid settle more rapidly than the smaller, and that in two parallel cases (1) the greater the difference in densities of the solid and liquid, and (2) the less the viscosity of the liquid, the more rapidly sedimentation takes places. In **centrifuging**, the machines in use are designed to subject the material which is treated to the action of centrifugal force. Sedimentation and centrifuging may be utilized to separate two immiscible liquids.

In the practice of filtration, two cases may be mentioned. First, in the case where the suspended solids to be recovered represent a *small* percentage of the total material to be treated. The filter cake is built up with a force and at a rate which depend upon the pressure with which the material is fed to the filter. It is desirable to start with a moderate to low pressure, and to

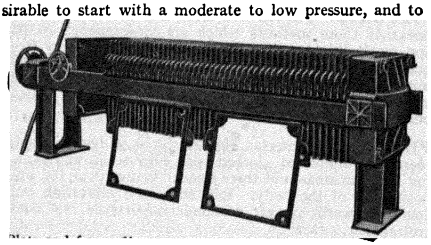
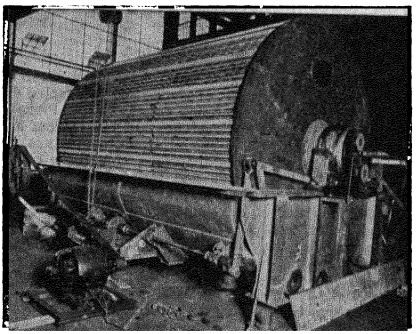


Plate and frame filter press (open), corner feed washing type.

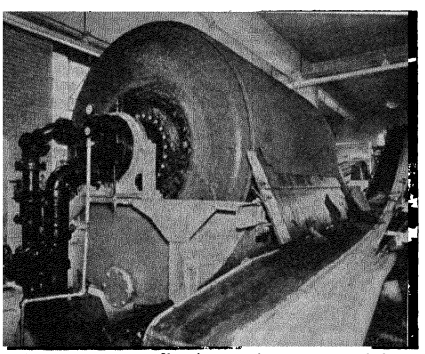
increase the pressure gradually as the resistance of the filter cake increases. In this way a practically constant rate of flow of filtrate is maintained during the desired interval until removal of cake is demanded because of the slow rate of flow at the maximum pressure. Second, in the case where the suspended solids to be recovered represent a *large* percentage of the total material to be treated. The formation of the filter cake will depend largely upon the kind of solid particles composing the precipitate. When these are granular and of the same size throughout, the resistance builds up gradually and the pressure should be moderate to low and increased as the resistance increases. When the solid particles are gelatinous, or are of uneven size, the increase in resistance to filtration and the decrease in rate of flow of filtrate occur relatively quickly. High initial pressure is to be avoided on account of the increased compacting effect, due to the force with which the particles come in contact with the filtering medium. It is frequently arranged to build up a layer of the precipitate and to utilize this layer as filtering medium. In such cases, since the initial filtrate is cloudy, it is returned to the filter after the filtrate runs clear. Another device to increase the rate of filtration of fine particles is to build up a layer of inert granular material.

The pressure utilized in filtering may be obtained by the use of negative pressure, that is, partial vacuum, or positive pressure, either hydrostatic head or pump. Filters are of the intermittent or batch and of the continuous types. In the latter type provision is made for the continuous removal of the filter cake as it is collected on a revolving filter.



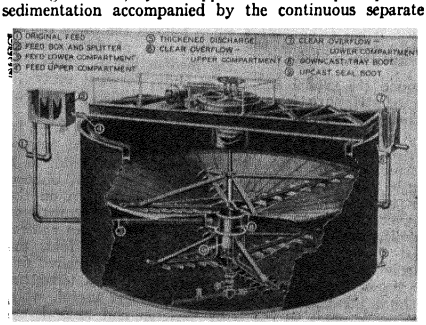
Conkey rotary vacuum filter in process of assembly for installation on sewage sludge at Detroit, Mich. (Courtesy of *Filtration Equipment Corporation.*)

Continuous separation of suspended solids and the liquid medium is also conducted, without the use of a



Conkey rotary vacuum filter in operation on sewage sludge at Elmira, N. Y. (Courtesy of *Filtration Equipment Corporation.*)

filtering medium, by the application of the principles of sedimentation accompanied by the continuous separate



Dorr thickener. (Courtesy of *The Dorr Co.*)

withdrawal of sedimented layer and clarified supernatant liquid at the proper rates. This method of clarification

is operated on an extensive scale. One modification of this method is utilized to remove the silt from the water of the Colorado River, immense settling basins in parallel arrangement being used. (R.K.S.)

FIMBRIATE. With a ruffled margin.

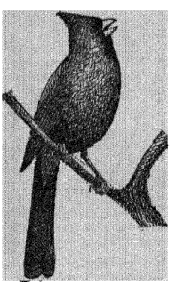
FIN. A broad thin appendage, primarily an organ of locomotion, and structures of similar origin adapted for other uses. True fins are found only in fishes (**Pisces**).

The two principal kinds of fins are the median and the paired. Median fins extend from the body along the median line of the dorsal surface, around the caudal end as the tail fin or tail, and forward as far as the vent. Paired fins include a pectoral pair attached to the pectoral girdle of the **skeleton** and the pelvic pair attached to the pelvic girdle. All fins are supported by bony or cartilaginous fin rays.

The median fin is broken up in most fishes to form separate dorsal fins and a ventral anal fin in addition to the caudal fin or tail. A caudal division of the dorsal portion is sometimes developed into the fleshy adipose fin. The tail fin may be heterocercal or homocercal. The former type has the end of the vertebral column extending into or toward its dorsal margin while the latter is evenly developed above and below the skeletal axis.

Paired fins are variously modified to form sensory lobes or supporting structures and the pelvic pair of some male sharks bear slender lobes, the claspers, which are thrust into the cloaca of the female during copulation. (A.W.L.)

FINCH. Aves, Passeriformes. Seed-eating birds (**Aves**) of many species, found chiefly in the northern hemisphere but to a limited extent in Africa and South America. They are small to moderately large and have a strong beak, usually conical and in some species very large.



The Cardinal (redbird), one of the many species of finches. The Cardinal is bright red, with throat and a ring around the beak black. It has a conspicuous crest, and light red bill. The female is duller.

In addition to the species whose names indicate their relation with the group, such as the greenfinches and the chaffinches, the finches include birds with distinctive names. The **grosbeaks, cardinals, brambling, siskins, linnets, redpolls, sparrows, canary,** and **crossbills** belong here. (A.W.L.)

FIN FOLD. A projecting ridge of the body wall in the lancelets which extends the lateral surface of the body and aids in swimming. The ridge follows the same course as the fins of fishes, along the median line of the back, around the caudal end of the body, forward ventrally to the **atriopore,** where it forks and continues forward as a pair of ventrolateral folds.

A fin fold is supposed to represent the earliest stage in the evolution of the locomotor appendages of **vertebrates.** At first a keel for **equilibrium,** extending as a single fold along the back and over the tail it divided to pass around the cloaca and extend forward on the ventral surface as a pair of folds. By the growth of cartilaginous rods for support and of muscle for control and the dropping out of portions of the fold, the median and caudal unpaired fins and also the paired fins of fishes developed. In the acquisition of a terrestrial habitat the unpaired fins were no longer useful, while further changes in the bony skeleton and musculature adapted the paired limbs first for supporting the body and then for propelling it. This theory is abundantly supported by paleontological and embryological evidence. (A.W.L.)

FINFOOT. Aves, Gruiformes. Birds (**Aves**) of a few species found in Africa, South and Central America, and the Oriental region. They are similar to the cormorants in form and frequent the water. The toes are lobed. (A.W.L.)

FINGER. Any of the second to fifth digits of the pectoral appendage of primates. (See **Hand.**) (A.W.L.)

FINGER LAKE. A glacial U-Valley or rock bowl which forms the basin for a fresh-water lake. Because of the character and origin of the basin, finger lakes are relatively long and narrow. Type locality, the finger lake region of New York State. (R.M.F.)

FINITE DIFFERENCES. Calculus of Finite Differences.

FIORD. A fiord is a glacially overdeepened **valley,** usually narrow and steep-sided, extending below sea level and occupied therefore by salt water. Typical fiords are to be found in Alaska and Norway; their depths, sometimes as much as four thousand feet, indicate that they are glaciated valleys which have been invaded by the sea after the disappearance of the glaciers. The word fiord is a variant of the Norwegian term for these features, *fjord.* The long fiord-like bays of the New England coast line are sometimes referred to as fiards. (R.M.F.)

FIR. Conifers.

FIREBALL. Fireball is a term used in astronomy to designate those **meteors** which are large enough to be apparently brighter than the **planet Jupiter.** They frequently leave a trail which may be visible for several minutes. Not infrequently a distinct sound is heard either during, or shortly after, the observation of a fireball. (W.K.G.)

FIRE BRAT. Insecta, Thysanura. A wingless **insect,** *thermobia domestica,* clothed with silky scales and bearing long antennae and three slender filaments at the opposite end of the body. Related to the **silverfish** but found in warm places; economic importance and control similar. (A.W.L.)

FIRE-BRICK. Fire-brick is a type of brick capable of withstanding high temperatures and is used to line flues, stacks, furnaces, etc. Good resistance to heat flow is not to be secured simultaneously with refractoriness—indeed, the most refractory bricks generally have the highest thermal conductivities. Where necessary, insulation is added to minimize heat leaks. It is important for the refractory brick to be satisfactory on a number of points in addition to refractoriness, for resistance to melting is only one of several requirements to be met. Among these might be cited resistance to erosion by ash-laden gases, and to the fluxing action of molten slag. A good refractory should not spall badly under rapid temperature changes. The structural strength of fire-brick should hold up well as its temperature approaches the fusion temperature.

Modern installations often impose furnace conditions so severe that refractories other than fire-clay are needed. High aluminum and silicon carbide refractories are typical of these. The heat conductivities of the super-refractories are larger than those of fire-clay brick, and such construction should be backed up with high temperature insulation. Carborundum blocks are the most refractory and have the quality of resisting clinker adhesion better than ordinary fire-brick. Their fusion temperature is about 4000° Fahrenheit.

Clay fuses at from 2800° to 3200° Fahrenheit, the upper limit being for flint clay and the lower for the plastic form which, due to its cementing qualities, is especially valuable in fire-brick manufacture. Red brick is not suitable for refractory service, nor is insulating

brick. There are several fire-clay furnace **cements** on the market that are adaptable to monolithic lining The standard size of fire-brick and insulating brick is 9 inches by 4½ inches by 2½ inches (F T M)

FIRECLAY. This term is chiefly used by British geologists to designate the leached **clays,** rich in **silica** and **alumina** and low in **alkalies** and **lime,** which lie directly beneath coal beds These clays are of economic importance because they are refractory, and do not melt when heated to high temperatures (R M F)

FIRE DAMP. Methane.

FIRE EYE Aves, Passeriformes A common species of **ant bird** in Brazil (A W L)

FIREFLY Insecta, Coleoptera Soft-bodied **beetles** with a luminous organ in the abdomen The flashing of these insects apparently enables them to find mates Also called lightning bugs (A W L)

FIREWALL. Industrial or commercial buildings, standing adjacent, with common division wall, may be required to have special attention given to this wall, as to apertures, thickness and material, so as to prevent ignition or transmission of conflagration from one building to another Such a wall would be a firewall

Aircraft having the **engine** mounted in the nose of the **fuselage** are required to have a firewall This consists of a bulkhead of sheet steel, dividing the engine compartment from the remainder of the fuselage. (F T M)

FIRN. Cirque.

FISH. Pisces.

FISHER. Marten.

FISHERIES. Pisciculture.

FISH FLY. Insecta, Neuroptera Species related to the **corydalus.** The **larvae** are aquatic and the adults are found near water (A W L)

FISH LOUSE. Crustacea, Copepoda Minute marine and fresh-water animals parasitic on fishes (A W L)

FISH MOTH. Silverfish.

FISSION A process of **reproduction** by the subdivision of the parent body into two or more approximately equal parts which become independent individuals

Fission is a common form of reproduction in the one-celled animals Division of the cell into two parts, known as binary fission, is accomplished by **mitosis,** often of a modified form In very simple species such as *Amoeba* reproduction is no more than cell division but in species with constant body form each half of the cell differs from the other and reproduction is not complete until it has undergone a reorganization with the development of all structures characteristic of its kind

Some protozoans (**protozoa**), notably parasitic species, go through a process of subdivision into a number of parts simultaneously This process is multiple fission or sporulation.

Fission occurs in multicellular animals of simple structure, including **polyps** and flatworms, by a gradual reorganization accompanied by the constriction and breaking of the body. (A W L)

FISSURE IN ANO. Such a condition is said to exist when an infected ulcer is present just internal to the margin of the **anus.** It is an exceedingly common condition, one that usually complicates **hemorrhoids** and causes excruciating pain Simple early cases can often be treated locally with success Many cases cannot be cured without operation (R S M)

FISTULA. A deep, chronically infected tract extending from the surface of the body deep into its tissues Fistula in ano is a fistula which is located around the anal margin, which runs upward through the deep tissues around the **rectum,** usually communicating with it This condition follows abscess formation around the lower rectum Surgery is required for its cure (R S M)

FIT. The clearance between working parts of machine elements or fastenings might be given rigorously in thousandths of an inch, but to do so as a general practice would involve much useless measurement Fit of two parts is given in thousandths of an inch only in the most exacting fits Instead, general classes of fits are known to the construction industry, and except for special cases, this classification is entirely satisfactory Examples of various types of fits specified by machine designers, and readily understood by machinists, are loose fit, free fit, medium fit, snug fit, wringing fit, tight fit, force fit, and shrink fit The first four of these are employed with interchangeable assembly methods, the latter four are practicable only for selective assembly Loose, free, and medium fits have application to different classes of **bearings,** pin joints, and the like, ranging from rough, heavy machinery, such as agricultural and mining machinery, to the more refined machine tool and automotive bearings A snug fit is not intended for a freely moving and loaded bearing The snug and wringing fits are used where there is to be no perceptible shake between the parts In general, tight fits are used for assembling parts which are to be permanently together except during replacement for breakage or wear Light pressure is required to assemble this fit, but it has not the holding and shock resisting power of the force fit or the shrink fit Shrink fits are not satisfactory for cast iron

There are four fit classes for screw-thread fits They are the loose fit, free fit, medium fit, and close fit. Of these, the free fit would cover the majority of screw threads of standard quality, and medium fit the best quality of commercial screw threads, exemplified by aircraft and automotive bolts and nuts (F T M)

FITCHEW. Polecat.

FITTIG REACTION The formation of aromatic hydrocarbons from aryl or aryl and alkyl bromides by the use of sodium, e g , brombenzene plus ethyl bromide plus sodium forms ethylbenzene plus sodium bromide ($C_6H_5Br + C_2H_5Br + 2Na \rightarrow C_6H_5 \cdot C_2H_5 + 2NaBr$). (See **Würtz-Fittig Reaction**) (R K S)

FIX. The point of intersection of two lines of position is known as the fix, and, since the observer must lie on both lines of position, the fix determines uniquely the position of the observer

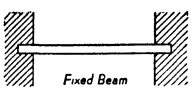
In case the two lines of position are obtained simultaneously the fix is immediately determined In case an appreciable time elapses between the determination of the lines and the observer has moved in the meantime, one of the lines must be carried to the time of determination of the other Any point on one of the lines is selected and this point is moved by methods of **dead reckoning,** either graphical or computational, through the **course** and distance traveled between the determination of the lines Through the point thus obtained a line of position is drawn parallel to the original line and the point of intersection of the unmoved and moved line is the position of the observer at the time of observation for the unmoved line

Due to errors in observation or in dead reckoning positions which must be used in solving the **astronomical triangle** to obtain the lines of position, the lines actually have a very appreciable width instead of being geometric lines In determining the fix the intersection is in reality a parallelogram instead of a geometric point Since the area of the parallelogram is a mini-

mum when the lines are perpendicular to each other, the more nearly perpendicular the lines are to each other, the more accurate is the determination of the fix (W K G)

FIXATION OF ATMOSPHERIC NITROGEN. Ammonia, and Nitric acid.

FIXED BEAM. A fixed or restrained beam is one having the ends so firmly connected to the supports that the tangent to the **elastic curve** at the ends remains fixed in direction under varying load conditions Theoretically, this requires the support to be absolutely unyielding In actual practice it is impossible to attain a perfectly rigid end support, and the design of a beam on the assumption of perfect restraint would be unduly optimistic Therefore a design intermediate between perfect restraint and perfect freedom should be adopted for built-in beams, the departure from the conditions of perfect fixity being based upon the rigidity of the end supports Since a fixed beam under load receives an end moment where it is built in, it will be stiffer than a freely supported beam, and thus have a smaller deflection under the same load (C W C)



FIXED OILS. These are compounds of **glycerin** and various complex fatty acids (See **Acids, Carboxylic; Esters;** and **Fats**) They are often called non-volatile oils, in distinction to the essential or **volatile oils,** which are readily vaporized by steam It is characteristic of them that they will leave a spot when dropped on paper Many of them remain liquid at common room temperatures, others are solid at such temperatures Solid forms are usually called fats, a rather arbitrary distinction since slight changes in temperature will cause many of them to change from liquid to solid or vice versa without any other external change

Fixed oils, especially those of economic importance are largely obtained from the seeds of plants They have a high energy value, so form a valuable food source if they prove palatable

Various methods are employed to obtain the oil from the vegetable tissues Quite commonly the seeds containing the oil are subjected to great pressures in **hydraulic presses.** This may be done without heating, but is frequently facilitated by heating the seeds, the oil being then hot-pressed instead of cold pressed Hot-pressing usually increases the yield but causes the product to be less valuable A third method of obtaining the oil is by means of solvents Following expression of the oil from the plant tissues, various methods of refining, decolorizing and deodorizing are employed

Fixed oils are usually classified into three groups, drying, semi-drying, and non-drying oils Often a fourth group is made of those which are usually seen in solid form, the vegetable fats, although they differ but little otherwise from the other groups

Drying oils are those which on exposure to air form a tough elastic film Linseed oil from **flax** seeds is one of the most important and is largely used in making paints and varnishes **Tung oil,** obtained from the fruits of *Aleurites cordata,* is a valuable oil much used in the manufacture of waterproof varnishes The tree, a native of China and Japan, has been introduced into Florida Other drying oils are nut oil, from walnut seeds, poppy seed oil, **hemp** seed oil, and sunflower oil, the latter largely a product of Russia

Non-drying oils are those which remain permanently greasy or sticky, becoming rancid after a time Among these oils the most important are **olive** oil, castor oil from the seeds of the **castor** bean plant, rape seed oil, **peanut** oil, **almond** oil, used medicinally, and tea seed oil.

Semi-drying oils are intermediate in nature The principal semi-drying oils are **cotton-seed. soybean** oil, **corn** or maize oil and sesame oil The latter is obtained from the seeds of *Sesamun indicum,* a member of the Pedaliaceae, cultivated in India, China and Japan, where the oil is much used as a food oil, and for cooking

Non-drying oils which are ordinarily solid are palm and palm-kernel oil, coconut oil, and cocoa butter Another interesting oil of this group is macassar oil, obtained from the seeds of *Schleichera trijuga,* one of the Sapindaceae, occurring in tropical Asia The oil was formerly much used as a potential hair restorer, necessitating the use of removable covers, or antimacassars, on the backs of upholstered chairs The same tree also yields a useful timber (R M W)

FLAGELLATES. This is a large group of organisms, of particular interest because of the position they occupy in the organic world In this article they are treated as plants, but they are also treated as animals (See **Mastigophora**) They are usually one-celled organisms, of extremely complex structure Many of them have no cell wall of **cellulose,** lack the green pigment, **chlorophyll,** and are definitely animals Others possess a distinct wall of cellulose and have **chloroplastids,** and are set off as plants The separation of these two groups is not sharp, however, and some of the plant members are obviously very closely related to very similar animal forms Therefore it is impossible to stress the differences which are used as a basis for classification Characteristic of the Flagellates is the flagellum, a long lash-like extension from the **protoplast.** The vibrations of the flagellum propel the organism through the water, in which they usually occur

The Flagellates are considered by many to represent the ancestral group from which higher organisms, both plant and animal, originated Many of the animal flagellates occur as parasites in the bodies of higher animals Some of these occur in the human body, commonly in the intestines It has been suggested that certain species may cause severe **dysentery.** (R M W)

FLAGELLUM 1 A movable slender process arising from a **cell** An organ of locomotion of certain one-celled animals (**Mastigophora**), occurring singly or in groups of two or four Occurs in sponges, where the action of flagella of many **choanocytes** draws currents of water into the body

In typical structure the flagellum has a delicate axial filament arising from a **blepharoplast** in the cell and surrounded by a sheath of protoplasm except at its tip In many cases there is also a larger parabasal body connected by fibrils with the axial filament and with the nucleus The flagellum is much larger than a cilium and moves in undulations

2 The whiplike terminal portion of the antenna of a **crustacean.** (A W L)

FLAME CELL, Excretory System.

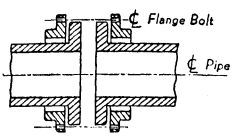
FLAMINGO. Aves, Ciconiiformes Large wading birds (**Aves**) of several species found in the warm regions of the world with the exception of Australia They have very long legs and neck and a broad beak bent sharply downward at the middle Red or rosy shades are characteristic in their plumage. (A W L)

FLANGE. A flange is a rim or projection extending completely around the object which is flanged Thus it is distinguished from an ear, which is a similar projection, but which extends only a small portion of the circumference Flanges are employed for a great many different purposes, among which is the juncture of adjacent shafts by flanged **couplings,** the flanges providing area through which connecting bolts may be passed. Flanged wheels are commonly used to maintain the position of a wheel and axle group upon parallel rails,

pipe flanges, for the connection of pipes which are not to be screwed together.

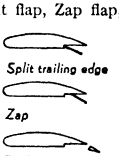
Low-pressure piping larger than 6 inch and high-pressure piping are, in the majority of cases, connected by companion flanges. Flanges are drilled to a standard templet and drawn tightly together by means of flange bolts. Alloy steel bolting to conform to A.S.T.M. specifications should be used when pressures exceed 160 pounds per square inch or temperatures exceed 450° F., but below these limits commercial bolting should be used.

Flanges are made of cast iron, cast steel, forged and rolled steel. The face of the joint is always machined smooth. The Van Stone joint has proved to be a satisfactory connection and is widely used. For the most severe service the lap is made full pipe thickness with a perfectly smooth finish to the laps. The flanges are loose on the pipe and the laps are clamped between them. The outside diameter and minimum thickness of pipe flanges are the same as those for fittings. (F.T.M.)



Loose flange (Van Stone) pipe joint.

FLAP. It is known that the maximum lift coefficient of a highly cambered airfoil is greater than that of a flat, thin one. Safety in landing an airplane demands low landing speed, which is obtainable by using wings with high maximum lift coefficients. On the other hand, maximum speed is only to be obtained with the thin, low drag type airfoil. Many manufacturers of aircraft have recently adopted the flap as a means for securing low landing speeds on aircraft fitted with inherently high speed wings. The flap, as illustrated in the accompanying figure, is akin to a flexible trailing edge, and by depressing the flap, the effective camber of the airfoil may be increased. The drag is also increased, giving a steeper gliding angle with flap down than without the use of the flap. Apart from any disadvantage, this factor may actually be beneficial, since with flap position variable and under control of the pilot, the angle of normal gliding is alterable, permitting steep approaches to small obstructed fields. Among the flaps having received a great deal of attention, have been the simple flap, the split flap, Zap flap, and the Fowler flap. The split flap is simplest to apply, and has been extensively used. The operation is simply that of a rotation of a panel on the lower side of the trailing edge about its forward edge. In the Zap flap, the rotation is accompanied by a backward movement of the pivoting point. In the Fowler flap, the motion is not one of simple rotation, and the effect is one of increase of airfoil area as well as change of camber. Most flap designs are patented. (F.T.M.)



Flaps.

FLASHING. Flashing is a method of sealing joints on buildings, especially around roofs, chimneys, gutters, and valleys, in order to render them water-tight. The method consists of using strips, or shingles of flashing material which are worked into the normal roof surface and turned over the joint. Where the flashing turns up, as along a brick wall, it is necessary to counter flash, that is to let a strip of flashing material into the brickwork, and bend it down over the other flashing. A sloped shingle roof flashed against a brick wall requires flashing shingles which are worked under the top course of the regular shingles and turned up along the bricks. Corresponding counter flashing let into the brick is bent down over these flashing shingles. A joint between the gutter and cornice is made weatherproof by flashing. Usually the flashing extends from under the lowermost course of shingles and is turned down over the edge of the gutter. The most common flashing materials are tin-coated sheet iron and copper. Lead and zinc are used to a limited extent. (F.T.M.)

FLASH POINT. The lowest temperature at which an oil will decompose to an inflammable gaseous mixture, demonstrable through its explosive quality, is its flash point. The flash point occurs at a temperature lower than the burning point, which is the lowest temperature at which the production of combustible gas occurs rapidly enough to support a steady flame. The flash point is an important characteristic of oils used for lubricating bearings, since any heating to the flash point would result in decomposition of the oil as a lubricant. On the other hand, the flash temperature is less important than the burning temperature in determining the fire risk of an oil. The flash point is tested experimentally by heating the oil under certain specified conditions in a cup. A thermometer is suspended in the oil so that the temperature may be read during the test. Periodically an open test flame is introduced through an opening in the cover to detect the slight explosive puff which follows when the flash point has been reached. (F.T.M.)

FLASH SPECTRUM. At the instant of second or third contact during a total solar eclipse the edge of the moon is tangent to the photosphere of the sun as shown in Figure 1. With the photosphere covered the highly heated atmosphere of the sun, known as the reversing layer and the chromosphere, flashes into view. With the photosphere covered the continuous spectrum of the sun is cut off and the bright line spectrum radiated by the atmosphere may be observed.

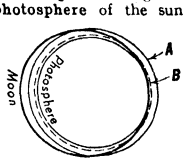


Figure 1. Flash spectrum.

If a photograph is taken with an objective prism at the instant of second or third contact, a series of curved images of the atmosphere of the sun will be obtained, each in one particular radiation. As indicated by Figure 1, radiations due to elements at the highest levels, as at *A*, will give longer curves, than the radiations due to elements at lower levels such as *B*. Such a bright line spectrum is referred to as a flash spectrum, since it is only visible for a few seconds at the instants of the contacts.

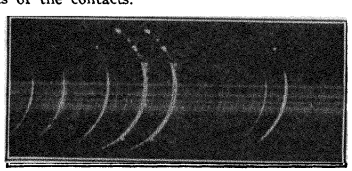


Figure 2. The flash spectrum. Photographed by J. A. Anderson near the end of the total eclipse of January 24, 1925. (By courtesy of the *Mount Wilson Observatory.*)

Figure 2 shows a section of a flash spectrum plate. The long curved lines are due to the so-called *H* and *K* lines of calcium and their extreme length indicates that this element rises to the very top of the chromosphere. The projections from the curves are due to prominences, and the breaks in the curves are caused by irregularities on the moon. Other lines, of shorter length, are due to elements in the lower regions of the solar atmosphere. A careful study of flash spectrum plates gives the distribution of elements throughout the solar atmosphere. Such results are of great value for a variety of problems of solar research, such as the selection of radiations to be used with the spectrohelio-

graph for obtaining photographs of the sun at different levels. (W.K.G.)

FLATFISH. Pisces, Teleostei. Fishes (**Pisces**) which lie on one side of the body when adult. The head is modified so that both eyes are on the upper side. Many species are valuable food fishes and the halibut is an important source of vitamin-bearing oil now widely used in place of cod-liver oil.

The flatfishes make up the family Pleuronectidae. Among the included species are the **halibut, plaice, flounder, turbot, brill, soles,** and **dabs.** (A.W.L.)

FLAX. *Linum usitatissimum.* Linaceae. Flax is the name given to the **bast** fibers of *Linum usitatissimum,* a plant native to Europe. (For a discussion of New Zealand flax, *Phormium tenax,* see the next article.) They were probably the first vegetable fibers to be used by man. Picture-writings at Thebes not only show the plant, but also give details of the processes used in making cloth from the fibers. Egyptians, Greeks, ancient Hebrews, and Romans knew the fiber and used it. Mummy-cloths are often of linen.

The flax plant is a slender annual attaining four feet in height and branching slightly. It has small **lanceolate** leaves and clear blue flowers. When mature it bears seed capsules containing ten seeds each and about a quarter of an inch in diameter. Successful cultivation demands an abundance of **potassium** and **phosphorus** in the soil and plenty of moisture. The plant is cultivated not only for the fibers, but also for oil. The best fibers are obtained from plants grown in cool regions, while the best oil is derived from plants grown in tropical countries like India.

For preparing flax, the plants are pulled or cut before they are mature, and stripped of all leaves and seed capsules. The denuded stems are then tied in small bunches and immersed either in stagnant or slowly running soft water, where they are left for several days. During this time, the stems are attacked by **bacteria,** which bring about fermentation, causing a breaking down of the woody tissues and a partial separation of cells due to the action of the bacterial **enzymes** on the substances binding the cells together. This process is called "retting." Sometimes the flax stems are spread on the ground in a thin layer and left exposed to the action of dew and sunshine for a few weeks. The same result is obtained, the process being now called "dew-retting." The retted stems are removed from the water, washed and cleaned of as much non-fibrous material as possible. This process is known as "Scutching." "Hackling" follows, and is a sort of combing which removes any remaining non-fibrous material. The fibers thus obtained are in reality bundles of cells which occurred as **bast** fibers in the stem. Good fibers vary from 12-36 inches in length, while many shorter ones are obtained. Short and tangled fibers are called "tow." The fibers vary in color from yellowish to dirty gray, largely depending on the attention paid to the retting process. They are soft and flexible, capable of division into smaller bundles of fewer cells. They are very strong, possess a uniformly thick wall which surrounds the very slender central cavity or lumen.

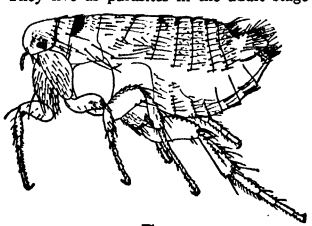
The principal use of the fibers is in the manufacture of thread requiring great strength, such as shoe thread, bookbinding thread, fish line and fish-net twine, and also in the making of fine cloth such as table-linen and handkerchief linen. All cloth made from flax fibers is called linen. Flax fibers conduct heat much more rapidly than cotton and so cloth made from them is cooler and much favored in tropical countries.

In addition to the fibers, flax plants yield a valuable oil, called linseed oil. (See **Fixed Oils.**) In making this the seeds are crushed by machinery, heated to 165° F. and treated with naphtha which extracts the oil. The seeds are about 40% oil. This oil, a drying oil, is used in the manufacture of paints, varnishes, and patent leather, as well as in making linoleum and oilcloth.

The oil cake left after the oil is pressed from the seeds is used directly as a cattle food or is ground up into oil meal and used for the same purpose. (R.M.W.)

FLAX, NEW ZEALAND. *Phormium tenax.* Liliaceae. (For a discussion of common flax, *Linum usitatissimum,* see preceding article.) The fibers of New Zealand flax occur as **sclerenchyma** bundles in the long straight rather stiff leaves of this plant. The plant, a native of New Zealand, has been introduced into Australia and other countries. In the United States, it is cultivated to some extent, often as an ornamental plant. The leaves, from four to eight feet long and up to eight inches wide, may be 20% fibrous material. To obtain the fiber the leaves are cut off and scraped to remove much of the non-fibrous material. After this the fibers are combed out and cleaned. They are very white, soft, flexible, lustrous and tough. They may be five feet long. The principal use of New Zealand Flax is binder twine, baling rope, and cordage, often in combination with sisal or other fibers. A fine cloth resembling linen duck can be woven from it. From 3000 to 5000 tons of this fiber are imported into the United States annually. (R.M.W.)

FLEA. Insecta, Siphonaptera. Small **insects** with transversely compressed bodies, sucking mouths, and no wings. They live as parasites in the adult stage on the



Flea.

bodies of mammals and more rarely on birds. The larvae having biting mouths and eat fragments of organic matter in the debris about the sleeping places of the hosts; they are never parasitic.

Pyrethrum powder is an effective deterrent for these pests. It can be dusted into the fur of dogs and cats and used about the house in regions where fleas are troublesome to man himself. (A.W.L.)

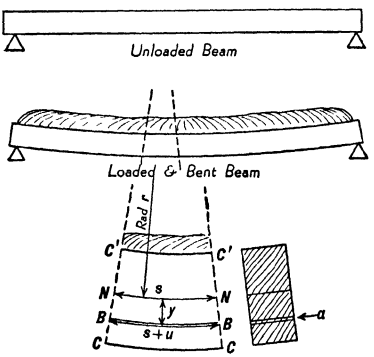
FLEXURE. Flexure is a term which is used to denote the curved or bent state of a loaded beam. A horizontally located **beam,** transversely loaded with vertically directed load offers an example of load-carrying ability derived through flexure. In flexure, an elastic structural material undergoes a deflection sufficient to set up in its material stresses which will support the load. Deflection under load is an essential and necessary part of the process of load carrying by a beam, for until the deflection has occurred, there are set up in the beam no resisting forces. Thus if an unloaded beam is perfectly straight and horizontal, it must assume a slightly curved position if any external load is supported by it. The only way in which a loaded beam could be straight would be to have had an initial deflection in a direction opposite to the loading.

The so-called flexure theory establishes a relation between the fiber stresses at any point in a beam and the bending moment causing these stresses. This theory is based on two fundamental assumptions whose validity, within ordinary working limits, has been established by experiment. The first assumption is that a cross-section which was a plane before bending remains

a plane after bending This implies that the unit deformations are proportional to the distance from the neutral axis The second assumption is that the fiber stresses are proportional to the deformations resulting from these stresses If a **tension** member is subjected to an axial load in a testing machine it will be found that, for stresses below the **proportional limit,** the ratio of the unit stress to the unit deformation is a constant called the modulus of elasticity This would also be true if the test specimen were a short compression member In order to reconcile the second assumption it must be further assumed that the fibers act similar to test specimens and that the modulus of elasticity is the same for tension and compression

It will now be shown how deflection and load-carrying ability are interrelated in a beam First, it will be assumed that the structural material is elastic, that is, within the elastic limit the stress is proportional to the strain inducing it, and that it is a homogeneous material The results produced by materials not exactly meeting these specifications are usually in good accord with the theory based on these assumptions

Assume that there is a beam of rectangular cross-section mounted horizontally between simple supports



If one were further to assume this material is weightless, the axis of the beam would be absolutely horizontal Next a gravity load is placed on the beam, resulting in a certain deflection which sets up resisting couples within the beam, enabling it to carry the load It must be evident that after a static condition is reached, the external **bending moment** thus imposed on the beam must, at any point, be balanced by an internal moment arising out of the stresses in the material of the beam (Next consider the enlarged section of the bent beam) If the section is taken sufficiently small, it can be assumed to be bent in the arc of a circle whose radius is r The upper fibers, i e, $C'C'$, are naturally compressed or shortened in length, and the lower, CC, are stretched At some intermediate plane, NN, there must exist an unstretched fiber whose length is the same as it possessed in the unloaded state This axis of no strain is called the neutral axis If its length is s, then the length of a typical fiber, such as BB, located at a distance y from the neutral axis, is $s+u$, in which u represents the stretch $\frac{u}{s}$ is the percentage stretch, or strain, of the material From the geometry of the figure it is apparent that the strain $\frac{u}{s}=\frac{y}{r}$. Since stress is proportional to strain, the factor of proportionality being the modulus of elasticity E, it follows that the stress on $BB=p=E/\frac{y}{r}$ Referring to the cross-section of this small element of the beam, the end area of fiber BB is taken as a The stress p acting on this area produces an elementary internal force ap Above the neutral axis there are similarly produced forces, but oppositely directed The sum of all these longitudinal forces is, of course, zero, since the beam is static, however, at any cross-section they produce, *in toto*, a torque or moment around the neutral axis which is exactly equal to the external bending moment at that section For example, the moment of the force acting on the fiber BB is apy about the neutral axis The total moment, then, is the Σapy about the neutral axis.

Substituting $\frac{Ey}{r}$ for p, the total moment equals

$$\frac{E}{r}\int ay^2=\frac{E}{r}I$$

The last step shows how the areal **moment of inertia** enters into the flexure formula Since r is not a convenient quantity to work with, a substitution of $\frac{p}{y}$ is made for $\frac{E}{r}$ resulting in the common flexure formula,

$$M=\frac{pI}{y}$$

In this formula, M is the bending moment at a section where the moment of inertia is I, and p is the unit stress at y distance from the neutral axis

It is readily shown that the neutral axis is coincident with the center of gravity of the cross-section of the beam From above, we extract the following equation

$$ap=\frac{E}{r}ay$$

$$\int ap=\frac{E}{r}\int ay$$

$\int ap$ is the total force within the beam parallel to the neutral axis, and is zero, as explained above, but this results also in $\int ay$ being equal to zero, which can be true only when the distance y is a moment arm around the center of gravity of the cross-sectional area

The flexure formula is valid as long as the stresses are within the proportional limit In the derivation of this formula it is assumed that the horizontal stresses are the only internal forces which resist the external bending As a matter of fact, the true maximum tensile or compressive unit stress, called a principal stress, is the **resultant** of the bending and the shearing stress acting at the point But, as has been previously stated, the stresses which are obtained by the flexure formula are reasonably correct for ordinary design purposes (C W C, F T M)

FLICKER. Aves, Piciformes Moderately large **woodpeckers** of North America which differ from the other woodpeckers in feeding habits Flickers eat many insects on the surface of the ground and are particularly fond of ants, which they catch on the long sticky tongue Three species are recognized, the common or yellow-shafted flicker, *Colaptes auratus*, the red-shafted, *C cafer*, and the gilded flicker, *C chrysoides*, of the southwest The common flicker is sometimes called the high-hole.

Other species of the same genus occur in South America (A W L)

FLICKER PHOTOMETER. Bench Photometers.

FLIGHT. Locomotion through the air Some animals travel through the air for short distances by gliding, supported by broad expansions of various parts of the

body, but in true flight the animal is able also to support and propel itself by muscular activity. True flight occurs only in the insects, birds and bats. The pterodactyls, an extinct group of reptiles, were also able to fly.

The gliding animals include the **flying fishes,** an **amphibian** (the flying frog), a **reptile** (the flying dragon); and several species of mammals (**flying squirrels, flying lemur**). With the exception of the flying fishes all are provided with broadly expanded thin structures on which they coast down the air from one place to another. The supporting structures of the frog are enormous webbed feet, those of the dragon are broad membranes along the sides of the body supported by elongate ribs, and those of the flying lemur and flying squirrels are folds of skin along the sides of the body between the fore and hind legs. Flying fishes are supported during long leaps through the air by the greatly enlarged pectoral fins.

True flight also depends partly on the possession of broad light planes, the **wings.** These organs are moved by special muscles in such a way that their pressure against the surrounding air lifts and propels the body. Flight demands relatively great expenditure of energy, hence the flight muscles are highly developed. In the most rapid and powerful fliers this is especially true; the wings are smaller and the muscles larger in contrast with the broad wings and relatively smaller muscles of weaker fliers.

In the birds flight is accompanied by accessory adaptations for securing large amounts of oxygen, for storing energy in abundance, and to provide rigid skeletal support against the stresses of flight. The feathers are an insulating coat of high efficiency in the cold upper air. Birds are, in fact, primarily adapted for flight and in other respects conform to the limitations imposed by this adaptation. Only by such extensive adjustment to life in the air are they able to remain on the wing for many hours without rest, like the albatrosses during their everyday life and like many other birds during migration. The flight of birds, moreover, is the most rapid locomotion of living things, rivaling even the mechanical transportation achieved by man. Birds commonly fly thirty or forty miles per hour and speeds in excess of one hundred miles per hour have been recorded.

Some birds are adept at soaring, a type of flight in which the wings are held extended and the bird depends on air currents to carry it. It may ride ascending currents to high levels and may always glide to lower levels, moving only to maintain its equilibrium. The vultures very commonly fly in this way for long periods without flapping a wing.

Since the aid is too light for an animal to float in it, all flying things must also have some other means of locomotion. The single known exception is a South American May fly. Although this insect walks beneath the water as a **larva,** during its adult life its legs are vestigial. When it once emerges from the water it must fly until the brief remainder of its life is ended, and when it once drops to the water or to the ground it never rises again. (A.W.L.)

FLINT. Flint is a rock composed essentially of a cryptocrystalline form of silica. It is very dense and tough, breaking with a **conchoidal** fracture; colors, usually dark grays, blues, or browns, often black. It occurs chiefly as nodules and masses in **chalks** and **limestones.** Flint is particularly interesting because it was used by primitive man for making instruments (artifacts) for thousands of years before he learned to use bone and metal. Flint still remained an essential mineral resource for making fire, including the flint locks on guns, until the close of the eighteenth century. From the dawn of civilization the best flint has come from Belgium and the coastal chalks of the British Channel and the Paris Basin (R.M.F.)

FLINTY CRUSH-ROCK. A term proposed by the Scottish geologist Clough for the almost structureless, flinty portion of **mylonite,** an extreme product of dynamic **metamorphism.** (R.M.F.)

FLIPPER. An appendage of the aquatic **mammals** in which the digits are enveloped by continuous tissue so that the entire structure forms a flat paddle for swimming. Flippers occur in seals, **manatees, whales,** and related forms. (A.W.L.)

FLOCCULI. Sun.

FLORET. A small flower; for example, one of the flowers forming the head of the plants of the **Composite Family.** (R.M.W.)

FLORICAN. Bustard.

FLOUNDER. Flatfish.

FLOUR. Wheat.

FLOW. Fluid Flow.

FLOWAGE (ROCK). This term, as used by geologists, signifies the internal movement of clays and rocks when stressed beyond the elastic limit. Important types of flowage are: **plasticity, granulation** and **foliation,** although the latter is primarily a physical-chemical rather than a purely mechanical process, as in the other types of flowage. (R.M.F.)

FLOWER. The flower is that part of the plant which is concerned in the sexual reproductive process of higher

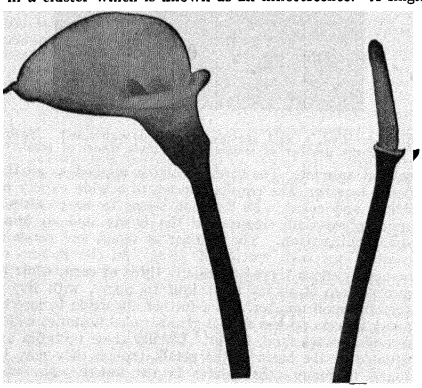
Anemonella, one of the buttercup family.

plants. The formation of the flower is preliminary to the production of **fruit** with its **seeds.**

Flowers may be borne at the tip of a stem or a branch, in which case they are said to be terminal flowers. Or they may be borne in the **axils** of leaf primordia

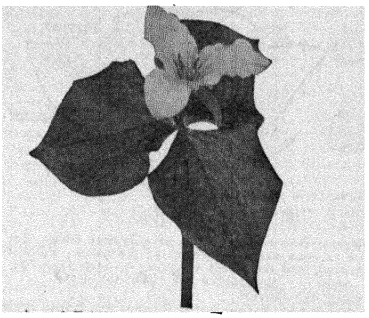
and called axillary. In very many plants the structure which subtends the flower does not develop into a leaf like the other leaves of the plant. Instead, it may remain very small and inconspicuous, or it may grow larger, but be of shape quite unlike that of an ordinary leaf. These structures which subtend flowers are called bracts. In a few plants the bracts are large and brilliantly colored, so that at times they are much more showy than are the flowers. The scarlet bracts of the *Poinsettia* and the white or pink bracts of the dogwoods are examples. In many **monocotyledons,** as Palms and Arums, there is a single large bract which subtends and often more or less surrounds the flowers. Bracts of this kind are called spathes. The striped "pulpit" of the Jack-in-the-Pulpit flower, or the white bract of the Calla Lily are well-known examples. The bract may surround and protect the flower in the bud.

Flowers may be borne singly or they may be associated in a cluster which is known as an inflorescence. A single



Spadix of Calla lily. This is not a flower but an inflorescence. In the center is a spike, the upper portion of which bears staminate flowers and the lower portion pistillate flowers. The showy white portion is a spathe—a special leaf surrounding the spadix. A, exterior view; B, with spathe removed to show spadix inside.

flower is called a solitary flower, and the stalk which supports it is a peduncle. The stem which supports an inflorescence is also a peduncle, while the individual flowers of the inflorescence are supported on pedicels. When there is a distinct axis extending through an inflorescence it is called a rachis. The arrangement of the flowers of an inflorescence varies in different groups. A common form of inflorescence is the raceme, in which the floral shoot grows at the apex and bears many branches, each ending in a single flower. The first flowers to open are those at the base of the raceme. If, in an inflorescence of this sort, each branch is a raceme bearing several flowers, it is called a panicle, or a compound raceme. If the flowers of the raceme are borne directly on the main axis, the inflorescence becomes a spike. A secondary spike, common in grasses, is a spikelet. A catkin is a spike which droops. A corymb is an inflorescence in which the pedicels of the lateral flowers grow fast enough to form a more or less flat-topped cluster. An umbel differs from a corymb in that it has no central rachis, all the pedicels of the inflorescence rising from a common point. More commonly umbels are compound, each of the main stalks of the inflorescence bearing an umbel at its tip. The inflorescence of the onion is an umbel, that of wild carrot a compound umbel. The inflorescence of the **composite family** is a head, which may be considered as an umbel in which the flowers are all sessile, without stalks, on the apex of the stem. A cyme is an entirely different type of inflorescence. In the cyme the first flower to open is at the tip of the cluster. Below it on the stem are a number of bracts. From the axils of these bracts branches develop and also end in a



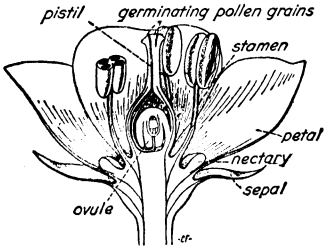
Upper portion of *Trillium* plant with whorled arrangement of leaves on the stem.

flower. This successive branching may be many times repeated, but always the flower terminates the stem and opens. Combinations of these types of inflorescences are found in many plants. A spadix is an inflorescence of the raceme form with elongated axis, sessile flowers, and enveloping leaf.

A flower of *Hippeastrum,* a member of the Amaryllis Family, showing three-parted stigma and the six stamens characteristic of the lily order, surrounded by perianth of six parts arranged in two whorls.

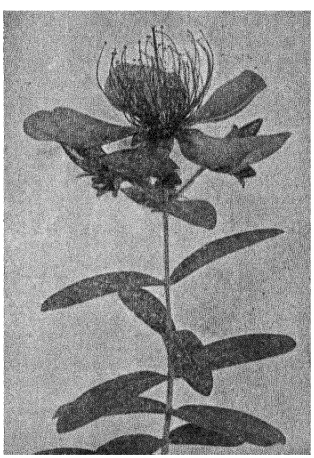
A flower consists of an axis, called the receptacle or torus, and, attached thereto, the pistils, the stamens, the petals, and the sepals. The first two are the essential organs of the flower, the other two are accessory organs. Any flower which has all four organs is a complete flower, while that which lacks one or more is incomplete. If the organs missing be either stamens or pistils, the flower is imperfect or unisexual. A perfect or bisexual flower has both sets of essential organs. If only the stamens are present the flower is staminate; if only pistils, it is pistillate. If the two kinds of flowers, staminate and pistillate, are found on the same plant,

that species of plant is monoecious. When the two unisexual flowers are found on different plants, the species



Diagrammatic representation of a typical flower, cut lengthwise to show the arrangement of the parts. Pollination has occurred, and the pollen tube may be seen extending toward the embryo sac within the ovary.

is dioecious. Infrequently flowers are borne which lack both stamens and pistils, and are sterile. When the flower lacks sepals and petals, it is a naked flower.



Flower of Saint John's-wort (polypetalous). The organs of this flower are unusually well exposed to view.

Flowers may also be distinguished as regular and irregular. Regular flowers are those in which all the members of any set of organs are alike, forming a flower which is radially symmetrical or actinomorphic. Often the organs of one or more sets are not alike, forming an irregular flower. An irregular flower may be bilaterally symmetrical or zygomorphic, one half being a mirror image of the other.

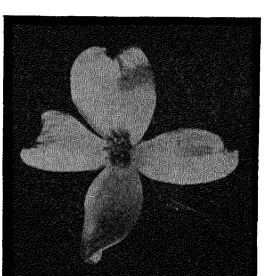
Flower of pea (irregular).

The accessory floral organs, the sepals and petals together, constitute the perianth. In the complete flower, the perianth is composed of a whorl of sepals which is called the calyx and inside the calyx a whorl of petals called the corolla. The sepals are usually green and small. The function of the calyx seems to be to protect the other parts of the flower before the flower bud opens. The petals are usually thin and bright

Rosa carolina, a wild species, sometimes cultivated. Notice the large number of stamens and single whorl of petals.

colored or white. The term corolla is applied to all the petals together. The corolla appears in a wide variety of shapes and colors. Its function seems to be to attract animals, especially insects, to the flower and so bring about **pollination.** The number of sepals and petals is constant for each species of plant. In the flowers of monocotyledons there are usually three of each, while in dicotyledons it varies from four to many, with five a very common number. As a further attraction to insects, many flowers possess special glands called nectaries which secrete a sweet fluid, nectar. Usually these nectaries are situated at the bases of the petals, though they may be found in many other places in the flower. Nectaries known as extrafloral nectaries are found on petioles of leaves or on the stipules.

The stamens, or microsporophylls, taken together constitute the androeceum. Usually a stamen consists of two parts, a stalk or filament and an anther. The filament may be short and stout, or more commonly long and slender, raising the anthers well above the base of the flower. The anther when first formed is an undifferentiated mass of cells. As it develops, four groups of cells become set off from the surrounding cells. In these masses, which usually appear as linear strands certain cells undergo reduction division or **meiosis** and become microspores. The sac which contains them is therefore a microsporangium. A microspore develops into a pollen grain. The anther sac, or sporangium, when mature usually opens by two longitudinal slits, or by special spores, and frees the pollen grains. The number of stamens in a flower varies from one to many. Often there are vestigial stamens, or staminoidea, present in the flower; in some plants these are large and brightly colored, in others they are small and inconspicuous.

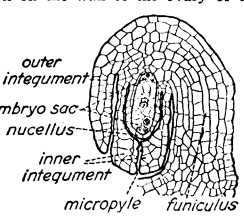


An inflorescence of the flowering dogwood, *Cornus florida.*

The pistil is the central organ of the flowers. A single pistil or several pistils, which may be separate or partly, or even completely, united, is called a gynoecium. A pistil is composed of one or more longitudinal units called carpels or megasporophylls. When there are two or more somewhat united carpels, the pistil is called compound. A pistil is composed of a basal ovary, a terminal stigma, and usually an intermediate style, which is often long and slender. The stigma is a receptive organ, the surface of which is often either sticky or hairy. It is to the surface of the stigma that the pollen grains are carried when **pollination** takes place.

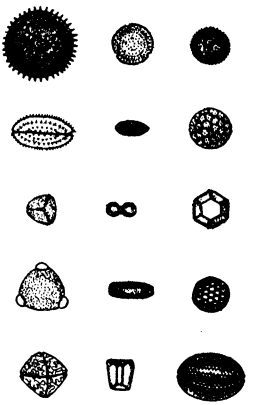
The style may be very much elongated to lift the stigma above the other parts of the flower and so increase the probability of pollination. The ovary has one or more cavities, or loculi. In these are located the ovules, which will become the seeds. The ovules are attached to the wall of the ovary or to a central column by a small stalk called the funiculus, through which the developing ovule receives nourishment. That region of the ovary to which the ovules are attached is called the placenta. The number of ovules in a single loculus varies from one to many.

Each ovule first appears as a minute rounded projection on the wall of the ovary or the columella. In the early period of its development this projection consists of an undifferentiated mass of cells known as nucellar tissue. One or two layers of cells, known as the integuments, rise from the base of the projection, and finally almost completely surround the nucellar tissue. A minute opening through the integuments, called the micropyle, is left connecting the cavity of the ovary to the surface of the nucellar tissue. Within the nucellar tissue a very important series of **cell divisions** has taken place. While there are many variations of the process as it occurs in different species, the process is essentially as follows. Within the mass of nucellar tissue a single cell has become differentiated from all the others by its larger size and denser cytoplasmic content. This is the megaspore mother cell. It divides twice to form a row of four cells. One of these divisions is the reduction division, so that the four cells have the haploid or reduced number of **chromosomes.** Three of the four cells disintegrate and are lost. The fourth, or megaspore, is usually the one nearest the micropyle. It enlarges greatly, while by three successive divisions its nucleus divides to form eight nuclei, all contained within the wall of the very much enlarged gametophyte, commonly called the embryo sac. The arrangement of these eight nuclei is quite uniform. In most plants there are four of them at each end of the embryo sac. One from each end moves to the center of the embryo sac, where they form an intimate association and eventually fuse. These two are the polar nuclei. Of the three nuclei which remain at the micropylar end of the embryo sac, one becomes larger than the other two. This cell is the egg or megagamete; the other two are called the synergids. The three nuclei at the opposite end of the embryo sac are the antipodals. The nuclei at the two ends of the embryo sac become separated by the formation of walls, so that the mature embryo sac is a seven-celled body, with seven nuclei.

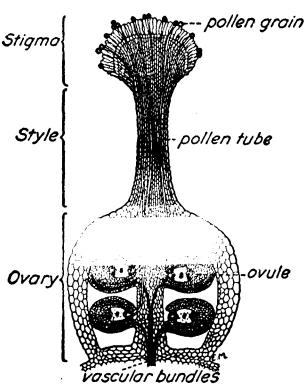


Mature megagametophyte of lily within an ovule. (Reprinted by permission from *Textbook of General Botany*, Third Edition, by Holman & Robbins, published by John Wiley & Sons, Inc.

The pollen grain is carried to the stigma by various agents. The pollen grains of different species of plants are very characteristically shaped, and are often strikingly beautiful because of the many ridges or protuberances with which the outer wall is marked. At first a pollen grain contains a single nucleus. This nucleus divides and gives fise to three nuclei, one of them called the tube nucleus and the other two the male nuclei. Usually these three nuclei are present when the pollen grain germinates. This it does when it reaches the stigma, putting out a slender pollen tube which grows down through the tissues of the style and into the ovary. There it grows towards an ovule, which it enters through the micropyle. The pollen tube continues to grow until its tip reaches the embryo sac. Into this the two male nuclei are discharged. One of them fuses with the egg cell of the embryo sac, while the other passes to the polar nuclei and fuses with them. The nucleus which is formed by the fusion of these three nuclei is called the primary endosperm nucleus; it contains three times the haploid chromosome complement. The act of fusion of the male nucleus with the egg is called fertilization. From the endosperm nucleus there is formed by repeated division and subsequent wall formation a mass of tissue known as the endosperm, which surrounds the developing embryo. The endosperm nourishes the embryo during the early stages of its growth. In many plants the endosperm is entirely absorbed by the developing embryo, while the seed is still immature; in others the endosperm forms a considerable part of the mature seed.



Pollen grains of various kinds of plants. (From Pope in the *Botanical Gazette.*)



Longitudinal section of flower pistil showing pollen tubes growing through the style and entering the ovules. Diagrammatic.

The act of fertilization causes the immediate growth of the fertilized egg. In most plants a series of cell divisions takes place, forming a short filament of cells which is called the proembryo. The appearance of the proembryo varies in different plants. The terminal cell

of the proembryo becomes by repeated cell divisions a spherical mass of cells which is the beginning of the true embryo. The embryo grows rapidly and becomes differentiated into three regions, a primitive root, or radicle, a primitive shoot, and **cotyledons.** This embryo is surrounded by the tissues of the nucellus and the integuments, which have grown larger coincident with the growth of the embyro. The mature ovule becomes the **seed,** and the ovary which contains it becomes the **fruit.** (R.M.W.)

Ovule of shepherd's purse containing an embryo and endosperm: (From Chamberlain's *Elements of Plant Science,* McGraw-Hill Book Co., Inc.)

FLOWERING PLANTS. Angiosperms.

FLOWER PECKER. Aves, Passeriformes. Brightly colored birds (**Aves**) of the Oriental and Australian regions, related to the sun birds. (A.W.L.)

FLOW METER. The flow of a fluid (See **Fluid Flow**) is one of the more difficult physical quantities to measure, especially if the fluid is a gas, and yet there often arises the necessity or desirability of measuring the flow of a vapor, liquid, or gas. Several meters have been developed for measuring these quantities. In distinguishing a flow meter from a quantity meter, flow is a quantity passing a given section of the conduit per unit of time; thus gallons per minute of water, cubic feet per minute of gas, and pounds per minute of steam, are flows. One of the most common principles employed in a flow meter is that of the interchangeability of pressure and velocity head of a fluid. Fundamental hydrodynamic theory indicates pressure and velocity to be interchangeable in the ratio as expressed by

$$v = \sqrt{2gh}.$$

We find the Venturi meter widely used in the application of this principle to fluids. The Venturi meter is shown in Figure 1. The instrument is essentially a manometer device calibrated to read flow in cu. ft. per sec., gal. per min., etc. Recording and registering features may be added to the single indicating meter. The Venturi meter principle rests on the reduction of pressure with increase of velocity, being based fundamentally on Bernoulli's principle. The velocity is increased by inserting a fitting in the pipe line which converges to a minimum section and then diverges to the normal pipe size. Pressure leads are brought from the low-pressure region and from the normal pressure region to the manometer of the instrument. The theory of the Venturi meter will be found in all standard works on hydraulics. The theory yields the equation

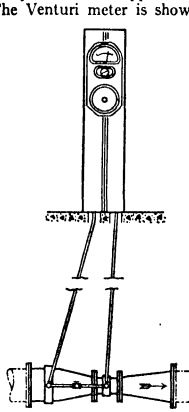


Figure 1. (Courtesy of *Builders' Iron Foundry.*

$$H = \frac{8Q^2}{\pi^2 g d^4}\left[\frac{d^4}{d_1^4} - 1\right],$$

in which H is the feet of water of differential head produced by a flow of Q cubic feet per second. The internal diameter of the pipe is d, of the minimum section, d_1. The actual discharge Q will be from 0.96 to 0.99 of the theoretical Q. The above equation shows that when the dimensions of the Venturi pipe span fitting have been fixed, the flow can be measured proportional to the square root of the differential head H.

This does not exhaust the list of apparatus devised to measure flow of liquids. For example, **weirs,** weighing tanks (in conjunction with a chronometer), and displacement type meters will measure flow. Lighter fluids, such as air or steam, are measured in meters of the orifice type. This is explained in connection with Figure 2.

A constriction of flow produced by an orifice in a metal disk inserted between pipe flanges creates a differential head that is proportional to the square of the flow. This pressure head is taken off through two small pipe connections and transmitted to a mercury U-tube in one leg of which are a large number of graded length contact rods connected to resistances. A flow of steam causes a certain pressure head on the manometer and a corresponding rise of the mercury level in the contact rod chamber. The rise of mercury cuts out a definite amount of resistance, depending on the steam flow. The meter itself is an electrical instrument which measures the varying conductance in the instrument circuit, reading directly in units of flow. The flow meter is operated on ordinary alternating current and is unaffected by slight voltage variations. The number of rods in the contact chamber is so great that slight changes of flow are indicated on the meter. The indicating or recording instruments may be placed in any convenient location and connected to the manometer by a two-wire circuit. (F.T.M.)

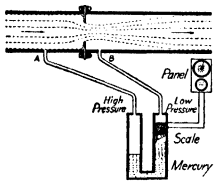


Figure 2. Republic electric flow meter.

FLOW-STRUCTURE. A type of banding in effusive **igneous** rocks (lavas) due to the alignment of minerals, inclusions or gas cavities during the movement of the still molten but viscous material. It is not to be confused with foliation. (R.M.F.)

FLUE. A flue is a channel for hot gases. The term is applied more to a channel for gases composing the products of combustion of a fuel than anything else. While frequently constructed of masonry or tile, or similar material, flues may also be sheet metal. Fire tube **boilers,** in which the hot gases pass through the inside of instead of around the tubes, are said to have flues, since the tubes themselves are often so described. The **chimneys** which carry off the wastes of **combustion** from domestic fires are called flues, though flue refers more specifically to the space provided for passage of the gases, whereas chimney is inclusive, and one chimney may contain more than one flue, and may have architectural embellishments which are entirely independent of the flue. Boiler flues are generally seamless, welded, or riveted flues five to eighteen inches in diameter. Chimney flues should carry a lining of material which, by its smoothness, reduces friction loss, and by its **refractoriness,** is able to withstand continued heating and cooling without cracking or deteriorating in other ways, and which provides a continuous lining free from cracks which might cause a fire hazard by allowing hot gases to seep through the cracks in the masonry comprising a chimney. Flue lining materials are **fire-brick,** plastic refractory **cement,** and hard burned **terra cotta** tile (F.T.M.)

FLUE GAS. Since the products of **combustion** of a fire are eventually led to the atmosphere through the

flues of a chimney, the products of combustion are commonly referred to as flue gas The fuel elements of all commonly used fuels are **carbon** and **hydrogen.** As air containing **oxygen** and **nitrogen** is supplied to make combustion possible, and as some **excess air** is generally needed, flue gas may be expected to be a composite gas composed of the following Carbon dioxide, carbon monoxide, oxygen, and nitrogen There should be little or no carbon monoxide, for that is indicative of faulty or incomplete combustion The oxygen content should be as low as it may be made consistent with maintenance of complete combustion Since air is so largely composed of the inert gas nitrogen, the bulk of flue gas is also nitrogen A typical analysis of flue gas by volume as produced by a coal fire, well tended, would be carbon dioxide, 12%, oxygen, 8%, nitrogen, 80% (F T M)

FLUE GAS ANALYSIS. While poor **combustion of fuel** is frequently detectable by eye through the evolution of dense clouds of smoke, smokeless combustion may not necessarily be the best possible that may be obtained in the circumstances, since unnecessary quantities of **excess air,** or the product of incomplete combustion, **carbon monoxide,** may be present to render combustion inefficient, even though the flue gas is not badly colored The flue gas content is the fireman's chief indication of actual combustion conditions The combustion of coal or oil can be accurately gaged simply by the **carbon dioxide** content of the flue gas as long as the same fuel is employed Consequently, the operating meter need record only carbon dioxide However, for combustion test purposes, including performance runs for **boiler efficiency,** checking boiler operation, etc, complete analysis of the four principal gases in the products of combustion is required For this analysis the Orsat apparatus is indispensable, indeed, the analysis is usually referred to as Orsat analysis The apparatus conceived by that eminent French chemist analyzes a measured volume of a mixture of gases by the process of absorption The volume remaining is measured, thus indicating by differences the gas absorbed The remainder is then exposed to another reagent, which removes another gas Upon remeasurement, the volume of that gas becomes known, and this process is continued a third time, so that the percentages of carbon dioxide, carbon monoxide, and **oxygen** are determined The remainder is assumed to be **nitrogen,** as it, in fact, is, for all practical purposes The analysis obviously is one by volume, and on account of the construction and use of the apparatus, it is made at atmospheric pressure and temperature

Similar type apparatus used for this purpose is the Hays' flue gas analyzer The water jacketed measuring burette is filled with the mixture to be analyzed simply by lowering the water bottle until the level of water in it is opposite the lower graduation in the burette During this operation the valves to the three reaction chambers are closed When the gas is ready for analysis, all valves are closed except that leading to the first absorption pipette The bottle is then raised, forcing the gas into the pipette, which previously contained **potassium** hydroxide solution The pipette is filled with metal wool, which presents a large surface to the gas, wetted with this carbon dioxide absorbing chemical The levelling bottle is next lowered, bringing the gas back into the burette But now, when water level in bottle and burette are even, the water will be found to have risen in the burette through a certain volume equal to the volume of carbon dioxide absorbed If the burette is graduated by volume into one hundred equal parts, the percent carbon dioxide may be directly read. The same process is repeated with **pyrogallic acid** for oxygen, and **cuprous** chloride for carbon monoxide. (F T M)

FLUID FLOW. An ideal fluid is one which is not only continuous and homogeneous, but also incompressible In addition, it should be inviscid, and should have physical properties which are unaffected by variations of temperature or pressure A liquid resembles this ideal fluid more than does a gas, and consequently behaves with a great deal more regularity in fluid flow. A fluid flow may be steady or unsteady, depending on whether the flow passing any given cross-section of the conduit is constant Furthermore, it may be uniform or non-uniform if, at different points along the flow, the velocity varies, due to changes of area or pressure

No fluid fulfills the requirements of the ideal fluid. All actual fluids have a certain amount of **viscosity** and compressibility An essential of fluid flow is that continuity be satisfied by equal inflow and outflow from a certain region within a given period of time A fluid flow is often thought of in the terms of streamlines, which are imaginary lines drawn in such a way that they are tangent to the direction of fluid motion No quantity of the fluid may cross a streamline

Elementary hydraulics always includes **Bernoulli's law,** and it is repeated here as being of great importance to the subject of fluid flow

Bernoulli's law is.

$$\frac{p}{W} + \frac{v^2}{2g} + z = \text{a constant},$$

and the symbols are defined as follows

p = static pressure in pounds per square foot
W = specific weight of fluid in pounds per cubic foot
v = velocity in feet per second
g = gravitational acceleration in feet per second per second
z = potential, or "elevation," head in feet

Bernoulli's law states that in steady flow, the total head is a constant at any point and equal to the sum of the pressure head $\left(\frac{p}{W}\right)$, the velocity head $\left(\frac{v^2}{2g}\right)$ and the potential head (z) Since there is actually a loss of head between any two points due to friction, the difference between the total heads at any two points must equal the friction head when the flow is steady

In this equation, $\frac{v^2}{2g}$ represents the velocity head, a pressure which could be recovered by the efficient reduction of the velocity in a conduit of expanding cross-section When this velocity head is multiplied by the specific weight of the fluid, it is reduced dimensionally to the unit of pressure, lbs per sq ft, and may be designated the dynamic pressure, in counter distinction to the static pressure p In the case of an expansionable fluid, such as gas, the total energy at two points in the flow must be the same, that is, the heat energy plus the kinetic energy of motion must be constant It is necessary to invoke this law of continuity of energy in dealing with the flow of gases or vapors through nozzles (See **Fluid Friction Orifice, Weir, Nozzle, Pitot Tube, Flow Meter.**) (F T M)

FLUID FRICTION. The flow of any actual fluid must of necessity be attended by the presence of **friction,** due to the physical nature of fluids, none of which meets the requirements of the ideal fluid, as mentioned in **fluid flow.** A great deal of time and attention have been devoted to the study of the properties of a flowing fluid The frictional effects present in the flow of liquids have been rationalized much more thoroughly than for vapors and gases However, for all three the friction is found to depend upon the nature of the fluid itself, its **viscosity,** and upon the conduit which contains it On account of the different molecular arrangement of liquids, vapors, and gases, the study of friction of fluids has become a specialized study of each of these three

Fluid flow rarely follows the commonly accepted idea of **streamlines,** since the velocities necessary for viscous flow of this nature are almost always lower than those found expedient to employ Most flows are turbulent in nature, and become turbulent at a definite velocity, the value of which was studied by Reynolds, and is incor-

porated in the well-known **Reynolds' Criterion.** A general thermodynamic equation of energy of a fluid under flow conditions would be as follows

Gain in kinetic energy + gain in potential energy + net work received + energy liberated by any chemical change = change in heat content between two states

In the case of a liquid, this equation can be considerably simplified —in fact, it becomes **Bernoulli's** well-known equation—but in the case of compressible fluids, which may also undergo some change of form, such as condensation or compression, the longer equation applies Most practical problems in fluid friction arise in connection with the flow of fluid through pipes, and for an extended discussion, including formulae, the reader is referred to **pipe friction.** (P T M)

FLUKE 1 A parasitic flatworm **Trematoda.** 2 The broad horizontal lobes of the whale's tail, also a fish (Paralichthys Dentatus) (A W L)

FLUME. An open channel for conveying water for some special purpose, such as water power, washing, etc, is a flume Flumes are frequently constructed of lumber having the boards placed in the direction parallel to the flow, these often being planed on the wetted side However, flumes are also constructed of concrete, brick, etc The flow in a flume is created by the slope of the bottom, releasing a certain amount of energy of position, which is converted into energy represented in the friction between the water and the flume, provided the flow in the flume is uniform (F T M)

FLUORESCEIN. Dye.

FLUORESCENCE. Luminescence.

FLUORINE. Symbol F Atomic number 9 Atomic weight 19 00 Density 1 70 grams per liter, 0° C, 760 mm, or 1 31 when air equals 1 00 Melting point —223° C Boiling point —187° C

Fluorine is a pale yellow gas, poisonous, very reactive, combines with most other elements in the dark, except it does not combine with oxygen Discovered by Scheele in 1771, but first isolated by Moissan in 1886, by **electrolysis** of fused potassium hydrogen fluoride in a **platinum** apparatus No isotope, but of single atomic form 19

Flourine occurs as **calcium** fluoride (CaF_2) in the mineral **fluorite,** fluorspar, as sodium **aluminum** fluoride (Na_3AlF_6) in the mineral **cryolite** in Greenland, and with **calcium** phosphate as fluoride in the mineral **apatite.**

Acids **hydrofluoric acid** (H_2F_2), hydrofluoboric acid (HBF_4) (See **Boron, Acids**), hydrofluosilicic acid (H_2SiF_6) (See **Silicon**)

Borofluoride (See **Boron**)

Bromide trifluorine bromide (F_3Br).

Fluoborate (See **Boron**)

Fluorides **sodium** fluoride (NaF), sodium hydrogen fluoride ($NaHF_2$), **potassium** fluoride (KF), potassium hydrogen fluoride (KHF_2), **ammonium** fluoride (NH_4F), ammonium hydrogen fluoride (NH_4HF_2), **silver** fluoride (AgF) are soluble fluorides, **calcium** fluoride (CaF_2), **strontium** fluoride (SrF_2), **barium** fluoride (BaF_2), **magnesium** fluoride (MgF_2) are insoluble fluorides (See **Hydrofluoric Acid**)

Fluosilicate (See **Silicon**)

Hydride hydrogen fluoride (H_2F_2), colorless gas, of marked odor, poisonous, melting point —83° C, boiling point 19° C, very soluble in water yielding hydrofluoric acid Formed by reaction of calcium fluoride and concentrated sulfuric acid upon heating Hydrogen fluoride etches glass by reaction with silicate forming volatile silicon tetrafluoride, forms hydrofluosilicic acid (See **Silicon**), hydrofluoboric acid, and fluorides (See **Boron**)

Iodide pentafluorine iodide (F_5I)

Silicofluoride (See **Silicon**)

Organic compounds Organic fluorine compounds are made by reaction of the corresponding paraffin chloro-compounds with silver fluoride, mercurous fluoride, antimony trifluoride, titanium tetrafluoride, and the benzenoid fluoro-compounds by the diazo-reaction using hydrofluoric acid

REPRESENTATIVE ORGANIC COMPOUNDS OF FLUORINE

1	Methyl fluoride (Fluoromethane)	CH_3F	−78°C
2	Ethyl fluoride	C_2H_5F	−32
3	Normal-propyl fluoride (1-fluoropropane)	$C_2H_5\ CH_2F$	− 3
4	Iso-propyl fluoride (2-fluoropropane)	$CH_3\ CHF\ CH_3$	−11
5	Allyl fluoride	$CH_2\ CH\ CH_2I$	
6	Benzoyl fluoride	$C_6H_5\ COF$	161 (745 mm)
7	Fluorobenzene (Phenyl fluoride)	$C_6H_5\ F$	85
8	Ortho-fluorobenzoic acid	$C_6H_4(F)(2)(COOH)(1)$	121
9	Meta-fluorobenzoic acid	$C_6H_4(F)(3)(COOH)(1)$	124
10	Para-fluorobenzoic acid	$C_6H_4(F)(4)(COOH)(1)$	183
11	Fluorodichloromethane	$CHFCl_2$	14
12	Fluorotrichloromethane	$CFCl_3$	25
13	Difluorodichloromethane (" freon ").	CF_2Cl_2	−29
14	Para-fluorobromobenzene	$C_6H_4F(4)Br(1)$	
15	Para-fluoroiodobenzene	$C_6H_4F(4)I(1)$	
16	Fluoroform	CHF_3	20 (40 atm)
17	Benzotrifluoride	$C_6H_5{\cdot}CF_3$	
18	Carbon tetrafluoride	CF_4	−128

(R K S)

FLUORITE. The mineral fluorite, **calcium** fluoride, CaF_2 is an isometric mineral with cubic habit, although **octahedrons** and **dodecahedrons** are not uncommon Penetration twins are frequent. Flourite may be also massive, granular to compact It has a very perfect octahedral cleavage, brittle, hardness, 4, specific gravity, 3 01–3 25, luster, vitreous, color may be white or colorless, blue, blue green, yellow, brownish yellow or red The blue kinds are often a delicate violet blue, sometimes amythestine in tint The streak is white, it is translucent to transparent Certain specimens appear blue by reflected, green or yellow by transmitted light. Fluorite sometimes **phosphoresces** when heated or scratched, other varieties **fluoresce** beautifully under the influence of **X-rays** or **ultraviolet** light Fluorite may occur as a vein deposit especially with the metallic minerals where it often forms a part of the gangue and may be associated with **barite, quartz** and **calcite.** It is a common mineral in the deposits of **pneumatolytic** origin and has been noted as a primary mineral in granites and similar rocks One of the most famous of the older localities is Derbyshire, England, where under the name of Derbyshire "blue john" beautiful blue fluorite is used for ornamental purposes, its softness, however, has been a bar to its general use It is found also in Cumberland, England, Saxony, Bavaria, Baden, Austria, Czechoslo-

vakia, Norway, Switzerland, and Italy. Colorless, transparent fluorite was formerly mined at Madoc, Province of Ontario, Canada; and in the United States has been found at Westmoreland and Chatham, N. H.; Trumbull, Conn.; Jefferson and St. Lawrence Counties, N. Y.; at Phoenixville, Pa.; Amelia Court House, Va.; and in commercial quantities in Kentucky and Illinois. It is used as a flux in the manufacture of **steel**, in making opalescent **glass**, **enamels** for cooking utensils and hydrofluoric acid. Its rare use for ornaments is due to its softness, above referred to. The name fluorite is derived from the Latin *fluo*, flow, in reference to its use as a flux. (E.S.C.S.)

FLUOROSCOPE. This device consists of a fluorescent screen mounted on one wall of a dark box having a hooded opening opposite to it into which an observer may look. When **x-rays** or other exciting radiations fall on the screen it glows brightly. The fluoroscope is generally used to observe x-ray shadows cast by parts of the human body or by other objects and, therefore, serves as a convenient means of making preliminary x-ray examinations. A material commonly used for the screen is barium platino-cyanide. (See **Luminescence.**) (L.D.W.)

FLUOR SPAR. Fluorite.

FLUX. One use of the term flux is to designate a material which by its chemical action facilitates the action of **soldering** and **brazing** of metals. A flux applied to a metallic surface cleans it and renders it receptive to amalgamation with the solder or brazing metal. Some fluxes are **resin**, for soldering tin; muriatic acid, for galvanized **iron** and other **zinc** surfaces; and **borax**, for brazing.

A related use of the term flux is to designate the material added to the contents of a smelting furnace or a **cupola** for the purpose of purging the metal of impurities, and of rendering the slag more liquid. The flux most commonly used in iron and steel furnaces is limestone, which is charged in the proper proportions with the iron and fuel. The slag is a mixture of ash, flux, and other impurities.

Magnetic flux is a term used in magnetism. A **magnetomotive force** will cause magnetic lines of force through a magnetic circuit. It is similar to a current flow created by voltage in an electric circuit. The magnetic flux is the number of lines of magnetic force set up in a magnetic substance, and thus flux becomes analogous to the current flowing in an electric circuit. The magnetic flux is numerically equal to the driving force called magnetomotive force, divided by the **reluctance** of the circuit, which is a quality analogous to the resistance of an electric circuit. The unit of the magnetic flux is the maxwell, and flux density is measured in units of maxwells per square centimeters, or gausses. (F.T.M.)

FLUX REFRACTION. This term refers to the fact that when a ferromagnetic body composed of two pieces of different magnetic **permeability** is placed in a magnetic field, or when a **dielectric** composed of two adjacent portions of different dielectric constant is placed in an electric field, the lines of magnetic induction in the former case, and the lines of electric displacement in the latter, if oblique to the interface, abruptly change their direction. The phenomenon is thus somewhat analogous to the **refraction** of light. But the law is different. Whereas, in the case of light the ratio of the sines of the angles of incidence and refraction is constant, in the case of flux refraction it is the ratio of the tangents of the angles that is constant.

For an electric current flowing across a boundary between two conductors of different electrical resistivity, there is a refraction of the lines of flow, likewise obeying the tangent law. (L.D.W.)

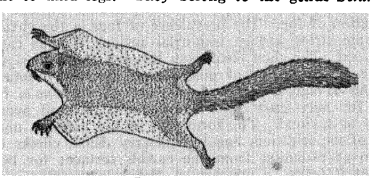
FLY. A two-winged insect belonging to the order **Diptera**. Also commonly applied with some qualifying word to many flying insects with membranous wings, such as May fly, dragon fly, stone fly, and caddis fly. These four examples belong to as many different orders. (A.W.L.)

FLYCATCHER. Aves, Passeriformes. Insect-eating birds (**Aves**) of many species and worldwide distribution. The North American species belong to the family Tyrannidae and include the **kingbirds**, the wood **pewee**, and the **phoebes**, in addition to the several species named as flycatchers. (A.W.L.)

FLYING FOX. Bat.

FLYING LEMUR. Mammalia, Insectivora. An arboreal Malayan animal, *Galeopterus temminckii*, of nocturnal habits. It glides from tree to tree by means of folds of skin stretching between the fore and hind legs and thence to the tail. A similar species, *Galeopithecus volans*, lives in the Philippine Islands. Both eat leaves and fruits. Not a true lemur, hence the names cobego and kaguan by which these animals are also known are less misleading. (A.W.L.)

FLYING SQUIRREL. Mammalia, Rodentia. Small arboreal animals of the northern hemisphere which glide by means of skin folds along the sides of the body from front to hind legs. They belong to the genus *Sciuropterus*. Their appearance is much like that of squirrels but they are as closely related to the ground squirrels and gophers. The African flying squirrels belong to a different family, the Aromaluridae. (A.W.L.)



Flying squirrel.

FLYWHEEL EFFECT. Since the main purpose of applying a flywheel to any machine is to steady the speed, any similar action or arrangement of apparatus to produce such action might be called flywheel effect. The ability of a flywheel to steady speed lies in its ability to absorb and release energy with small variations in speed. Now, since the **kinetic energy** contained by a rotating flywheel is $\frac{1}{2}I\omega^2$, I being the **moment of inertia** of the **mass** about the center of rotation, ω being the angular velocity in radian units, energy will be absorbed when ω changes slightly only upon the condition that I be a large quantity. Consequently, flywheels are characterized by large moments of inertia. Mass alone is no criterion of flywheel effect, since moment of inertia involves as well the disposition of the mass; in other words, the shape of the body. Hence flywheels are not only massive, but the mass is placed as far as practicable from the center of rotation, as in a heavy rim. Flywheel effect, then, is to be secured wherever large masses having large amounts of inertia about the center of rotation are steadying rotational motion in the face of uneven power impulses by the absorption or release of kinetic energy by slight changes of angular rotation.

In the hydraulic turbine field, flywheel effect has a very definite and special meaning. The flywheel effect of a hydraulic turbine is the weight of its rotating element, multiplied by the square of the **radius of gyration** of the same. (F.T.M.)

FOAMING. Feed-water Treatment.

FOCAL INFECTION. A localized infection producing symptoms in other parts of the body by absorption from **bacteria** or the **toxins** liberated by bacteria The most common sites of focal infection are the tonsils, teeth, nasal sinuses, genito-urinary tract, appendix and gallbladder

Among the conditions which may arise from focal infections are the infectious type of **arthritis, neuritis, neuralgia,** and **myositis**

Treatment lies in the successful removal of the infection, once it is discovered (R S M)

FOCAL LENGTH. Mirrors and Lenses.

FOCAL POWER Mirrors and Lenses.

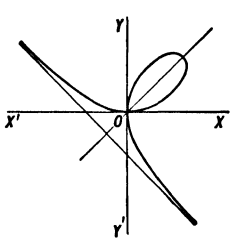
FOCI OF A CONIC. Conic Sections.

FOG. The formation of fog in the natural atmosphere is usually the result of the cooling of air, nearly saturated with water vapor, caused by radiation to a clear sky or by admixture with colder air in such proportion that the whole is below the **dew point** Apparently a necessary condition, however, is the presence in the air of particles on which the droplets can begin to form, called condensation nuclei These may be dust or smoke particles, or, as has been shown by Barus, they may be molecular ions, a fact utilized in the **cloud chamber** for the detection of ionizing emissions Dust-free and ion-free air may become greatly supersaturated without the formation of fog The prevalence of fogs in the vicinity of large cities and in industrial regions is thus easily explained The chief distinction between fogs and clouds is the arbitrary one of position, a cloud may, indeed, envelop a high hilltop and be observed there as a fog, or a fog may issue from a ravine and drift off over a valley as a cloud The formation of fog liberates much heat of vaporization, and if it is very dense, checks the escape of radiation from the earth's surface, for both reasons it tends to maintain a higher temperature near the ground (L D W)

FOLIATION. Metamorphism.

FOLIUM OF DESCARTES. This is a plane curve represented by the **parametric equations**

$$x = \frac{3at}{1+t^3}, \quad y = \frac{3at^2}{1+t^3},$$



Folium of Descartes

its equation in **rectangular coordinates** is

$$x^3 + y^3 - 3axy = 0.$$

It is shown in the accompanying figure (L L S)

FOLLICLE. In zoology, a glandular cavity or sac The small spherical chambers in the thyroid gland, the fluid-filled cavity in the vertebrate ovary in which the ovum develops, and the chambers of the **arthropod** testis are examples of the application of the term For the use of the term follicle in botany, see **Fruit** For its detailed physiological discussion, see **Menstruation.** (A W L)

FOLLICLE CELL. Cells of the ovarian **follicle** which nourish the ovum during its development They occur in the Graafian follicles of vertebrates and in the open follicles of invertebrates In the insects specialized cells of similar function contained within the follicle are termed nurse cells (A W L)

FOLLICULIN. Sex Hormones.

FOMALHAUT. Fomalhaut (Pisces Australis) is interesting as the most southern first **magnitude** star visible from the latitude of New York It rises almost simultaneously with **Capella** and is above the southern horizon during the evening in the autumn months It was one of the Royal stars of **astrology,** ruling over the southern sky The astrologers believe the star to portend eminence, power, and fortune to those born under its influence (W K G)

FONTANELLE Any one of the places in an infant's skull that have not become bony These places are usually situated at the junction of different bones forming the dome of the skull At the age of one year they are normally filled in with bone Fontanelles also occur in the skulls of other vertebrates, in their immature form (R S M, A W L)

FOOD The raw material taken into the body of a living organism as a source of energy and material for the renewal of its own structure The food of animals is chiefly organic, consisting of plant or animal tissue, either dead or alive, or waste products The food must contain **protein** or another source of **nitrogen.** Animals can live on this substance alone but not on **fats** or **carbohydrates** without a nitrogenous compound to supplement them

Food materials for human use should be (1) digestible, furnishing materials and energy adequate for body functions, (2) pure, not furnishing materials deleterious or capable of becoming deleterious to body functions, (3) palatable, of agreeable odor and taste, (4) such that a proper amount of indigestible roughage and bulk are furnished

The first and fourth criteria, those of digestibility and indigestibility, are related directly to the composition of foods as such, and the changes undergone by foods in the body organs The purity and palatability are largely affected by conditions outside the body, as by the methods used in gathering, storing and preserving, and in preparation for use A satisfactory diet must supply sufficient amounts and kinds of various food materials to maintain health, and supply sufficient energy It has been demonstrated that certain accessory materials such as the **vitamins** must be present in foods or must be supplied otherwise, in order to maintain health and prevent disease

Flesh of terrestrial and marine animals, milk, fruits, and cereal grains seem to have been the principal diet of primitive men One writer states that all civilizations have been built around some cereal grain as the principal source of food, and cites rice in Asia, wheat and rye in Europe, millet and sorghum in Africa, and Indian corn in America In the United States, the average distribution of foods consumed has been estimated as meat and dairy products 37%, fish 2%, cereals 31%, Irish and sweet potatoes 13%, other vegetables 8%, miscellaneous foods 9% The estimate of the consumption of some food materials per capita in the United States in the years 1900 and 1920 is as follows (mainly from data in the "Statistical Abstract of the United States")·

CONSUMPTION OF CERTAIN FOOD MATERIALS IN THE UNITED STATES

Food Material	Average Pounds per Capita	
	1900	1929
Dairy products	840	1040
Meat	144	137
Wheat flour	222	175
Sugar	62	105
Fats and oils	34	44
Fresh fruits	169	192

The non-skeletal portion—muscles and vital organs—of the human body are made up of about three-fourths water and one-fourth solids These solids consist of about three-fourths protein Foods, therefore, must supply ample amounts and varieties of proteins (See **Aminoacids, Polypeptides, and Proteins** for further data on proteins and food composition) The sources are of animal or vegetable origin The former include meats, poultry, fish, eggs, milk and cheese The solid matter of all of these except fish and milk is approximately one-half protein and one-half fat (about two-thirds to three-fourths of the total weight is water) In fish the ratio of protein to fat is frequently considerably greater than the above Milk contains about 3 3 per cent protein, 4 per cent fat, 5 per cent lactose and the remainder water The milk product, cheese, contains protein, with fat varying from all in the milk to practically none depending upon the quality of milk used

FOODS

Meats, Poultry, Fish, and Eggs

(See **Aminoacids, Polypeptides, and Proteins; Esters** (for fats))

Food—Edible Portion	Protein	Fat	Ash
Beef	18%	13–22%	0 9%
Pork	9	55	0 5
Lamb	18	23	1 1
Fowls	19	16	1 0
Salmon	22	13	1 4
Halibut	19	5	1 0
Eggs	13	10	1 0

Milk and Cheese

Food	Protein	Fat	Sugar	Ash
Milk	3 3% (3 6)	4% (3-4)	5%	0 7
Cheese	18–30	27–37		

Nuts

Food—Edible Portion	Protein	Fat	Carbohydrates Non-cellulose	Cellulose (fiber)	Ash
Peanuts	25 8%	38 6%	22%	2 5%	2 0%
Almonds	21 0	54 9	15	2 0	2 0
Walnuts	18 4	64 4	13	1 4	1 7
Brazil nuts	17 0	66 8	7		3 9
Filberts	15 6	65 3	13		2 4
Pecans	9 6	70 5	15		1 9
Chestnuts	6 2	5 4	40	1 8	1 3
Coconuts	5 7	50 6	28		1 7

Chocolate and Cocoa

Food	Protein	Fat	Carbohydrates	Ash
Chocolate	13%	48%	30%	2 2%
Cocoa	22	29	38	7 2

Legume

Food	Protein	Fat	Starch (Approx)	Fiber	Ash
Beans, dried	25%	1–2%	55%	4%	4%

Cereals

Food	Protein	Fat	Starch (Approx)	Fiber	Ash
Wheat, flour, entire	12%	2%	73%		1%
Corn, kernel	10	4	72	2%	1 5
Oats, rolled	17	7	66	1	2
Rye, kernel	12	1 5	71	2	2
Barley, kernel	11	2 2	73		2 5
Rice, cured	8	2 0	76	1	1
Rice, polished	7	0 3	79	0 5	0 5

Tubers

Food	Protein	Fat	Starch	Starch plus Sugar	Ash
Potatoes, Irish	2%	1%	15%		1%
Potatoes, sweet	1 5	0 5		22%	1

Sugars and Starch

Food	Starch	Sugars	Dextrin
Sucrose (cane and beet sugar)		100%	
Glucose (corn syrup)		38 5	42 0%
Lactose		100	
Maltose		100	
Starch	100%		

Fats and Oils (See **Esters**)

Food	
Butter, average	Fat 84%.
Lard and suet, rendered	Fat 100%.
Oleomargarine Shortenings, prepared	Composed of various mixtures of oleo oil of beef, neutral lard, cottonseed oil, cocoanut oil, peanut oil, hydrogenated vegetable oils Fat 100%, except oleomargarine.

Olive oil
Corn oil
Cottonseed oil } Fat 100%

FRUITS

Food—Edible Portion	Protein	Fat	Sugar plus Starch (approx.)	Fiber	Ash
Tomatoes	0 9%	0 4%	33%	0 6%	0 5%
Oranges	0 8	0 2	11		0 5
Lemons	1 0	0 7	7	1 1	0 5
Pineapples	0 4	0 3	9	0 4	0 3
Bananas	1 3	0 6	21	1 0	0 8
Apples	0 4	0 5	13	1 2	0 3
Pears	0 6	0 5	11	2 7	0 4
Peaches	0 7	0 1	6	3 6	0 4
Plums	1 0		20		0 5
Prunes	0 9		19		0 6
Grapes	1 3	1 6	15	4 3	0 5
Berries	0 6–1 3	0 6–1 0	7–16	1 5–2 5	0 3–0 6
Squash	1 4	0 5	8	1	1

Fruits also contain, in distinction to other foods, (*a*) organic acids, (*b*) tannins, both in varying percentages in different fruits and at various stages of ripeness for the individual fruit

VEGETABLES

Food—Edible Portion	Protein	Fat	Sugar plus Starch (approx.)	Fiber	Ash
Carrots	1 1%	0 5	8%	1%	1%
Beets	1 5	0 1	9	1	1
Parsnips	1 6	0 5	11	2	1
Turnips	1 3	0 2	7	1	1
Onions	1 5	0 3	9	1	0 6
Cabbage	1 5	0 3	5	1	1
Cauliflower	1 8	0 5	4	1	0 7
Lettuce	1 2	0 3	2	1	1
Spinach	2 1	0 3	2	1	2

FOOD ADJUNCTS

Water (See **Water**)
Coffee } Contain caffein, tannin and volatile oil (caffeol of
Tea } coffee contributes the characteristic aroma)
Carbonated beverages
Alcoholic beverages
Salts
Spices
Vinegar
Flavoring extracts
Sugar, starch, water, it may be remarked, are the only pure individual chemicals of the 70 odd substances mentioned above The others are mixtures

The data published on the composition of the corn kernel and its parts are interesting

	Percentage of the Kernel	Protein	Fat	Carbohydrates Other Than Fiber	Fiber (Cellulose)	Ash
Original kernel	100 0%	12 6%	4 3%	79 4%	2 0%	1 7%
Skin	5 5	6 6	1 6	74 1 (Pentosan)	16 4	1 3
Endosperm	84 3	12 2	1 5	85 0 (Starch)	0 6	0 7
Germ	10 2	21 7	29 6	34 7 (Sugar and starch)	2 9	11 1

Fats and carbohydrates furnish only three chemical elements, namely, carbon, hydrogen, oxygen, to the body, and proteins only these three and nitrogen and sulfur The remaining elements required by the animal organism (See **Biochemistry**) are in the ash when food materials are burned in air Study of the ash gives no information as to the *form* of chemical existence of the contained elements present in the food before burning, but simply proves their presence

Calcium is so important for the growth of bones that special attention should be paid not only to its supply but to proper conditions for its assimilation The proper assimilation of calcium and phosphorus are dependent upon the presence of vitamin D (See **Vitamins**) in the diet or upon sunlight

Iodine is necessary for the proper functioning of the thyroid gland and iron for the hemoglobin of the blood

ENERGY PRODUCING VALUE OF VARIOUS FOODS

Carbohydrates.

Glucose	3 75 calories per gram
Sucrose	3 96
Starch	4 22
Glycogen	4 22

About 98% absorbed, so that the average physiological fuel value is about 4 calories per gram

Fats

Butter fat	9 2 calories per gram
Animal fats	9 4
Vegetable fats	9 4

About 95% absorbed, so that the average physiological fuel value is about 9 calories per gram

Proteins

Casein	5 85 calories per gram
Albumin	5 80
Gelatin	5 30
Gliadin	5 74
Legumin	5 62
Edestin	5 64

About 92% absorbed Deducting the fuel value of the nitrogenous materials eliminated in the urine, e g, urea 2 53 calories per gram (or 0 9 calorie per gram protein), creatinine, uric acid, the average net physiological fuel value is about 4 calories per gram

The chemical analysis of a foodstuff does not throw light upon certain aspects of its dietary properties The use of biological methods is necessary to ascertain the effectiveness of foods for the maintenance of growth in the young, health at all ages, and resistance to certain diseases (See **Vitamins**)

In milk, vitamins A, B, C, D occur in fairly well-balanced proportions A quart of milk each day for every child and a pint for every adult, including that used in cookery, is the minimum amount recommended Weight for weight, egg yolk contains 10 times as much vitamin A and 2 times as much vitamin B as milk Nuts, meats and cereals are low in vitamins A and C Fish liver oils are desirable to supply vitamin D, but sunlight, milk or egg yolk compensate

A varied diet supplying energy foods—sugar, starch, fats, protein—supplemented by protective foods—milk, eggs, fresh fruits, green vegetables—appears to furnish all the dietary demands The following table presents a summary of some important data regarding foods

SUMMARY OF SOME IMPORTANT DATA REGARDING FOODS

(√ MEANS AN EXCELLENT SOURCE)	PROTEINS	FATS	CARBOHYDRATES	ASH	VITAMINS A Anti-xerophthalmia	VITAMINS B Anti-neuritic	VITAMINS C Anti-scorbutic (Relative value)
Meats, poultry, fish	√	√		1%	Low	√	Negligible
Eggs	√	√		1	√	√	Negligible
Milk	√	√	(Lactose)	0 7	√	√	√
Cheese	√	√			√		
Nuts	√	√	√	√	√		
Legumes	√		√(Starch)	4	Low	High	70 (Green, raw)
Cereals	√	0 3–7	√(Starch)	2	Negligible	Degermed—Neg Germ—High	Negligible
Potatoes, Irish			√(Starch)		Low	√	20 (cooked)
Potatoes, sweet			√(Starch, sugar)		√		
Sucrose			√(Sugar, 100%)		None	None	None
Starch			√(Starch, 100%)		None	None	None
Fats and oils							
animal		√100%			Butter, cod-liver oil, high, others low		
vegetable		√100%					
Fruits (contain also organic acids)							
citrus			(Sugar)	0 5		√	100
tomatoes				0 5	√	√	100 (raw, canned)
pineapples			(Sugar)		0 3		70
bananas			(Sugar, starch)	0 8		√	20 raw
apples			(Sugar)	0 3		√	20 raw
grapes			(Sugar)	0 5			5
Vegetables							
green				1–2			
white			√	1			
roots			2				
onions				1		√	100 (raw)
cabbage						√	100 (raw) 5–30 (cooked)
turnip						√	70 (juice)
carrots					√	√	20 (raw)
spinach					√	√	20 (cooked)

The treatment which foods undergo before being used is of great importance from the points of view of digestibility and palatability Starch-containing foods are generally heated to render them edible The treatments may be classified as follows

A Cooking
  Boiling, grilling, baking, frying
B Preservation
  Cold storage, drying and evaporating, canning, preserving with sugar, vinegar, brine, smoking
C Bleaching and Coloring
D Flavoring

On account of the widespread adoption of refrigeration, data on the proper storage temperature of various foods is given

PROPER STORAGE TEMPERATURE FOR VARIOUS FOODS

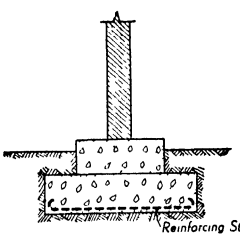
Meats, fresh	29–33° F
Fowls	26–30
Fish, fresh	20–28
Canned meats	35–40
Eggs	31
Milk	35
Cheese	34
Butter	18–20
Lard	38
Oranges	34–45
Lemons	33–45
Bananas	34
Apples	32–36
Pears	34–36
Peaches	34–36
Canned fruits	35–40
Grapes	34–36
Canteloupes	40
Berries	36
Potatoes	36–40
Carrots	34–35
Parsnips	34–35
Onions	36
Cabbage	34–35
Flour	36–40
Nuts, dried	35–40

(R K S)

FOOT. 1. The ventral protuberance of the body of a **mollusk**, usually an organ of locomotion 2 The terminal portion of a jointed appendage which comes into contact with the supporting surface In quadrupedal **vertebrates** the term is applied to both fore and hind appendages and in bipedal forms to the latter only (A W L)

FOOT-CANDLE. The foot-candle is the unit of **illumination** used in English-speaking countries (F T M)

FOOTINGS. A footing is a **foundation** used to distribute concentrated loads in walls or **columns** over a suitable area of soil or subsoil Footings must be spread wider than the base of a column or wall for a number of reasons They must give stability by reducing the unit pressure below that at which there might be local settlement along one side of the foundation They must be thick enough to resist the punching shear of the column, and they must not flare so rapidly as to cause them to be weak in bending Spread footings are generally constructed of reinforced **concrete**, and may be either in the form of a truncated pyramid or rectangular steps The latter type, illustrated in the figure, predominates, due to the ease with which forms may be constructed In case the soil is so weak as to require an extremely wide footing, a steel **I-beam** grillage is incorporated in the footing (F T M)



Section—Spread Footing

FOOT-POUND Work.

FOOTWALL. Fault.

FORAMEN An opening, especially in bone, through which other structures pass, such as nerves and blood vessels (A W L)

FORAMINIFERA Sarcodina, and **Invertebrate Paleontology.**

FORBIDDEN TRANSITIONS. Combination Principle.

FORCE. Our basic concept of force is that afforded by the muscular sense We exert muscular effort upon objects and thereby produce certain effects, and when we observe similar effects produced by other means, we attribute them to the action of forces, whatever the ultimate nature of those agencies may be Thus, if a strip of steel is clamped at one end and pulled sidewise at the other with the finger, it bends A magnet placed near it will cause it to bend in the same way, and though we may know nothing of the nature of magnetic influence, we say that a force is acting upon the steel spring

Force produces other effects than elastic deformation **Newton's Laws of Dynamics** deal primarily with forces, and the first of his Laws points out that force, and force alone, can alter the motion of free bodies He also recognized that the earth exerts forces upon all bodies near it, the measure of which is the weight of those bodies Other examples are magnetic and electric interaction, cohesion, adhesion, and chemical affinity

With so many objective manifestations, it becomes necessary to choose a suitable standard measure of force from among them Elastic deformation and the sustaining of weight are actually used in familiar methods of force measurement, as with the spring balance and certain engineering testing machines But these methods have the disadvantage of variability with time or place, since springs lose their elasticity and the intensity of gravity varies with latitude and altitude A plan better adapted to accuracy is to accept Newton's second Law as the definition of our standard measure of force, and to agree that forces are to be considered proportional to the rates at which they cause free bodies to change their motion

This "inertia measure" gives rise to a system of absolute units of force, recognized by Gauss and sometimes therefore called Gaussian units Such units, for example, are the **dyne** and the less used poundal, each of which is defined as the force required to give some specified unit of mass a specified (linear) acceleration

Expressed in these absolute units, the force required to give to the mass m an acceleration a is $f = m\ a$, this being the mathematical expression of the second Law in terms of these units Thus, if a force of 1000 poundals were to be exerted upon a free mass of 500 pounds, the acceleration would be $a = f/m = 1000$ poundals/500 pounds $= 2$ feet per second per second

While the dyne and the poundal are thus conveniently related to problems of motion, and are invariable, they are awkward to apply in actual measurement The units ordinarily used in practical engineering are gravitational, viz, simply the weights of suitable units of mass Thus, tension in a truss rod is customarily expressed in pounds, the pound of force being the pull of gravity on a standard pound mass While this pull differs by about one part in 160 between equator and poles, the variation with latitude is not important in engineering, and since gravitational units are so easily applied by simply balancing the unknown force against weights, they are in more general use than any others

The **equilibrium of forces** is the subject-matter of **statics**, while the relation of forces to the motions of bodies is treated under **kinetics**, forces are also involved in the discussion of **work** and of **power** (L D W)

FORCE PUMP. Pumps.

FORCIPULATA Asteroidea.

FORE PUMP. Air Pumps.

FORE-SKIN. The prepuce, a prolongation of the skin covering the shaft of the **penis** or **clitoris**, covering the head of either of these organs It is this fold of skin that is removed in **circumcision** (R S M)

FORESTER Mammalia, Marsupialia The great gray **kangaroo**

FORGING. Forging is one of the methods of mechanically working **steel** and other metals During the process of forging the metal is made to assume some preconceived shape, and, at the same time, has its quality improved by the process A metal may be forged either by being hammered or pressed Both methods are in use at present

At first, forging was accomplished by hand hammering Before the introduction of power hammers the forging of metals by hand was one of the most highly developed of the handicrafts When the power-driven hammer, the steam hammer, was invented, it took the larger forging jobs from the hand-forging process, as it enabled extremely large shapes to be made by forging In the pressing method of forging, the piece is squeezed between two bitts under extremely high pressure generated in a hydraulic cylinder

Forging is essentially the kneading and refining of the coarse crystals of a metal resulting from the pouring of the liquid metal into an **ingot** or billet mold Voids and layers of **slag** are closed up and welded together, and the crystalline structure is compacted and consolidated, producing greater strength and resistance to shock than could be obtained in cast metal The action of

hammering and pressing is very different The hammer applies a pressure instantly to a small area, the press has a slower action which penetrates deep into the material Consequently, a higher degree of refinement is present on the surface in hammer forging, whereas the average quality throughout a thick piece will be better in a pressed forging Forging may also be considered to include such welding together of ends, edges, or separate pieces required in forming the shape which is being forged This applies to both types of forging, especially hammer forging

General practice is to forge with heated billet or stock Large billets or ingots are heated in soaping pits, receiving heat from externally fired **furnaces** The stock for small forging jobs, especially that practiced by hand, is heated in a forge, which is a hearth arranged so that a fire of coke, charcoal, or coal may be built upon it, and supplied with air through openings or tuyeres suitably placed The source of the air is a blower The forge is lined with a refractory material such as fire-brick, clay, or tamped sand Above the forge is a hood connected to a chimney which serves to remove the smoke and products of combustion from the forge room The piece to be forged is buried in the hot coals of a thick fuel bed It must be carefully watched against overheating, for if the piece be too hot when withdrawn from the forge, it will oxidize rapidly with the formation of a large amount of scale on the surface, thus not only wasting iron, but rendering it impossible to make a satisfactory weld The piece is laid upon an anvil, and bent or transformed as desired It is reheated in the forge should it become too cool to work well before the operation is completed (F T M)

FORK-TAIL. Aves, Passeriformes Indian birds related to the European **chats** (A W L)

FORMALDEHYDE. Formaldehyde (HCHO) is a colorless, soluble gas, boiling point —21° C, commonly encountered as a 40% solution in water ("formalin"), which frequently contains **methyl alcohol**, up to about 20%, to increase the stability of the solution especially when exposed to winter temperatures Both the gas and the solution have a pungent, irritating, characteristic odor, and the solution acts upon the skin to form a leather-like layer and frequently causes sores Formaldehyde reacts with many chemicals in a marked manner, (1) with ammonio-silver nitrate (Tollen's solution), to form metallic silver, either as a black precipitate or as an adherent mirror film on glass, (2) with alkaline **cupric** solution (Fehling's solution), to form cuprous oxide, red to yellow precipitate, (3) with rosaniline (fuchsine, magenta) which has been decolorized by **sulfurous acid** (Schiff's solution), the pink color of rosaniline is restored, (4) with **sodium** hydroxide, yields methyl alcohol plus sodium formate, (5) with **ammonium** hydroxide, when evaporated, yields hexamethylene tetramine "urotropine" ($(CH_2)_6N_4$), white solid, melting point 263° C, (6) with **sodium** or **hydrogen peroxide** in sodium hydroxide, yields sodium formate, (7) with **manganese** dioxide and **sulfuric acid**, forms methylal, dimethoxymethane ($CH_2(OCH_3)_2$), colorless liquid, boiling point 42° C.

Formaldehyde gas, when cooled under certain conditions, yields trioxymethylene, metaformaldehyde ($(CH_2O)_3$), formaldehyde solution, when evaporated, upon standing, or upon being subjected to low temperatures, yields paraformaldehyde ($(CH_2O)_x$), white solid, from which formaldehyde is regenerated upon heating, dilute formaldehyde, in the presence of calcium hydroxide solution, yields a mixture of sugars called formose from which fructose ($C_6H_{12}O_6$) has been prepared, suggesting the intermediate formation in nature of formaldehyde in the photosynthetic process of the conversion of carbon dioxide to sugars Formaldehyde stands chemically between methyl alcohol on the one hand—to which it can be reduced—and formic acid on the other hand—to which it can be oxidized Formaldehyde is made by passing methyl alcohol vapor mixed with air over a **catalyzer**, e g, smooth copper wire gauze, at a dull red heat, and collecting the resulting solution Formaldehyde is commonly detected by the Schiff test (above), and confirmed by the formation of a dimethyl derivative with a melting point of 189° C Formaldehyde is extensively used (1) as an antiseptic, disinfectant, and insecticide, in the preservation of glue, in the preparation of anatomical specimens, in embalming fluids, in treatment of pests in enclosed spaces and on seeds before planting, (2) as a constituent, along with a **phenol**, of synthetic **plastics** and **resins**, (3) as a hardener, stabilizer or preservative in casein, starch, and sugar preparations, (4) as a reducing agent in gold and silver metallurgy, and in silvering mirrors (R K S)

FORMALIN. **Formaldehyde.**

FORMATION. A distinct lithologic unit which may be used in geologic mapping The term formation is usually confined to **bedded** or **stratified rocks**, including lava flows and volcanic **ejectamenta** (R M F)

FORM FACTOR. Form factor is a means for describing the shape of an **alternating current** wave The strength of an alternating current constantly varies in magnitude and direction The effective value of an alternating current is equal to the direct current, which will produce the same heating effect as the alternating current wave The average value of an alternating current is that value which, multiplied by the length of time consumed in a cycle, would result in the same number of ampere seconds as are included under the actual curve showing the wave form The form factor is the ratio of the effective value of a current to its average value, and is smaller for a flat wave than for a peaked wave (F T M)

FORMIC ACID AND FORMATES. Formic acid ($HCHO_2$ or HCOOH) is a colorless liquid, melting point 8.4° C, boiling point 100.5° C, miscible with water, alcohol or ether in all proportions Formic acid solution reacts (1) with **hydroxides**, **oxides**, **carbonates**, to form formates, e g, **sodium** formate, **calcium** formate, and with **alcohols** to form **esters**, (2) with silver of ammonio-**silver** nitrate to form metallic silver, (3) with **ferric** formate solution, upon heating, to form red precipitate of basic ferric formate, (4) with **mercuric** chloride solution to form mercurous chloride, white precipitate, (5) with **permanganate** (in the presence of dilute **sulfuric acid**) to form carbon dioxide and manganous salt solution Formic acid causes painful wounds when it comes in contact with the skin At 160° C, formic acid yields carbon dioxide plus hydrogen When sodium formate is heated in vacuum at 300° C, hydrogen gas and sodium oxalate are formed With concentrated sulfuric acid heated, sodium formate, or other formate, or formic acid, yields carbon monoxide gas plus water Sodium formate is made by heating sodium hydroxide and carbon monoxide under pressure at 210° C The following are representative esters of formic acid

		Boiling point, °C.
Methyl formate	$HCOOCH_3$	32
Ethyl formate	$HCOOC_2H_5$	54
Glycol diformate	$HCOOCH_2CH_2OOCH$	174
Ethyl orthoformate	$HC(OC_2H_5)_3$	146

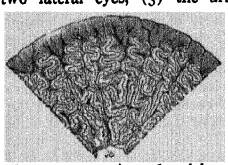
Formic acid may be obtained (1) from some natural products, e g, the juice of the hairs of the stinging nettle plant, the juice of the giant nettle tree, the juice of ants and some caterpillars, (2) from sodium formate solution by addition of sodium hydrogen sulfate or dilute sulfuric acid, and then distilling, preferably in vacuum, (3) by reaction of **oxalic acid** and **glycerol** at 100° to 110° C, (4) from **lead** formate solid and **hydrogen sulfide** at 100° C. yielding anhydrous formic acid. Formic acid is

used (1) in the textile and leather industries, (2) in reaction with glycerol at 220° C. to form allyl **alcohol**, (3) in the preparation of metallic formates, and **esters**. (R.K.S.)

FORMULAS, CHEMICAL. Chemical Composition.

FOSSA. 1. An anatomical term indicating a depression or furrow. 2. **Civet.** A species found in Madagascar. *Cryptoprocta ferox.* (A.W.L.)

FOSSIL AMPHIBIA. The first or earliest evidence of an **amphibian** is a primitive footprint in formations of upper **Devonian** age. The footprint is of particular significance because it suggests a transition stage in the development of the primitive limb structure of the first terrestrial **vertebrates** from the pectoral fins and limb girdle of the air-breathing ganoids, which also occur in the Devonian. The first known skeletons of amphibia occur in formations of Pennsylvanian age. These earliest known amphibia are called Stegocephalia, because their heads are covered or "roofed" with thick dermal bones. In some species both the back and stomach were covered with bony plates or scales. Thus the earliest known amphibia (Stegocephalia) were armored as compared with most of their modern descendants. Other particularly significant anatomical features are: (1) A third, or pineal, eye, (2) presence of a ring of plates around the **two lateral eyes**, (3) the arrangement of the dermal plates in the head, (4) conical teeth, showing an infolding of the dentine and enamel. This type of tooth structure is particularly characteristic of one group called *Labyrinthodonts.* All of the aforementioned features suggest ancestral relationship to the ganoid fishes. The fossil record of the amphibia is the poorest of all the terrestrial vertebrates. They are therefore not particularly valuable as index fossils, their place



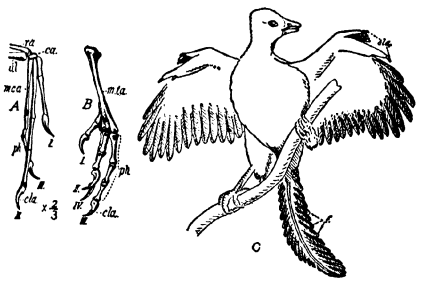
Transverse section of a labyrinthodont tooth. (After Owen from Norton's *Elements of Geology,* Ginn and Company.)

A **Pennsylvania amphibian (labyrinthodont).** Key 26. This creature attained a length of 6 or 8 feet. (Courtesy of the *American Museum of Natural History.*)

being taken by the **Mesozoic** reptiles and **Cenozoic** mammals. See chart illustrating the geologic range of the vertebrates under the title **Vertebrate Paleontology.** (R.M.F.)

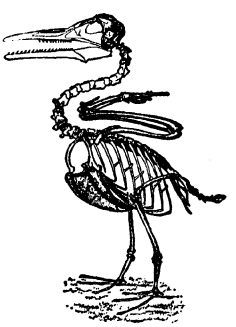
FOSSIL BIRDS. Probably one of the most famous fossils in the world is Archaeopteryx, or the flying reptile which had feathers. Fossil birds are rare, therefore it is all the more remarkable that this "missing link" between the reptiles and the birds should have been discovered as a natural lithograph in the fine-grained lithographic limestones of Upper Jurassic age at Solenhofen, Bavaria. Only two specimens of this genus are known. Archaeopteryx was about the size of a crow, with the combined reptilian and bird-like claws upon each of the three fingers terminating the wings, and lit-

been several theories as to the origin of Archaeopteryx. One is that it evolved from a small carniverous bipedal **Triassic** dinosaur. Toward the close of the Mesozoic



The earliest known bird, *Archeopteryx macrura,* from the Jurassic. A, right hand; B, right foot; C, restoration modified after Pycraft. (Shimer's *Introduction to the Study of Fossils,* The Macmillan Company.)

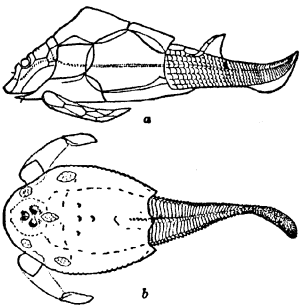
the birds evolved rapidly. Fossils from the **Cretaceous** show both flying and diving forms, such as *Ichthyornis,* shown in the accompanying illustration. The birds did not lose their teeth until the **Tertiary.** It is also interesting to note that one of the largest known birds that ever lived, *Dinornis maximus* from New Zealand, stood twelve feet high and has only recently become extinct. The nearest living relative of the ancestral bird (Archaeopteryx) appears to be the Hoactzin of the Amazon Valley. The embryonic history of this bird repeats many of the adult features of Archaeopteryx, and the young hoactzin still retains claws on its wings, but these claws disappear in the adult stage. As has been previously implied, birds do not make good index fossils primarily because of their rarity as fossils even in the later periods of the earth's history. See chart illustrating the geologic range of the vertebrates listed under **Vertebrate Paleontology.** (R.M.F.)



A Cretaceous toothed bird, *Ichthyornis victor.* Height, about 8 inches. (After Marsh.)

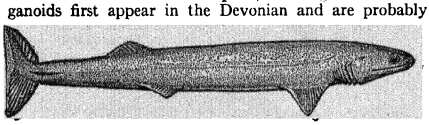
FOSSIL FISH. The earliest fish may be represented by a "fish-scale" in the **Cambrian.** Problematical fish remains have also been found in the **Ordovician,** and small fin spines in the lower **Silurian.** A famous upper Silurian occurrence is the Ludlow bone bed of England. Probably none of the aforementioned bones and scales belonged to true fishes but to the so-called "bony-skinned fishes" or Ostracoderms, which are particularly characteristic of the **Devonian.** The Ostracoderms became extinct at the close of the Devonian, and there is no direct ancestral connection between them and either the sharks or the true fishes, although it is probable that all the types mentioned had a common ancestor. The Ostracoderms were armored with placoid bony plates or scales. They had no interior skeleton, and certain types such as Pteraspis and Cephalispis were probably adapted to bottom feeding in relatively quiet marine waters. Other types such as Bothriolepis and Pterichthys probably frequented fresh water ponds and lakes. The earliest known sharks occur in the late Silurian or Devonian

one phase of their development during the upper **Paleozoic** with a decline during the early **Mesozoic**. The **Cenozoic** has seen the gradual increase of a new phase with rapid and continuous expansion in diversity of



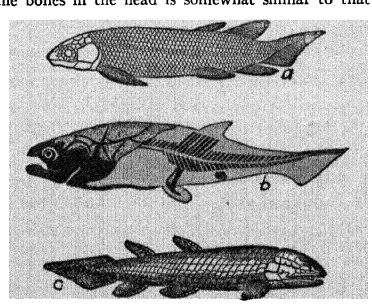
Devonian Ostracoderms; a, *Pterichthys testudinarius*, restored (Dean after Woodward); b, Trematapsis, restored (after Patten.)

form and adaptability during the late **Tertiary** and **Quaternary**. One of the most interesting groups of the fossil fishes are the **Dipnoi**, or lung fishes. The ganoids first appear in the Devonian and are probably



A Paleozoic (early Mississippian) Selachian or shark, *Cladoselache fyleri*. (Restored by Dean.)

closely related to the progenitors of the first terrestrial vertebrates. The structure of the pectoral fins foreshadows a primitive limb and foot. The arrangement of the bones in the head is somewhat similar to that in

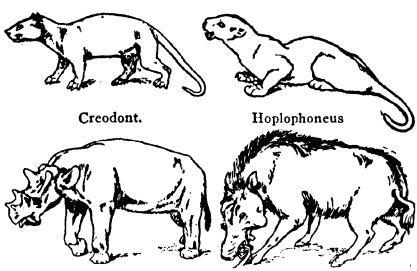


Devonian fishes: a, dipnoan. *Dipterus valenciennesi* (restored by Traquair); b, arthrodiran, *Coccosteus decipiens* (restored by Woodward); c, ganoid, *Osteolepis* (restored by Nicholson.)

the earliest known **Amphibia** (Stegocephalians) also, a peculiar ring of bony plates around the eye, and the conical teeth of infolded dentine and enamel are similar to those of the earliest known Amphibians. See chart on geologic range of the vertebrates under the title **Fossil Vertebrates**. (R.M.F.)

FOSSIL MAMMALS. The paleontological record suggests that the mammals have evolved from the reptiles through a common ancestor with the Theriodontia (beast-toothed reptile) of the **Permian**. The rise of the reptilian mammals began as early as the **Triassic**, as disclosed by small lower jaws and teeth. These animals have been classified as multituberculates, so named because the teeth have coned or tuberculated surfaces. Living descendants of this primitive group include the spiny ant-eater, Echidna (**duck-bill**) and the duck-billed mole, *Ornythorynchun*, now living in Australia. Small mammalian jaws similar to those of insectivores have also been discovered in the **Cretaceous**. Most of the **Mesozoic** pro-mammals were probably egg-laying, relatively small in size and quite unable to usurp the place of the great host of **dinosaurs** which had become adapted to all types of environment. Following the extinction of the dinosaurs at the close of the Mesozoic, the mammals rapidly evolved soon after the beginning of the **Cenozoic**, and especially from the **Oligocene** on.

The reptile-like mammals of the Mesozoic, which may be termed pro-mammals, were followed by the archaic mammals of the **Paleocene**. Nearly all of the forms were small, primitive and generalized, with long and heavy tails, short limbs and five digits on each foot. The principal flesh eaters were the creodonts, and of the modern orders of mammals only the **insectivores** and **marsupials** are present. The ancestors of the first modern mammals such as Eohippus (a diminutive **horse**), cursorial **rhinoceroses**, the creodonts and other earlier



(Field, *Outline of Geology*, Barnes and Noble.)

archaic forms are also present but are rapidly being replaced by more active and intelligent types. One of the large-hoofed giant herbivores or hippopotamus-like forms

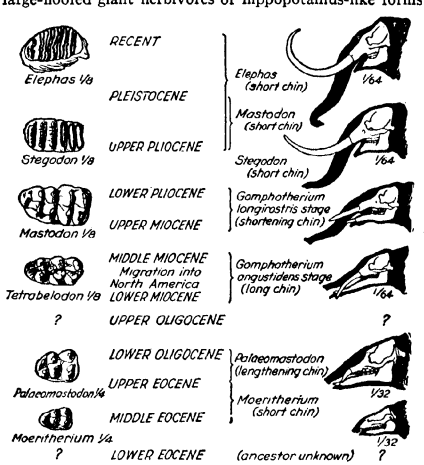


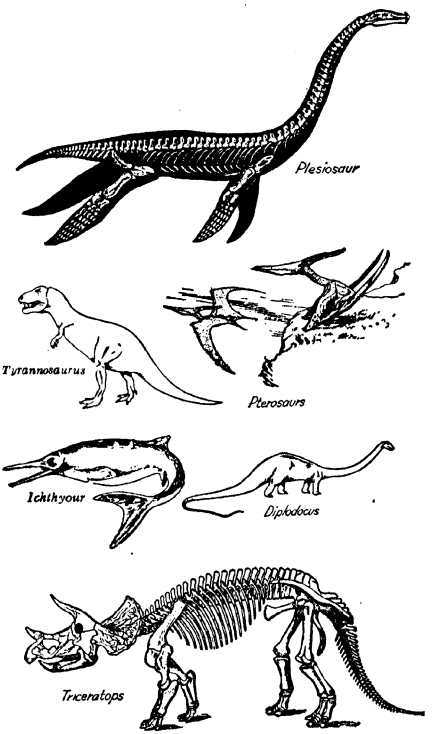
Chart to illustrate the evolution of the elephants. (From Scott, after Lull, modified by Sinclair. Courtesy of The Macmillan Company.)

is called uintatherium. The mammals first begin to take on a modern aspect in the Oligocene, including a large number of forms which grazed on the open plains. The true carnivores have replaced the creodonts, including Hoplophoneus, ancestor of the saber-toothed cats. The remainder of the Cenozoic saw the gradual evolution of the modern mammals. Among the many modern forms the paleontological record of the horse and the elephant have been remarkably well worked out as shown by the accompanying charts. Because of the strongly marked climatic zones of the **Pleistocene**, as well as the glacial and interglacial cycles within the areas subjected to continental glaciation, the end of the Cenozoic is remarkable for the large number of mammals as well as the origin and evolution of man. (See **Paleontology of Man**.) (R.M.F.)

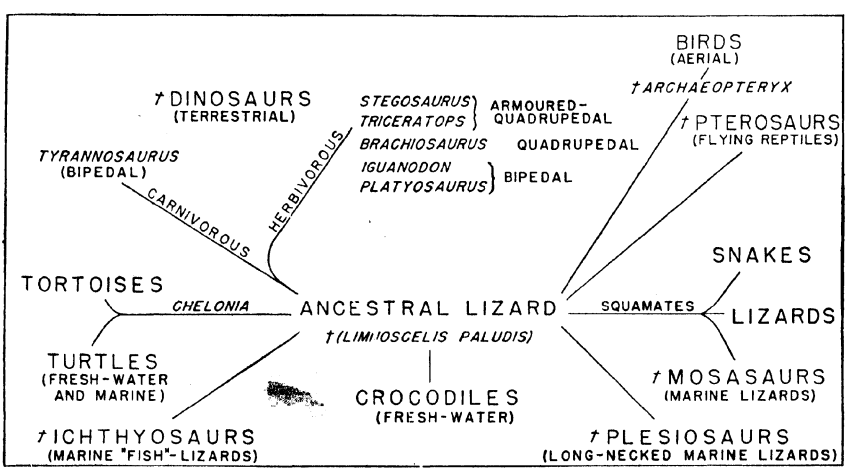
FOSSIL MAN. Paleontology of **Man.**

FOSSIL PLANTS. Paleobotany.

FOSSIL REPTILES. The first or earliest evidence of reptiles is in the **Permian**. Most of these reptiles were sluggish animals, probably not much more active than their amphibian progenitors, and equally adapted to both water and land. Some forms, however, such as the Pelycosaurs, or sail-backed lizards, had a great dorsal "fin," and thus appear to have been highly specialized. Most of the forms were distinctly lizard-like in appearance. The cotylosauria were the most primitive of the **Paleozoic** reptiles showing many of the ancestral **Stegocephalian** characters. Another and particularly interesting group of reptiles which lived during the **Permian** and **Triassic** periods are the Theriodontia. Fossil skeletons of these are found only in South Africa. Although these animals were reptilian, their teeth show a differentiation into incisors, canines, and molars, a decidedly mammalian characteristic. Because of this and certain other anatomical features the Theriodontia are considered by some paleontologists as the "missing link" between the reptiles and the mammals. The reptiles reached their all-time development during the **Mesozoic**, thus this era has been termed the age of reptiles. Among the Mesozoic reptiles the great group of the **Dinosaurs** command particular attention because they varied in size from the smallest bird-like creatures to huge forms,



Fossil reptiles.
(Field, *Outline of Geology*, Barnes and Noble.)



† = extinct.

ADAPTIVE EVOLUTION OF THE REPTILES
Field, *Laboratory Manual*, Princeton University Press.

both carnivorous and herbivorous, which rival the mightiest animals that ever lived. The evolutionary vitality was particularly well expressed in the extreme adaptation of body forms to all types of habitat as outlined in the accompanying chart The dinosaurs became extinct at the close of the Mesozoic, and the modern reptiles, such as the lizards, snakes, and turtles are but a remnant of the great record of reptilian evolution (R M F)

FOUCAULT PENDULUM. In 1851 Foucault performed his celebrated **pendulum** experiment at Paris, designed to give physical proof that the earth is in rotation about an axis The pendulum, consisting of a very large iron ball suspended by a steel wire over 200 feet long, was suspended from the center of the dome of the Pantheon Great care was exercised in the support for the wire so that no external forces should be effective at this point other than a vertical force to prevent the system from falling On the floor, immediately under the pendulum, a layer of fine sand was placed so that the direction of the swing could be observed The pendulum was started by drawing it to one side with a fine thread and, after the system was at rest, the thread was burned off, thus avoiding any lateral motion

After such a pendulum is started swinging in one plane, it is soon observed that the plane of swing is apparently deviating slowly (in the clockwise direction in the northern hemisphere and the opposite in the southern) The rate at which the plane of swing deviates is equal to 15° per sidereal hour (c f **time**) multiplied by the **sine** of the **latitude** Thus at the pole it would make a complete rotation in one sidereal day, while at the equator it would not rotate at all At Paris (latitude 48° 50′ N) the rate of deviation is about 11° 18′ per hours

Foucault reasoned quite correctly that, in accordance with **Newton's Laws of Dynamics**, the direction in space of the plane of swing should not change unless the pendulum was acted upon by some external force other than that of gravitation and the counteracting force parallel to the direction of gravitation at the support That the direction of the plane does apparently change can only be accounted for on the hypothesis that the earth is in rotation Foucault's demonstration attracted wide scientific and popular attention and was accepted as a conclusive proof that the earth does rotate upon an axis, a fact which was not universally accepted at that time (W K G, L D W)

FOUNDATIONS. The structural foundation is that part of a structure which transmits the loads to the supporting material In the design of a foundation it is essential that the settlement shall be reduced to a minimum and that this settlement shall be uniform at all points The first requirement may be fulfilled by providing a **bearing** area which is large enough to reduce the bearing pressure on the underlying material to a safe value In the case of soils having low bearing values **pile** foundations can be used to reduce settlement The second requirement may be secured by designing the foundations so that the **resultant** of the vertical **loads** passes through the **center of gravity** of the foundation If the material under the foundation is structurally sound rock, having a bearing value within safe limits, there will be no appreciable settlement of the structures, but there is bound to be settlement in structures whose supporting medium is earth since it is a compressible material

A floating foundation is a reinforced **concrete mat** which covers the entire area under the structure and transfers the loads to the supporting soil This mat may be a thick slab or a system of beams and thinner slabs. Floating foundations are generally used for soils having very low bearing values

For different types of foundation refer to **Caisson, Footings, Grillage, Pier** and **Pile.**

The machine foundation performs more than a simple bearing function It must:

1 Distribute the weight of the machine, the machine bedplate, and its own weight over a safe subsoil area If heavy unbalanced vertical kinetic forces (See **Mechanics**) are produced by the machine, they should be added to the dead weight and the bearing power of the soil must be well in excess of these vertical forces
2 Provide sufficient **mass** to absorb machine vibration Satisfactory foundation weight for this factor is not readily calculable The accompanying table is given to provide an indication of minimum weights

WEIGHT OF ENGINE FOUNDATIONS PER BRAKE HORSEPOWER

Prime Mover	Single Cylinder	Multi-Cylinder
Gas engine	2500 lb	1600 lb
Diesel engine	2000 lb	1250 lb
Steam engine	700 lb	500 lb
Steam turbine	Not to exceed permissible deflection as stated by turbine manufacturer	

3 Be rigid enough to prevent undue deflection of any part of the machine bedplate

Machine foundations are usually made of concrete and unless an unyielding foundation soil is available, the concrete at the bottom of the foundation is subjected to **tension** Since this is generally the case, the heavy foundation should have reinforcement near the bottom

Large turbine (See **Steam Turbine**) foundations are not required to contain foundation masses comparable with those necessary for similar reciprocating units Still, the necessity of providing space beneath the turbo-generator for condenser, pumps, generator, air cleaner, or cooler, and sometimes the throttle lead, materially complicates the design of the turbine foundation This foundation does not carry the turbine upon a heavy bedplate and hence a study of the foundation **deflections** is all important No two foundations are alike Reinforced concrete and structural steel foundations each have their advocates, but any installation should be figured upon a basis of comparable costs of the two types, because each is suited to a particular field of utility and economy The concrete base gives more rigidity to the turbine, but it is claimed for steel that its flexibility is an advantage in large units since it prevents distortive bowing of the shaft and attendant difficulties The concrete foundation will require less maintenance, the steel type yields more available space below the unit

When bringing a machine into alignment on its foundation, shims or sole plates are placed beneath the frame or bedplate and adjusted until the alignment is level in two directions A spirit level can be used when aligning small machines, but the engineer's level is best for all classes of work After alignment is secured, an earth dam is built around the top edge of the foundation and a **grout** flower beneath the bedplate until it stands above its edge all around (C W C, F T M)

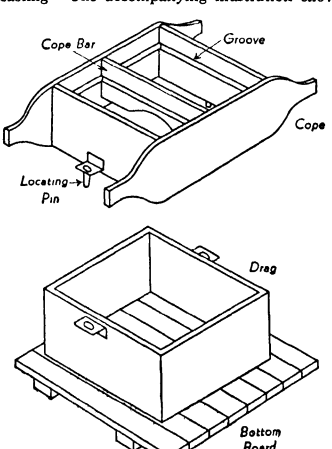
FOUNDING. Founding is the art of casting various shapes in metal On account of the importance of iron founding, the principal divisions of this art are iron founding and all other founding Iron founding, itself, may be subdivided into **malleable cast iron, steel,** and gray cast iron founding By far the bulk of iron casting is of the latter type, and it is the gray iron foundry which forms the subject of this article To a very marked degree, the conquest of machine methods of production rested on the art of founding, although at the present time the casting is frequently superseded by rolled steel shapes, and by welded construction making use of steel shapes Even so, there continues to be an enormous production of all sorts of iron castings varying

in size from a few ounces to many tons, and of all conceivable shapes and forms While it is true that any shape desired by the designer of a machine can be produced in iron, the making of a casting may tax the efforts of a very ingenious person if it is extremely irregular The art of founding is one requiring skill and close attention to both the commercial and technical problems involved if a foundry is to be successful financially

By way of introduction to a brief description of the foundry, the process of founding may be described as the melting of a quantity of metal of predetermined analysis, followed by the pouring of that metal into hollow molds which have been constructed in a refractory material such as a sand-clay mixture The metal solidifies in the molds, assuming the shape of the **pattern** employed, after which the mold is torn apart and the casting removed and cleaned to the desired finished state A foundry often incorporates a shop in which the patterns are made to the customer's plans, but whether or not such is the case, there will be maintained a pattern repair and storage department The other principal divisions of the foundry are the molding floor, the melting equipment, usually a **cupola**, the core-making department, and the finishing department

There are three principal methods employed in making molds, the use of which depends on the size, complexity, and shape of the casting, and upon the number of units to be made In quantity production foundries, where thousands of identical castings are to be made, molding machines are rigged up employing special metal patterns, since considerable money can be expended before the first unit is produced in arranging high-speed production This, of course, would be impracticable in an ordinary jobbing foundry, where often only one casting is to be made from a pattern Most of such work is done in hand-manipulated flasks, and constitutes the second system of molding This will be described at greater length The third system, known as sweep molding, is suitable when large circular castings, such as kettles, cylinders, and the like, are to be made In sweep molding, a templet bearing the outline of the surface of the casting is revolved about a central axis in such a manner as to cut the molding sand to the desired final shape of the mold

Some idea of the art of molding may be gained from the following description of the production of a typical small casting The accompanying illustration shows the



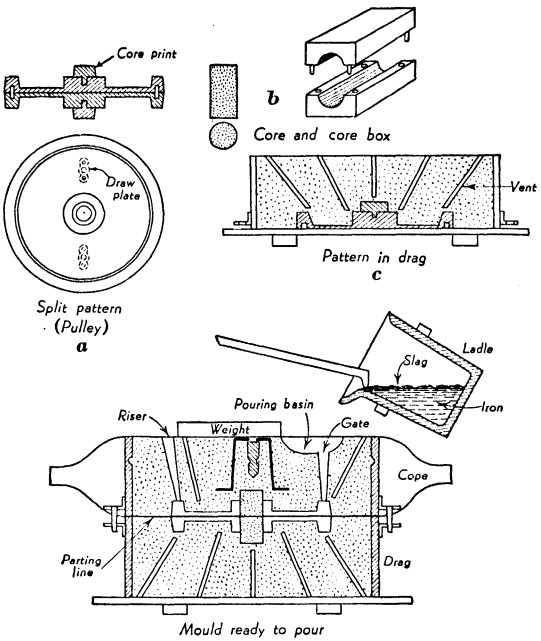
Simple two part flask.

arrangement of a two-part molding flask, consisting of a cope and drag Some patterns may require to be molded in three or four-part flasks In these the layers intermediate between drag and cope are called cheeks A foundry will have many flasks of various sizes on hand, since a flask must be allowed for each casting to be made on any certain "melt" An exception to this statement will be found in the collapsible flask sometimes used for quantity production of small castings by hand molding If the flask is small enough, no cope bar is needed, and by hinging the sides of the flask it may be removed from the mold after the latter has been rammed up The flask shown has a plain lower part known as the drag, and an upper cope which may be accurately located on the drag by pins If large, the cope is provided with handles, and is internally grooved and barred so as to retain the sand when it is lifted from the drag during the process of molding Flasks are frequently built of wood, especially in the jobbing foundry where a special sized flask may often have to be knocked together for the production of a limited number of castings Cast iron and pressed steel flasks are also to be found The raw materials which the molder must use in his work include pattern, flask, and molding sand The latter must actually be a mixture of clay and sand, the sand to give refractoriness and body, the clay for binding purposes, so that the mold will cohere when the sand is rammed into the flask A natural sand containing about 70% silica and 30% alumina will generally make a suitable molding sand Sands containing more clay than this pack nicely in the mold, but produce faulty castings because the mold is insufficiently porous to vent the gases attending pouring The molding sand is re-used, in fact, its properties improve with use, although sometimes clay must be added to maintain the proper texture

Holes and other hollow spots in castings are not always easily made by forming the hollow in the pattern Rather, a preformed and baked sand core is made to be inserted in the mold during its construction Sand cores are made of a mixture of fine sand and binder, such as molasses or flour paste The damp mixture is formed in a core box, after which it is baked hard in a core oven Holes for shafts, water jackets on cylinders, and numerous other such openings, are generally cored into castings, and the more intricate a casting, the more likely that cores will form an important part of its production

The accompanying illustration shows how a casting of a pulley might be made The pulley is chosen for illustration because it exemplifies both the split pattern and the use of a core As is seen from the sectional view of the pattern at *a*, the pattern is split horizontally, and the two parts are aligned by dowel pins To the hub are affixed core prints, the purpose of which is to leave an impression in the sand to accommodate the core The molder dampens his sand until it coheres well, and inverts the drag on a follow board, which is similar to the bottom board He next places the half-pattern in the drag flat against the board and shovels the sand in on top of it, tamping it carefully and evenly all around In this manner the drag is filled with sand, leveled, and struck off smoothly Vent holes are rammed into the sand, and a bottom board placed on top, after which the drag is rolled over into its normal position, and the follow board removed The surface of sand showing at the parting line between cope and drag is then dusted with drying powder of fine dry sand or graphite to prevent the cope sand from sticking to that in the drag Now the other half of the pattern is joined, and sand is tamped into the core Tapered sticks are set over the correct places for entrance and exit of the iron When withdrawn, these will form, respectively, the pouring gate and riser If it seems to the molder that there is some likelihood of the sand dropping out of the cope, he will embed angular shaped lengths of rod called gaggers, here and there in the

cope thoroughly. The cope is then lifted off the drag, cope, and, after cutting the pouring basin, will vent the carrying with it the half of the pattern embedded in it.



Moulding a typical split pattern.

The molder next must apply a draw screw to the plate sunk in the surface of the pattern, and after rapping the pattern to loosen the sand, carefully withdraw it. Any small imperfections occasioned during this process are then repaired, and the surface of the mold is slicked down with **graphite** or some other preparation. The core is then set, and the cope replaced. Weights are added to the cope to offset the floating tendency arising from the hydrostatic head of iron pressing upwards on the mold. A cross-section of the mold then appears as at *d* in the illustration. It is poured full of molten iron by bringing a refractory lined ladle containing the iron over the pouring basin and tilting it so as to cause the iron to run into the pouring basin. The pouring basin is kept full while the iron runs down the gate and fills the mold. Pouring is terminated when the iron appears up the riser. The steam and hydrogen, generated when molten iron comes in contact with the damp sand of the mold, escapes through the pores of the mold and the vents. If the sand is rammed too hard, or improperly vented, or too rich in clay, the gases will bubble through the body of the iron and spoil the casting by creating blow-holes. After the casting has solidified and partially cooled, the cope is removed and the casting taken from the sand. The gates and risers, and any fins that might happen to have been made, are knocked or cut off, and the core is cleaned out, after which the casting may, if desired, be further cleaned by pickling, sand blasting, or by revolving it in a "rattler" containing stones, iron stars, or other polishing objects. The lumps of sand are broken down into grains and piled into a heap ready for the next mold. This, in substance, is a sample of the principal operations of founding; however, the procedure must be individually adapted to suit each pattern, since, for example, some patterns are not split, while some require two or three parting lines, not all of which are the plane surfaces of the illustration.

Steel founding is somewhat similar, except that the molten metal is not produced in the cupola, but rather by **electric furnace, Bessemer** converter, or **open hearth** furnace. On account of the higher temperature of the metal, the character of the molding sand required is slightly different from cast iron molding sand.

Brass and other non-ferrous **alloy** founding follows much the same procedure insofar as molding is concerned. The nature of the molten metal, together with the smoother surfaces usually desired, makes it advisable to pack immediately around the pattern with a specially prepared molding sand of very fine texture. This sand is then backed up with the ordinary type. The non-ferrous metals are generally melted in either an electric furnace or a crucible furnace. Coke, oil, and gas are variously employed to fire these crucible furnaces. In its simplest form, the crucible furnace consists of a refractory lined chamber in which the **crucibles** containing the pig metal are set. The combustion of the fuel may take place in this chamber, or in an external one connected to it with a flue. A slightly reducing atmosphere is maintained, so as to prevent oxidation of the metal. This is very necessary in the case of copper, which in its molten state has a strong affinity for oxygen. In the making of copper alloys, such as brass, if scrap metal is not being remelted, the copper is melted first, after which the alloying substances are added. The crucibles are either closed with a cover, or the molten metal is protected by a cover of slag or molten glass. (F.T.M.)

FOUNDRY. Founding.

FOUR-CYCLE. An abbreviated expression for four-stroke cycle. The four-stroke cycle is one upon which either the **Otto** or **Diesel** types of **internal combustion engines** may operate, since it describes, not **thermodynamic** aspects of a cycle, but rather the sequence by which the cylinder is charged and exhausted. The four-stroke cycle is described as follows. Beginning with a suction or induction stroke, the **cylinder** is filled with a fresh charge by the outward motion of the **piston.** Next, on the return motion, this charge is trapped in the cylinder by closure of all **valves** leading to and from the cylinder, and is thereby compressed. On the next outward stroke, the power stroke, the fuel is burned or exploded to the accompaniment of energy liberation, a great deal of which is made usefully available on the power stroke. The final, or fourth stroke, is a return stroke, or exhaust stroke, during which the contents of the cylinder are exhausted through a port opened by an exhaust valve. The four strokes described are suction, compression, power, and exhaust. During the suction stroke, an inlet valve is open, during the exhaust stroke, an exhaust valve is open. The advantage of the four-cycle principle is that it gives a full stroke for induction of the fresh charge, and another full stroke for scaveng-

ing of the burned gas In this way it promotes high **volumetric efficiency** A disadvantage of the four-cycle principle is the intermittent delivery of power every fourth stroke This contributes to making the four-cycle engine bulky in comparison with the two-cycle, but by employing multi-cylindered engines a steady flow of power may be secured through overlapping of power strokes (F T M)

FOURIER SERIES. An **infinite series** of the type

$$\tfrac{1}{2}a_0 + a_1 \cos x + a_2 \cos 2x + a_3 \cos 3x + \quad + b_1 \sin x + b_2 \sin 2x + b_3 \sin 3x + \quad ,$$

or, more briefly written,

$$\tfrac{1}{2}a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx),$$

where the coefficients a_n and b_n are independent of x, is called a trigonometric series

If we assume the possibility of expanding any arbitrary function $f(x)$ in a series of this form, and if we assume the uniform convergence of the series, the coefficients a_n and b_n are found to be given in terms of $f(x)$ by the formulas

$$a_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x) \cos nx\, dx, \quad b_n = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x) \sin nx\, dx.$$

A trigonometric series whose coefficients are given by these formulas is often called the Fourier series of $f(x)$ The problem still remains of investigating the convergence of this series and of the question as to whether the series represents the function

A fundamental theorem concerning Fourier's series is the following Fourier's theorem

Any single-valued function $f(x)$, which is continuous except possibly for a finite number of finite discontinuities in the interval $-\pi$ to π, and which has only a finite number of maxima and minima in that interval, may be represented by a Fourier series

$$f(x) = \tfrac{1}{2}a_0 + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx),$$

where the coefficients a_n and b_n are given by the previous formulas in terms of integrals (See **Harmonic Analysis; Vibration and Waves**) (L L S)

FOWL. Aves, Galliformes Birds of the domesticated varieties (A W I)

FOWLERITE. Rhodonite.

FOX Mammalia, Carnivora *Vulpes* Members of the **dog** family (Canidae) of moderate size and slender build, with a sharp muzzle, long bushy tail, and unusually large ears Most species inhabit the northern hemisphere but a few are found in Africa with the closely related fennecs

The fur of the fox is valuable The excellent market for that of the silver fox has led to extensive breeding of these animals in captivity

North America has several species of red foxes and several of gray The silver fox is a variety of a red fox, and kit fox is a related species (A W L)

FOXGLOVE. Figwort.

FRACTIONAL EQUATIONS. An **algebraic equation** in which one or both sides are rational **fractional functions** is called a rational fractional equation

Such an equation may in general be solved by clearing the equation of fractions by multiplying its terms by the **least common multiple** of the denominators of its fractions, thus reducing it to a **polynomial equation** (frequently of first or second degree)

In this method of solution, by clearing of fractions, **extraneous roots** may arise, so that the solution of each fractional equation should be checked by substituting in the original equation, and all values not satisfying this equation should be rejected (L L S)

FRACTIONAL FUNCTION. A rational fractional function is a **rational function** which is not a **polynomial function** (rational integral function), it involves the variable in a denominator of a **fraction**

A rational fractional function can be expressed as a quotient of two polynomials (L L S)

FRACTIONS. A fraction is an indicated **quotient** of two numbers or two expressions The dividend and divisor of the quotient are called respectively the numerator and denominator of the fraction

A fundamental principle for operations with fractions is the following The numerator and denominator of a fraction may both be multiplied or divided by the same number without changing the value of the fraction

$$\frac{a}{b} = \frac{ma}{mb}$$

A fraction is said to be in its lowest terms when its numerator and denominator have no common factor A fraction can be reduced to its lowest terms by dividing the numerator and denominator by their **highest common factor**

The signs of both numerator and denominator of a fraction may be changed without changing the value of the fraction If the sign of either numerator or denominator is changed, the sign of the fraction is changed Thus.

$$\frac{-a}{-b} = \frac{a}{b}, \quad \frac{-a}{b} = \frac{a}{-b} = -\frac{a}{b}.$$

Two or more fractions may be changed to equivalent fractions with a common denominator by multiplying the numerator and denominator of each fraction by the quotient obtained by dividing the **least common multiple** of all the denominators by the denominator of that fraction

The sum (or difference) of two fractions with a common denominator is a fraction with the common denominator and whose numerator is the sum (or difference) of the given numerators

$$\frac{a}{c} \pm \frac{b}{c} = \frac{a \pm b}{c}.$$

To add (or subtract) any two fractions (with different denominators), change each fraction to equivalent fractions with a common denominator (usually the least common denominator), and then combine them by the preceding rule

$$\frac{a}{b} \pm \frac{c}{d} = \frac{ad}{bd} \pm \frac{bc}{bd} = \frac{ad \pm bc}{bd}$$

The product of two fractions is a fraction whose numerator is the product of the numerators of the given fractions and whose denominator is the product of their denominators

$$\frac{a}{b} \cdot \frac{c}{d} = \frac{a \cdot c}{b\ d}$$

To divide one fraction by another, invert the divisor fraction and multiply the dividend by this inverted fraction.

$$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c} = \frac{a\ d}{b\ c} \qquad \text{(L L S)}$$

FRACTURE. In medicine, a fracture is a breaking of any solid structure or organ of the body Colle's fracture is the term applied to a break near the wrist involving the lower one-fourth of the radius (one of the two bones of the lower forearm) In a comminuted fracture the bone is splintered into several fragments at the site of injury A compound fracture is one that is accompanied by such an injury to the soft parts that an external wound leads to the fracture at the site, or, as often happens, the bone projects beyond the skin A

depressed fracture is a fracture of the skull in which a portion of the skull is pushed inward The term green-stick fracture is used when the shaft of the bone is broken, without involving both sides Such a break is associated with bending In an impacted fracture, one fragment is driven or jammed into the other Pott's fracture occurs at the ankle joint, and involves both bones of the leg (the tibia and fibula), which form a mortise at that point An ununited fracture is one that is not followed by bony union

In mineralogy, fracture is the property of minerals to break with curved or uneven surface When a mineral has three planes of cleavage it has no fracture Some minerals, such as **quartz**, have no well-defined planes of cleavage but may be distinguished by their fracture, such as conchoidal (shell-like), splintery, etc (R S M, R M F)

FRANCOLIN. Aves, Galliformes Birds (**Aves**) of Africa and the Oriental region, related to the partridges (A W L)

FRANGIPANGI. *Plumeria acutifolia* Apocynaceae This is a shrub or small tree native to Mexico and Central America, which is often cultivated for the beauty and fragrance of its flowers The plant has but few, rather coarse, branches Its deciduous leaves are thick, smooth, and oblong to ovate in shape, in length they vary from 5–15 inches The flowers, which often appear when the plants are leafless, are showy, and borne in terminal cymes The flowers are red and extremely fragrant, and much used for decorative purposes Several other species of *Plumeria* are known, some of which yield woods of some economic value (R M W)

FRANKLINITE. The mineral franklinite is a **zinc-iron-manganese** mineral whose formula may be written $(Fe,Mn,Zn)(FeO_2)_2$, but the composition varies considerably, in respect to the amounts of the several metals that may be present Its isometric crystals have an **octahedral** habit, it may be coarse or finely granular or compact It shows a parting parallel to the octahedron, fracture, uneven, brittle, hardness, 5 5–6 5, specific gravity, 5–5 2, luster, usually metallic, occasionally dull, color, black, streak, brown to black, opaque, may be slightly magnetic Only in one place in the world does franklinite occur in quantity, at Franklin Furnace, New Jersey, from whence it was named Here there are two bodies of this mineral, which is used as a zinc ore, about three miles distant from each other The franklinite is found in pre-**Cambrian** limestones that are associated with **gneisses** believed to be of igneous origin and responsible for the mineralization Associated minerals are **willemite**, zinc silicate, and **zincite**, zinc oxide Franklinite has been found at Eibach, Germany, in cubic crystals (P S C S)

FRASCH PROCESS Sulfur.

FRAUNHOFER LINES The dark lines constituting the **absorption spectrum** exhibited by sunlight are frequently called the Fraunhofer lines There are thousands of these lines of which Fraunhofer, early in the nineteenth century, first observed the most prominent. To these particular lines he assigned letters for reference purposes These lines, together with their origin and approximate wave lengths, are listed as follows

A	Terrestrial oxygen	7594 A	(extreme red)
B	Terrestrial oxygen	6867 A	(red)
C	Hydrogen	6563 A	(red)
D_1	Sodium } doublet	5896 A	(yellow)
D_2	Sodium }	5890 A	(yellow)
E	Iron	5270 A	(green)
F	Hydrogen	4861 A	(blue)
G	Iron and Calcium (group)	4308 A	(violet)
H	Calcium	3968 A	(extreme violet)

The lines of solar origin are due to absorption by gases and vapors in the solar **atmosphere** (L D W)

FREEMARTIN. A sterile cow, born as a twin of a bull The sterility is due to the action of **hormones** produced by the male twin, which enter the circulation of the female in the **extraembryonic membranes.** (A W L)

FREEZING POINT. The freezing point of a liquid is the temperature at which the solid form and the liquid form are in **equilibrium** (See **States of Matter**, and **Melting Point**) (R K S)

FREQUENCY. In electricity, frequency is the number of complete alternations per second of an **alternating current** Sixty cycles per second is becoming the standard frequency for alternating current generation in the United States Elsewhere 25 and 50 cycles per second have some vogue In an **alternator**, the number of alternations per second of the output is the speed, in revolutions per second, multiplied by the number of poles The number of poles in alternators is usually two or four for steam turbine driven alternators, or 24, 26, 28, 30, 36, 48, or 60 in the case of engine-driven alternators The formula for frequency, cycles per second, in terms of the rotative speed, revolutions per minute, and the number of electrical poles, is

$$\text{Frequency} = \frac{\text{revolutions per minute} \times \text{number of poles}}{120}$$

In **acoustics**, the frequency represents the number of sound waves passing any point of the sound field per second (See **Audio Frequency**) In the case of **light** or other **electromagnetic radiation**, frequency may be expressed in this same way but is usually so enormous (500 million per second for yellow light) that wave lengths are ordinarily used instead **Radio frequencies** are commonly given in thousands of cycles (kilocycles) per second (F T M)

FREQUENCY CHANGER. Wherever there is to be an interchange of electrical energy between two systems which operate at different **frequencies**, the tie together must be through the medium of a frequency changer, since it is impossible to have two **alternators** electrically connected to the same line operating at different frequencies The one operating at higher frequency will tend to motor the other, and take unto itself enough of the load so that through the slowing down of it, and the speeding up of the slower, their frequencies will coincide The simplest plan for connection of two such systems, and the one usually employed, is to couple, mechanically, two rotating machines of the **synchronous motor** or **generator** type, which have, respectively, the correct number of electrical poles to permit one to operate at the frequency of one system, while the other is at the frequency of the other system, both, of course, having the same rotative speed This is relatively simple in the case of the drawing of power, say, from a 60-cycle system to supply energy for 25-cycle use, but has serious disadvantages as a means of interconnecting two power systems of different frequency, each having considerable amount of generating equipment Any slight alteration in the relative frequencies of these two systems results in heavy fluctuations of the frequency changer load, and necessitates the employment of extremely large and bulky frequency changers Nevertheless, this is the system usually employed Fortunately, the necessity for such frequency changing is rare in this country at the present time (F T M)

FREQUENCY METERS AND WAVEMETERS. Any instrument used to measure the frequency of **alternating currents** or of **electromagnetic waves** is a frequency meter For low-frequency alternating currents, such as those used for power distribution, a simple mechanical resonance device may be employed For ex-

ample, a number of elastic steel tongues vibrating naturally in successively shorter periods, and bearing light disks at their ends, are all arranged in a row above the same elongated electromagnet, with the disks along a suitable frequency scale, when the magnet is energized by an alternating current, the tongue which is set into most violent vibration indicates the frequency of the current

A wavemeter is a frequency meter adapted to measure the frequency of radio waves or of high-frequency oscillations Such an instrument utilizes the principle of electrical **resonance** and consists of a circuit which may be tuned to the waves or oscillations and a sensitive current detector to indicate when the circuit is in synchronism with the waves A "thermogalvanometer" is commonly employed as detector, it consists of a fine wire which is heated by the resonance current, together with a sensitive thermocouple and galvanometer arrangement to indicate its heated condition In some of the older forms, the wire filament alone was used, visibly glowing upon approach to resonance In a sense the frequency dial of a radio receiving set may be regarded as a wavemeter, the condition of resonance being indicated by maximum acoustic response of the set (L D W)

FRESNEL COEFFICIENT OF DRAG. Ether.

FRESNEL MIRRORS. Young's Interference Experiment

FRICTION The chief causes of friction are the interlocking of the minute irregularities on the rubbing surfaces, adhesion between the surfaces, and the indentation of the softer by the harder body Friction between solid bodies may be classified as sliding and rolling The laws of sliding friction were investigated by Coulomb, who found that, approximately and within limits, (1) the friction between two surfaces is slightly greater just before motion begins than when the surfaces are in steady relative motion, (2) the friction is proportional to the force pressing the surfaces together, (3) it is independent of the area of contact, and of the speed of relative motion The constant ratio of the friction to the force pressing the surfaces together is called the coefficient of friction, some typical values of which are as follows

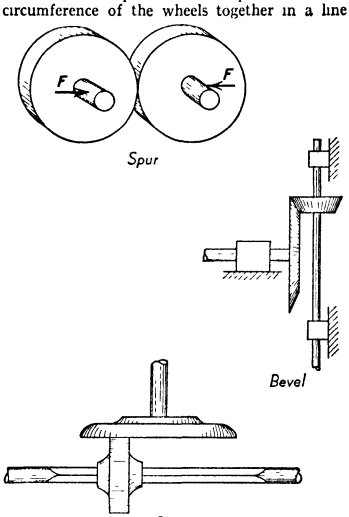
Dry wood on dry wood	0 35
Leather on metal	0 55
Iron on stone	0 50
Wood on stone	0 40
Stone on stone or brick	0 65
Well oiled metals	0 05

By means of such coefficients, it is possible to calculate what the friction will be between two bodies, as a wooden sill on a stone foundation, when the force pressing them together is given

The angle at which a plane surface must be inclined for a solid block to slide slowly down it is the angle of friction, its tangent is the coefficient of friction between plane and block Lubrication greatly reduces the coefficient by separating the solid surfaces Rolling friction, due to the indentation of the surfaces in rolling contact, is much less than sliding friction, as illustrated by the use of ball-bearings The **viscosity** of liquids and gases is sometimes called "internal friction" (L D W)

FRICTIONAL ELECTRICITY. This familiar phenomenon is technically known as **tribo-electrification** When two dissimilar substances are rubbed together, they become oppositely electrified, and if either is an insulator, it retains a charge For example, if glass is rubbed with silk, the glass becomes positive and the silk negative Careful experiments make it appear probable that this is a type of **contact potential difference**, and that the friction serves only to bring about surface contact over a larger area Accurately ground and polished disks of steel and glass, when pressed firmly together to ensure close contact and then separated, show the same effect, the glass again being positive Various experimenters have arranged lists of substances in such order that when any two are pressed together, the one higher in the list becomes positive with respect to the other, but the data have often been conflicting Coehn concluded from his experiments that the potential difference of the charges developed by two contacting **dielectrics** is proportional to the difference between their **dielectric constants**, the one having the greater constant being positive (L D W)

FRICTION GEARING. One rotating part may be driven by contact with another through the medium of **friction** set up between them at the contact point This friction **gearing** is satisfactory for drives which do not require a positive transmission of relative motion between the driver and the driven **shaft** Friction gearing is unable to satisfy the condition of a constant velocity ratio because of variation in slip at different speeds The friction is set up between a friction surfaced wheel, which should be the driving member, and an iron or friction surfaced follower There are three types of friction gears, the spur gear, the beveled gear, and the crown gear All are illustrated in the accompanying figure The spur gear consists of two plain cylindrical wheels mounted on parallel shafts spaced so as to hold the circumference of the wheels together in a line contact Pressure applied between the shafts results in an equal pressure between the friction surfaces This pressure, when multiplied by the coefficient of friction, is equal to the tangential driving force between the gears at the point of contact If the peripheral speed of the gears is V feet per minute, the horsepower which can be transmitted is $\frac{\mu FV}{550}$ F is the pressure between the friction faces, and μ is the coefficient of friction



Friction gearing

The above equation shows that the pressure between the friction faces is directly proportional to the horsepower transmitted Limitations of the bearing power of the friction material thus may be expected to limit the maximum horsepower which may be transmitted by spur friction gearing This limitation has been overcome in some cases by multiple grooving of the contact surfaces.

By grooving, a certain radial pressure results in a much greater pressure on the contact surfaces, which are the sides of the grooves. The increase of pressure is due to wedge action.

Where the shafts are not parallel, beveled friction gears can be used. The beveled gear arrangement has the added advantage of introducing, in effect, a disengaging clutch to the mechanism. One of the gears may be splined on its shaft, then by means of a thrust collar operated by a lever, it can either be brought into contact, or released from the other. A very useful combination of friction gearing is that of the crown friction gear, since this apparatus not only introduces a clutch action, but also allows a variable speed ratio between driven and driving gears. This power transmission mechanism was at one time applied to the drive of a light automobile, but in the course of time was superseded by the toothed gear type change speed transmission. It has had, however, considerable use in other machinery such as the drive of screw and drill presses. As applied to the automotive drive, the fiber surfaced friction wheel was the driven member, and an aluminum disk was the driving member. The disk could be moved endwise and brought in contact with the friction wheel or released from it by the action of a foot pedal. The friction wheel was mounted on a splined or square shaft, and was free to slide along that shaft. That shaft was a jack shaft, and carried **sprockets** from which the drive was taken to the rear wheels by means of a chain. The position of the friction wheel on its shaft, and consequently its position relative to the disk, could be varied by a mechanical linkage deriving motion from a hand lever by the driver's seat. Thus a large number of speeds forward was provided, and when the friction wheel was on the other side of the center of the disk reverse speeds were obtained. (F.T.M.)

FRIEDEL-CRAFTS REACTION. Aluminum chloride anhydrous, introduced by Friedel and Crafts, is used as reagent, generally in **carbon disulfide** solution to avoid rise in temperature, for the preparation of (1) arylalkyl **hydrocarbons**, (2) di- and tri-phenylmethane and derivatives, and (3) aryl-alkyl and diaryl **ketones.**

(1) Aryl-alkyl hydrocarbons. The reaction takes place between **benzene** or its homologues and the alkyl haloid, thus:

$$\underset{\text{Benzene}}{C_6H_5\cdot H} + \underset{\text{Methyl chloride}}{Cl\cdot CH_3} \longrightarrow \underset{\text{Toluene}}{C_6H_5\cdot CH_3} + \underset{\text{Hydrogen chloride gas evolved}}{HCl}$$

$$\underset{\text{Benzene}}{C_6H_4\begin{matrix}H\\H\end{matrix}} + \underset{\text{Methyl chloride}}{\begin{matrix}Cl\cdot CH_3\\Cl\cdot CH_3\end{matrix}} \longrightarrow \underset{\text{Xylene}}{C_6H_4(CH_3)_2} + HCl$$

(2) Di- and tri-phenylmethane, derivatives. The reaction takes place between **benzene** and benzyl haloid or methylene haloid in the case of diphenylmethane, and between benzene and benzal haloid or chloroform in the case of triphenylmethane, thus:

$$\underset{\text{Benzyl chloride}}{C_6H_5CH_2Cl} + \underset{\text{Benzene}}{HC_6H_5} \longrightarrow \underset{\text{Diphenylmethane}}{C_6H_5CH_2C_6H_5} + HCl$$

$$\underset{\text{Methylene chloride}}{H_2CCl_2} + \underset{\text{Benzene}}{\begin{matrix}HC_6H_5\\HC_6H_5\end{matrix}} \longrightarrow \underset{\text{Diphenylmethane}}{C_6H_5CH_2C_6H_5} + \begin{matrix}HCl\\HCl\end{matrix}$$

$$\underset{\text{Benzal chloride}}{C_6H_5CHCl_2} + \underset{\text{Benzene}}{\begin{matrix}HC_6H_5\\HC_6H_5\end{matrix}} \longrightarrow \underset{\text{Triphenylmethane}}{C_6H_5CH\begin{matrix}C_6H_5\\C_6H_5\end{matrix}} + \begin{matrix}HCl\\HCl\end{matrix}$$

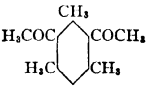
$$\underset{\text{Chloroform}}{HCCl_3} + \underset{\text{Benzene}}{\begin{matrix}HC_6H_5\\HC_6H_5\\HC_6H_5\end{matrix}} \longrightarrow \underset{\text{Triphenylmethane}}{C_6H_5CH\begin{matrix}C_6H_5\\C_6H_5\end{matrix}} + \begin{matrix}HCl\\HCl\\HCl\end{matrix}$$

(3) Ketones. The reaction takes place between **benzene** and paraffin or benzenoid acyl haloid, thus:

$$\underset{\text{Acetyl chloride}}{CH_3COCl} + \underset{\text{Benzene}}{HC_6H_5} \longrightarrow \underset{\text{Acetophenone}}{C_6H_5COCH_3} + HCl$$

$$\underset{\text{Benzoyl chloride}}{C_6H_5COCl} + \underset{\text{Benzene}}{HC_6H_5} \longrightarrow \underset{\text{Benzophenone}}{C_6H_4COC_6H_5} + HCl$$

The keto-group occupies the position para to alkyl already present. Two acyl groups have been placed in mesitylene to form diacetylmesitylene



Summarizing: **Benzene** or its homologues plus paraffine substituted haloid in the presence of **aluminum** chloride anhydrous react with the elimination of **hydrogen chloride.** In several cases an intermediate compound of the reactants with aluminum chloride has been identified. The reaction has been studied in detail by J. F. Norris and his co-workers.

Other reactions involving aluminum chloride anhydrous are:

(a) **Xylene** plus **benzene** to yield **toluene,** and the reverse, namely, toluene to yield xylene plus benzene. Boiling temperature.

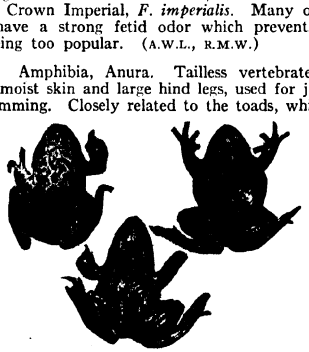
(b) Benzene, toluene and homologues chlorinated by reaction with chlorine gas.

(c) Benzene sulfinated by reaction with sulfur dioxide. Benzene sulfinic acid ($C_6H_5\cdot SOOH$) formed. (R.K.S.)

FRIGATE BIRD. Aves, Pelecaniformes. *Fregata.* Marine birds (**Aves**) of slender build and powerful flight. They live chiefly on fish which they force other birds to give up to them. (A.W.L.)

FRITILLARY. Insecta, Lepidoptera. A **butterfly** of the genus *Argynnis.* Most species are red-brown with black markings and are spotted beneath with silver. Fritillary is also a genus of plants of the Lily Family, containing some fifty species growing in north temperate regions. They are mostly spring-blooming plants having bell-shaped flowers. The flowers are often spotted or mottled with dark purple and green spots. Most frequently grown are the snakes' head, *Fritillaria Meleagris* and the Crown Imperial, *F. imperialis.* Many of these plants have a strong fetid odor which prevents them from being too popular. (A.W.L., R.M.W.)

FROG. Amphibia, Anura. Tailless vertebrates with smooth moist skin and large hind legs, used for jumping and swimming. Closely related to the toads, which dif-



Three species of bull frogs. (Courtesy of *American Museum of Natural History.*)

fer in their more terrestrial habits and warty skin. The forms are not sharply separated; arboreal species of the family Hylidae are called both tree frogs and tree toads. (A.W.L.)

FROG HOPPER. Insecta, Homoptera. Small jumping **insects** whose form faintly resembles that of the frogs. The immature insect sucks the sap of a plant and secretes about itself a protective frothy mass, hence they are also called spittle insects or spittle bugs. (A.W.L.)

FROG MOUTH. Aves, Caprimulgiformes. *Podargus.* Birds (**Aves**) of the Oriental and Australian regions with very short beaks and wide mouths. Related to the whip-poor-will and other goatsuckers. (A.W.L.)

FRONTAL APPENDAGE. An appendage of an extra pair between the second antennae of some **crustaceans.** (A.W.L.)

FRONTAL BONE. Bones of the **vertebrate** skull lying between and behind the eyes, usually paired but in most human skulls united to form the single large bone of the forehead. (A.W.L.)

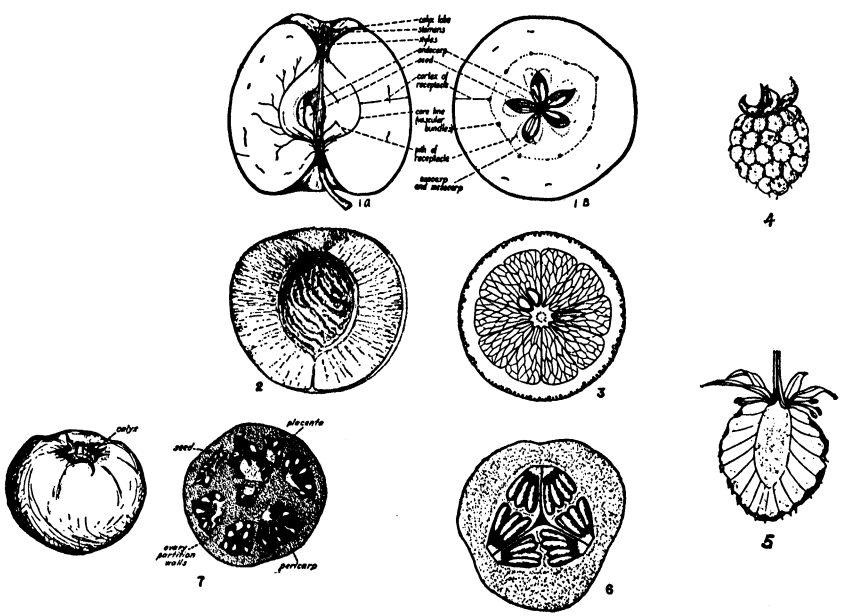
FRONTAL ORGAN. An organ found on the front of the head of some **crustaceans.** Usually paired and probably sensory. (A.W.L.)

FROST. Frost, like **snow,** is the result of the **sublimation** of water vapor in saturated air. If there is excessive radiation from solid objects, as on a clear night in late fall, the air coming in contact with them may be chilled below the sublimation point, and spicules of ice grow out from the cold surfaces. The process is entirely similar to the formation of metallic crystals artificially from vaporized metals on the interior of a glass tube communicating with the vaporizing furnace. In either case the size of the crystals is a matter of time and the supply of saturated vapor. Frost is often observed around cracks in a wooden sidewalk, because of the damp air escaping from the ground below. The objects upon which frost forms most readily are those of low specific heat and high thermal emissivity, such as blackened metals; hence the marked accumulation of frost on the heads of rusty nails. The apparently erratic occurrence of frost in adjacent localities is due partly to differences of level, the lower areas becoming colder; but also largely to differences in absorptivity and specific heat of the ground, which, in the absence of wind, greatly influences the temperature attained by the superincumbent air. It should be understood that vegetation is not damaged by frost itself, but by cold air; the appearance of frost merely indicates that the temperature has dropped below the freezing point. (L.D.W.)

FRUCTOSE. Carbohydrates.

FRUIT. While this word is often used to describe any product of the soil, to the botanist a fruit is the ripened ovary of the **flower.** Often, however, it is necessary to amend this definition in order to include certain other tissues which are a part (often a very large part) of a fruit. In the strawberry, for instance, the red pulp is not the ovary, but a very much enlarged and modified stem tip. Another illustration is found in the "fruit" of the pineapple, a large part of which is stem and not ovary. Often, too, it is difficult to distinguish a fruit from a seed, and many fruits are invariably called seeds. Sunflower "seeds" are really fruits, as are the "seeds" of grasses.

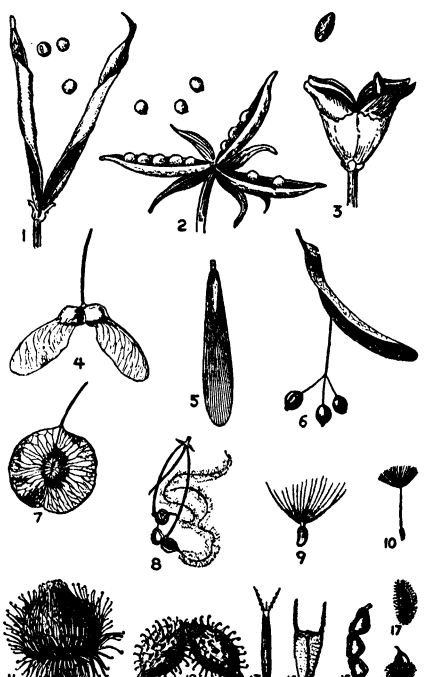
There are many kinds of fruits. Usually they are separated into two classes, dry fruits and fleshy fruits. Dry fruits are again separated into dehiscent fruits, those which split open when ripe, and indehiscent fruits, which do not do so. Common dehiscent dry fruits are the legume, the follicle, and the capsule; dry indehiscent fruits are the achene, the caryopsis or grain, the samara and the nut. A legume is a fruit which when ripe splits along both edges; it develops from a single **carpel.** The pods of peas and beans are legumes. A follicle is similar to a legume, but splits along one side only. Milkweed pods are follicles. The fruits of the columbine and larkspur are also follicles. A capsule is a dehiscent fruit which develops from a compound ovary. The fruit of a lily or an iris is a capsule. The achene is a single-seeded indehiscent fruit which when mature has the seed free from the ovary wall except at the point of attach-



Fleshy fruits. 1a and 1b, apple, illustrating pome (after Robbins); 2, peach, illustrating drupe (after Decaisne); 3, orange, illustrating berry (after Decaisne); 4, raspberry, illustrating aggregate fruit (after Chamberlain); 5, strawberry, illustrating aggregate fruit (after Brown); 6, cucumber, illustrating pepo (after Chamberlain); 7, mature fruit of tomato: left, surface view; right, cross section. (Redrawn.)

ment. The fruits of the buttercup are achenes; also the fruits of the strawberry, which are the small hard bodies borne on the surface of the "berry." The achene of the composite family differs from the others in having the calyx tube coalesced with the ovary wall. A caryopsis or grain is very similar to an achene, but has the seed coat fused with the pericarp so that the seed cannot be removed from the ovary wall. The fruits of all cereal grasses are caryopses. The samara is an indehiscent fruit which has a wing. The fruits of the maple and elm tree are samaras. A nut is a very hard-shelled fruit, usually one-seeded. Walnuts, acorns, and beechnuts are examples.

Fleshy fruits include the pome, the drupe, the berry, and many special types often called aggregate and multiple fruits. A pome is a fleshy fruit developed from an epigynous flower having a compound ovary. The flesh of the pome consists of an enlarged and ripened receptacle together with the outer layers of the pericarp. An apple is a pome. The tough paper-like part of the core is the endocarp. A drupe, or stone fruit, is developed entirely from the ovary. It is a one-seeded fruit having a fleshy mesocarp and a hard endocarp. Peaches, cherries, prunes and olives are drupes. A berry is a fleshy fruit having all the pericarp fleshy, and containing one or more seeds. The fruit of the tomato, the grape, the banana and the cranberry are true berries. In many plants the fruit is very similar to a berry, but is partly composed of receptacle tissue which forms a hard rind. These fruits, such as squashes, cucumbers and melons, are called pepos. If the outer wall of a berry is leathery, as in the orange, it is known as a hesperidium.



Dry fruits with devices for dispersal of their seeds. One to three, by sudden dehiscence. 1, wild bean; 2, violet; 3, witch hazel. Four to ten, by wind. 4, maple; 5, ash; 6, basswood; 7, elm; 8, *Clematis;* 9, thistle; 10, dandelion. Eleven to seventeen, by animals. 11, burdock; 12, cocklebur; 13, Spanish needle; 14, beggar's tick; 15, beggar's lice; 16, agrimony; 17, carrot. (Redrawn from various sources.)

Aggregate fruits are those which are formed from a single flower which had many simple pistils. In these fruits the receptacle forms a considerable part of the whole. Strawberries, raspberries and blackberries are aggregate. In some fruits of this class the separate fruits break from the receptacle, as in the raspberry, while in others they remain firmly attached. A multiple fruit is formed from the ovaries of many flowers growing in a compact mass. Mulberries and pineapples are fruits of this type.

As the fruit ripens, the ovary wall or pericarp grows. Three layers of cell tissue are usually recognizable as the ovary matures. The outermost layer or exocarp, which is usually a thin layer, often an epidermis only one cell thick. The innermost layer is the endocarp. Between these is the mesocarp, in which the vascular tissues ordinarily occur. The relative thickness and appearance of these layers varies greatly in different fruits.

Often the structure of the fruit is directly correlated with the dissemination of the seeds. The principal agencies for fruit dispersal are wind, water, and animals. Many fruits are provided with wings, thin blade-like structures which enable the fruits to drift slowly downward and generally away from the parent plants. The fruits of the maple, the ash, and the **ailanthus** are provided with wings. The fruits of the dandelion and the thistle are familiar to all, though usually they are called "seeds." In them a group of slender hairs forms a parachute which enables the fruit to drift far away from its parent plant into new regions. Sometimes the fruit lacks any special structures which will aid in its dissemination, but is itself very easily blown about. The large pods of the honey locust are of this sort.

Many fruits, especially those of plants which grow along the shores of streams and other bodies of water, are carried about by the water. The large fruits of the coconut are often carried far from the parent plant.

Animals are an important means of dispersal of fruits and seeds. There are two ways in which the fruit may be thus carried. Very commonly hooks or barbs are formed on the surface of the fruit. Beggar's lice (the fruit of *Bidens*), and burdock, for example, are easily caught on the fur of a passing animal, and stay until some mechanical injury breaks off the hooks or barbed bristles and allows the fruit to fall. Some fruits, on the other hand, are covered with a sticky coating which causes them to adhere to the coats of passing animals, to be rubbed off later. Still other "seeds" have a soft, often tasty, outer wall, and are eaten by animals. The hard inner wall of the fruit resists the action of the digestive juices, so that the seed passes uninjured through the digestive tract and is voided in a region often far distant from the place where it was eaten.

The explosive splitting of the walls of many fruits ejects the seeds violently, hurling them away from the parent plant. The seeds of the sand-box tree (*Hura crepitans*) are said to be hurled fifty yards and more, and those of the witch hazel 15 to 20 feet. (R.M.W.)

FRUIT FLY. Drosophila.

FRUIT SUGAR. Carbohydrates.

FUCHSINE. Dyes.

FUCOXANTHIN. Pigments in plants; and Amino-acids and Proteins.

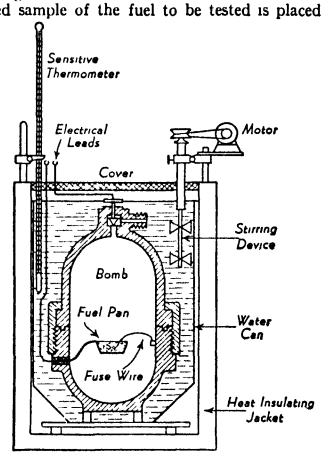
FUEL CALORIMETER. The heating value of a **fuel**, in terms of heat units such as the British Thermal Unit, may be obtained experimentally with the use of a fuel **calorimeter.** As fuels exist in solid, liquid, and gaseous states, fuel calorimeters would, of necessity, be required to be able to measure the heat of either solids, liquids, or gases. The conditions of measurement of a gas

call for an instrument different in many essential respects from that which would be satisfactory for a solid or liquid fuel, principally because it is impractical to measure out a gas in definite isolated quantities, as is so easily done with liquids and solids Hence a gas calorimeter is a continuous flow instrument, whereas the liquid and solid fuel calorimeter is an intermittent type, wherein a known weight is burned Nevertheless, the principle underlying the measurement of heat in all fuel calorimeters is the absorption of heat by water, creating a temperature rise Measurements of the quantity of water and temperature rise are used directly to determine the heat units, since a unit of heat raises the temperature of a unit weight of water one degree. In the English system, the British Thermal Unit is indicated when one pound of water at about 60° is raised in temperature a degree Fahrenheit

The Junker's gas calorimeter is a chamber wherein a known metered flow of gas is burned in an efficient type burner, with liberation of heat which is absorbed in water as the products of combustion flow through the tubular passages of the calorimeter The water which absorbs the heat is likewise flowing steadily through the calorimeter, being separated from the gas by the walls of the tubes The temperature of the water entering and leaving is measured by thermometers, while the rate of flow of water is measured by catching and weighing it Thus the heat measured is a rate of heat liberation obtained by multiplying the rate of flow of water per minute by the temperature rise in degrees This quantity, when corrected for radiation, moisture condensation, emergent stem, and other conditions, becomes the heating value of the gas per cubic foot

The intermittent type fuel calorimeter consists of a bomb which is charged with fuel and oxygen, and immersed in a bucket of water, which serves to absorb the heat when the charge inside the bomb is ignited The temperature rise of the water is observed and the heat release determined by multiplying that rise by the known weight of water That heat, divided by the weight of the measured sample of fuel, is the heating value—in the rough Several corrections must be applied

The figure illustrates a bomb calorimeter A carefully weighed sample of the fuel to be tested is placed in the



Emerson bomb calorimeter

pan within the steel bomb A calibrated length of fuse wire is drooped into the pan, then the bomb is screwed tightly together It is next connected to a tank of oxygen and charged with that gas to a pressure of several atmospheres, after which it is removed and immersed in the water of the calorimeter When the water and calorimeter have arrived at room temperature, the electric leads are connected to a source of voltage through a switch, a stirring device is started, and the circuit is closed The rush of current fuses the calibrated wire, raising it to a temperature sufficient to ignite the fuel in the presence of oxygen The fuel then burns rapidly—almost explosively—and the heat it liberates is absorbed by the water Temperature rise is measured by a sensitive thermometer A large amount of water is used, so that the temperature rise will be very small Corrections must be made for radiation, emergent thermometer stem, heating value of the fuse wire, water equivalent of the calorimeter, and energy input of the stirring device (F T M)

FUEL OIL. The petroleum oil obtained from wells in various parts of the earth is rarely suitable as a fuel oil in its crude form Fuel oils are the crude oil after some of the lighter and heavier fractions have been removed (See also **Fuels; and Hydrocarbons.**)

The principal production fields in the United States are in Pennsylvania, Ohio, Texas, and California Petroleum is composed of a series of hydrocarbons in various proportions A typical analysis of crude oil would be 84% carbon, 13% hydrogen, 1% sulfur, 1% nitrogen, 1% oxygen Practically all of the hydrogen is "free" (that is, it is in a state of combination, as with carbon, in which most or all of its heat of combustion is available), and since it is in larger proportions by weight than in coal, fuel oil might be expected to have a considerably higher heating value The principal uses of fuel oil at the present time are in **Diesel** engines, for firing in the furnaces of steam **boilers**, and for use in domestic oil-burning furnaces The value of a fuel oil may be gaged by the following properties

Calorific value This, of course, is important because it shows the amount of energy available The calorific value of fuel oils is from 18,000 to 20,000 B T U per lb

Viscosity Viscosity is one of the most important qualities of a fuel oil It determines the fluidity of the oil and is a fair indication of how readily the oil will atomize A very viscous oil may prove troublesome to handle without heating to a point where viscosity is more satisfactory Viscosity is generally stated in terms of seconds, Saybolt Universal, at some specified temperature, usually 100° Fahr

Solid Impurities, Ash and Asphalt Content The effect of these is to cause deposits in the combustion chamber and around the piston rings, necessitating increased maintenance Ash is the most detrimental quality in fuel oil

Water content Few oils are free from water, but a good oil will not contain more than one per cent of water Besides forming sludge, the water content decreases the calorific value of a fuel

Sulfur and acid These components will cause corrosion of cylinders and valves under certain conditions

Degrees Baumé The Baumé scale is one of specific gravity

$$\text{Degrees Baumé} = \frac{140}{\text{specific gravity}} - 130$$

(For liquids lighter than water)

The specific gravity is referred to water as 1 Suitable fuel oils range from 15° to 32° Baumé The Baumé reading is useful in determining whether the oil is burdened with an undue amount of heavy residue which is difficult to burn successfully

Flash and boiling points These indicate the degree to which a fuel can be vaporized, also the inflammability, and hence the fire risk of storage and handling (F T M)

FUELS. Fuels are those materials which when burned with air or **oxygen,** furnish heat energy The rate at

which a given fuel is burned determines the temperature at the point of burning. Since heat flows from bodies at a higher to those at a lower temperature in proportion to the temperature difference between them, the temperature of combustion is important when the rate of heat flow is a consideration.

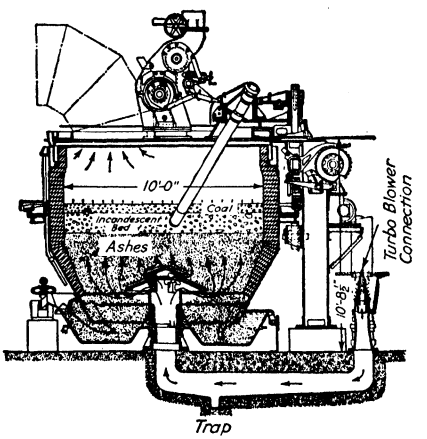
The materials used as fuels fall into two grand divisions, (1) Fuels—gases, liquids, solids—for ordinary combustion, (2) Fuels for non-ordinary or **internal combustion engines,** motor and stationary. These are either gases or volatilizable liquids, usually **petroleum** or coal tar products, capable of rapid reaction (explosion) when mixed with air or oxygen and ignited. This **ignition** is usually accomplished by an electric spark, but high and rapid compression (that is, **adiabatic,** without heat loss, energy of compression being accounted for by temperature rise) is sufficient in certain cases, for example, in the **Diesel engine.**

The heat evolving chemical elements in domestic and industrial fuels are **carbon** and **hydrogen.** Carbon as such is utilized in coke and charcoal, and hydrogen as such in hydrogen gas for high temperature combustion, and in fuel gas mixtures, such as coal gas, water gas, producer gas and blast furnace gas. Carbon and hydrogen compounds are present (a) in the hydrocarbons of natural gas, petroleum and most of its products, and coal and most of its products, and (b) in the carbohydrates and lignins of wood and peat.

The naturally occurring fuel materials are (1) natural **gas,** (2) **petroleum,** (3) **coal** (a variety of forms), (4) **wood,** (5) **peat,** and (6) **lignite.** Artificial fuels are prepared (1) by the **destructive distillation** of coal (soft or bituminous coal) resulting in coal gas, coal tar and coke, (2) by the destructive distillation of wood resulting in charcoal, (3) by the fractional and destructive (cracking) distillation of petroleum, resulting in **gasoline,** and lower and higher boiling point distillates in "still" gases and in fuel oil residue, (4) by fuel gas reactions, resulting in water gas from coke and steam, in **producer gas** from coal or coke and air, oil-water gas from petroleum and steam. Other fuels are (1) blast furnace and other gases containing combustible material often with sensible heat at temperatures sufficiently high to be useful as sources of heat, (2) **alcohol,** (3) **benzene,** (4) **ethylene,** (5) **acetylene.**

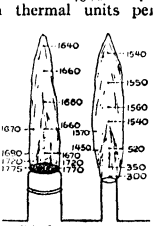
Naturally Occurring Fuels: (1) *Natural gas.* Contains up to 95 percent of **methane.** Used as a fuel, and by incomplete combustion as a source of carbon pigment or lamp black (2) *Petroleum.* (See **Hydrocarbons.**) Distilled to obtain gasoline, kerosene, lubricating oils, low boiling distillates, high boiling distillates, fuel oil, gas carbon. (3) *Coal.* (a) Bituminous, of 12,000 to 15,000 British thermal units per pound, of variable ash content as to amount of ash and as to the clinkering or fusing temperature of the ash. Used as fuel, or treated by destructive distillation to obtain coal gas, coal tar, coke, thence **benzene,** water gas, producer gas. Current and future developments are powdered coal, low temperature distillation, hydrogenation. (b) Sub-bituminous, of less than 12,000 British thermal units per pound. Used as fuel. Important future reserve. (c) Lignite and peat. Used as fuel. Important future reserve. (d) Anthracite, of 14,000 British thermal units per pound, more or less. Used as fuel, of diminishing importance. (4) *Wood.* Used as fuel, value as such markedly affected by the water content as heat from combustion is required to vaporize the water. Freshly cut wood usually contains 60 percent or more water, calculated on the weight of dry wood. Heating value of air dried woods approximately 21 (plus or minus 10%) million British thermal units per cord, equivalent to approximately 0.8 short ton of coal of 13,000 British thermal units per pound. Treated by destructive distillation to obtain methyl alcohol, woodtar, charcoal, and by burning to obtain carbon dioxide. (5) *Carboniferous shale.* Important future fuel reserve by treatment by destructive distillation to obtain hydrocarbon distillates. (See **Destructive Distillation.**)

Artificially Prepared Fuels. (6) *Coal gas.* Used as fuel. Treated to obtain **benzene, toluene, ethylene.** Oil-water gas is practically the same mixture as coal gas. Approximate composition: **methane** 30%, **hydrogen** 50%, **carbon monoxide** 6%, **ethylene** 2.5%. Fuel value: 550 (more or less) British thermal units per cubic foot. (7) *Coal tar.* Treated by fractional distillation to obtain benzene, toluene (and other coal tar crudes). (8) *Coke.* Used as fuel and metallurgical reducing agent. Treated to obtain water gas, producer gas, carbon monoxide. (9) *Charcoal.* Used as fuel and metallurgical reducing agent. (10) *Gasoline.* Used as motor fuel (and as solvent and diluent). See **Hydrocarbons,** paraffin. (11) *Low boiling naphtha.* Used as special motor fuel (and as solvent and diluent). (12) *High boiling kerosene and stove oil.* Used as fuel and illuminant. (13) *Fuel oil.* Distillation residue used as fuel in ordinary or internal combustion. Heating value approximately 19,000 British thermal units per pound, which is more than 150,000 British thermal units per gallon. (14) *Water gas.* Made by reaction of coke and steam at furnace temperatures. Used as fuel, and source



Gas producer.

of **hydrogen** and **carbon monoxide.** Approximate composition: hydrogen 45%, carbon monoxide 45%. Approximate fuel value: 350 British thermal units per cubic foot. (15) *Producer gas.* made by reaction of coke or coal and air at furnace temperatures. Used as internal combustion fuel. Approximate composition: 25% carbon monoxide. Approximate fuel value: 100 British thermal units per cubic foot. (16) *Blast furnace gas.* Used as fuel and for the sensible heat content. Approximate composition: 25% carbon monoxide. Approximate fuel value: 100 British thermal units per cubic foot. (17) *Alcohol.* Future fuel possibility, either straight or blended with other liquid fuels. When 1.1 percent of water is present in a mixture containing 80 percent gasoline plus 20 percent alcohol separation into two layers takes place. (See **Ethyl alcohol.**) (18) *Benzene.* Minor use as fuel. Future fuel possibility,



Temperatures in degrees Centigrade of gas flames.

either straight or blended with other liquid fuels. Excellent anti-knock fuel for internal combustion, and miscible with gasoline (See **Benzene.**) (19) *Ethylene* Excellent fuel for local high temperatures, used in special burner with oxygen (See **Ethylene.**) (20) *Acetylene* Excellent fuel for local high temperatures, used in special burner with oxygen (See **Acetylene**) (21) *Hydrogen* Excellent fuel for local high temperatures, used in special burner with oxygen An important component of coal gas, water gas (See **Hydrogen**)

HEATING VALUE OF VARIOUS INDIVIDUAL FUEL SUBSTANCES

Individual Fuel Gases	Higher Heating Value (Water Condensed as formed in Combustion) In B T U per cubic foot at 60° F and 30 in (Hg) pressure	In kilogram-calories per gram-molecular weight
Methane	995	211
Ethane	1730	368
Propane	2465	526
Butane	3200	680
Ethylene	1615	332
Acetylene	1455	312
Hydrogen	319	68 4
Carbon monoxide	317	67 1

Individual Fuel Liquids	Higher Heating Value Kilogram-calories per gram	Kilogram-calories per gram molecular weight
Normal-pentane	11 6	883
Normal-hexane	11 5	990
Normal-heptane	11 5	1150
Normal-octane	11 4	1303
Methyl alcohol	5 34	171
Ethyl alcohol	7 13	328
Normal-propyl alcohol	8 00	481
Benzene	10 0	782
Toluene	10 2	934

Individual Fuel Solids	Higher Heating Value Kilogram-calories per gram
Carbon, amorphous, to carbon dioxide	8 08 (97 0 Kg-Cal per g mol wt carbon dioxide)
Carbon, amorphous, to carbon monoxide	2 49 (29 9 Kg-Cal per g mol wt. carbon monoxide)
Cellulose	4 21

The examination of fuels is conducted with various purposes in mind An "ultimate" analysis is designed to give the percentage of each element present, by burning **carbon** element to **carbon dioxide, hydrogen** element to water, **sulfur** element to **sulfur dioxide** or to **sulfate, nitrogen** element to nitrogen gas, **phosphorus** element to phosphate, inorganic residue as ash The ash may be analyzed The heating value of a fuel is determined by burning a definite weight, or volume of a gas in a calorimeter A "proximate" analysis is designed to give the percentage of water, of volatilizable material under given conditions of temperature and time, and of non-volatile combustible residue A determination of the softening temperature of the ash may be made A "rational" analysis is designed to give the percentage of each compound in the fuel This is accomplished in the case of gases by measurements of volume before and after absorption in definite reagents or other treatment applied in a definite order For complex mixtures of liquids and solids this type of analysis is difficult, and at present impossible in the case of some, for example coal, although some progress has been made. Special tests are sometimes demanded, as in studying the coking conditions of coal, and the explosive and power characteristics of internal combustion fuels. The velocity of explosion of certain gas mixtures has been measured by Dixon

Gas Mixture Taken	Products Obtained	Observed Velocity of Explosive Meters per Second
$2H_2 + 2O_2$	$2H_2O + O_2$	2328
$8H_2 + O_2$	$2H_2O + 6H_2$	3532
$CH_4 + O_2$	$H_2O + COH_2$	2528
$C_2H_4 + 2O_2$	$2H_2O + 2CO$	2581
$C_2H_2 + O_2$	$2CO + H_2$	2961

Industries using fuels for the production of high temperatures are ceramics, Portland cement, glass, pig iron, steel, copper, zinc, lead, nickel, tin, destructive distillation of coal The economies introduced in the use of coal since the Great War are of such degree as to appreciably affect the demand for this fuel In 1919, the fuel consumption per thousand gross ton miles by one large railroad system in America was 153 pounds while in 1931 it was 114 pounds (R K S)

FULGURITE. A vertical, sometimes branching tube of fused quartzitic sand formed from the intense heat developed when the sand is struck by lightning (R M F)

FULLER'S EARTH. This is a fine grained earthy substance similar to **clay** both in appearance and composition, but it lacks plasticity and is usually high in **magnesia.** It has the property of decolorizing oils and removing grease from raw wool (E S C S)

FULMAR. Aves, Procellariiformes Large marine birds (**Aves**) resembling the gulls **Petrels** (A W L)

FULMINATES. See **Cyanic Acid.**

FUMAROLE. Derived from the Latin *fumus,* smoke, the term fumarole is applied to openings in the earth's crust, often in the neighborhood of volcanoes, which emit steam and gases such as **carbon dioxide, hydrochloric acid,** and **hydrogen sulfide** A special name, solfatara, from the Italian *solfo,* sulfur, is given to fumaroles that emit sulfurous exhalations Perhaps the greatest area of fumarole activity is the famous Valley of Ten Thousand Smokes, adjacent to Katmai volcano, Alaska (R M F)

FUNCTIONAL. In medicine, functional means pertaining to or affecting the function of the body, and not its structure A functional disorder is one in which there are no obvious anatomical changes

In mathematics, a functional is a **function** whose argument or independent variable is a curve or surface (or a corresponding function) It may also be described as a function of a function (R S M, L L S)

FUNCTIONS. If two **variables** are so related that to each value of one variable in a given range there correspond one or more values of the other variable, the second variable is called a function of the first variable

The first variable is often called the independent variable and the function is sometimes called the dependent variable

If one variable is so related to several variables that to each set of values of the last mentioned variables there correspond one or more values of the first variable, the first variable is called a function of the other variables

If a variable y is an **explicit function** of another variable x, the function is often denoted in general by such symbols as $f(x)$, $F(x)$, $\phi(x)$, etc, and we write $y = f(x)$, etc The symbol $f(a)$ then denotes the value of the function $f(x)$ for the value $x = a$

A function of two variables, as x and y, may be represented in general by such symbols as $f(x,y)$, $F(x,y)$, etc ; and similarly for functions of more than two variables.

A function which takes one value only, corresponding to any given value of the independent variable, is called a single-valued function

A multiple-valued function is a function which takes more than one value corresponding to any given value of the independent variable

Functions may be classified in many ways, as **explicit functions** and **implicit functions; continuous functions** and discontinuous functions, **algebraic functions** and **transcendental functions,** and each of these classes into many sub-classes, **periodic functions,** etc (L L S)

FUNCTIONS OF A COMPLEX VARIABLE. The theory of functions of a complex variable may be described briefly as the **differential** and **integral calculus** of complex variables (L L S)

FUNCTIONS OF REAL VARIABLES. The theory of functions of real variables may be described briefly as a critical study of the fundamental concepts and processes of the **differential** and **integral calculus.** (L L S)

FUNGI. Mushrooms, Toadstools, Smuts, Rusts, Molds and Mildews The fungi are a group of plants of such diverse habit that they cannot easily be collectively described Among the more than seventy thousand species described at the present time are many microscopic unicellular forms, as well as plants of elaborate structure and considerable size Fungi grow in almost every habitat where organic substance exists, and the external conditions are suitable Many species are found in water, either fresh or salt Others are adapted to life on land, or in the ground Even in the Arctic regions fungi appear in numbers during the short summer In the tropics fungi are particularly abundant, the hot, often humid climate greatly favoring their existence

In one particular, however, fungi are all alike they have no **chlorophyll,** and so are unable to synthesize food from simple substances Instead, the fungi obtain their nourishment from various organic substances Many attack living organisms, both plant and animal These are parasites, often of great importance to man because of the damage caused to crops Other fungi attack dead organisms, breaking down the organic compounds present into simpler forms and obtaining thereby their own sustenance—these are saprophytes

Excepting the entire absence of chlorophyll, the structure of fungi resembles that of the **algae,** the other main division of the **Thallophytes** The vegetative body of a fungus, except for the unicellular forms, is always composed of slender branching threads, or hyphae, making up what is known as the mycelium Mycelia in many cases are colorless, but may contain pigments of every color, including green Each hypha is ordinarily composed of a row of cells, each containing one (or more) minute nucleus, in many species cross walls are rarely formed, the hypha being coenocytic Even the largest, most complex fungi are composed entirely of tangled masses of hyphae, which may be loosely aggregated or so densely packed as to form a hard body suggestive of woody structure, as for example in the Bracket Fungi

In their reproductive processes fungi again remind one of the algae Both asexual and sexual reproduction occur in the life histories of these plants, which also often show very distinctly an alternation of vegetative growth and reproductive activity As may be expected, in so diversified a group of plants a considerable variety of reproductive processes occurs

Among the lower forms, many of which occur in water, asexual reproduction is accomplished by means of zoöspores The zoospores are formed in sporangia from which they escape at maturity. After a period of motility, each zoospore settles down, loses its **cilia** and at once gives rise to a new plant In the non-aquatic fungi asexual reproduction ordinarily occurs by means of non-motile spores, called conidia, which have a rigid cell-wall These conidia, often produced in immense numbers, are carried about by air-currents, sometimes to great distances, and on reaching a favorable habitat, germinate to form a new plant The methods of sexual reproduction found in fungi are extremely varied, and can best be considered under the different groups Sexual reproduction usually occurs in a distinct body, the sporophore, which forms in many fungi a very conspicuous part of the life cycle of a fungus This is frequently the only part recognized by the ordinary observer In each kind of fungus the sporophore assumes a very definite and distinct form In the cup fungi the sporophore is frequently a saucer- or cup-shaped structure Other types are found in the familiar mushroom, in the puff-balls, and in the Bird's-Nest Fungus, the sporophore here having many small somewhat spherical objects contained in an open cup-like body In all of these, spores are formed, often in unbelievable numbers, a common puff-ball contains millions of them The spores are borne about in the air currents, and germinate when brought to a favorable environment It is obvious that many spores must fail to reach such a favorable spot, else the world would be overrun with fungi

Fungi are separated into three classes, the **Phycomycetes,** in which the mycelium is non-septate and coenocytic, the **Ascomycetes,** characterized by having spores borne in special sacs or asci, and the **Basidiomycetes,** distinguished by the basidium, a spore-bearing cell which bears externally four spores, in some cases more or less In addition to these three classes there is another group known as Imperfects, or Fungi Imperfecti, which contains those forms of plants in which the sexual or perfect stage is not known, and which therefore cannot be assigned to one of three mentioned classes Some botanists would include in the Fungi two other groups of plants the **Bacteria** and **Slime-molds.**

Fungi are of prime importance to man, first because of the immense loss caused by saprophytic forms These attack food-stuffs, causing complete spoilage, attack fabrics which they mildew and so ruin, and attack and cause the destruction of timbers In spite of all this, it must be stated that such forms are very necessary, for the very processes of destruction they perform are necessary preparations for new growth Were all rotting prevented the accumulation of dead matter would soon become so great as to hinder and stop life Only the lower plants, notably fungi and bacteria, are able to break down complex matter to a form in which it is again available for higher organisms

Somewhat less important to man are the parasitic fungi They may attack his crops and cause immense damage, as in the case of Wheat **rust,** but usually remedies or preventatives are found to keep such pests under control, and to prevent them from becoming serious problems Not many species attack man himself Some, like Athlete's Foot, are annoying Since few are fatal, the fungi of this type have received little attention until recently

Many edible forms of fungi are enjoyed by man Of these many are species which grow wild To distinguish those species which are edible from those which are harmful is an ever present problem To style the edible species mushrooms and reject the others as toadstools does not solve the problem, since it first becomes necessary to define the terms "toadstool" and "mushroom" And there is no obvious distinction The only safe rule to follow is that of total abstinence from any doubtful species until one is absolutely certain that it is safe It is thus only natural that man has turned to the cultivation of fungi Of all the edible species known, only a few have been successfully cultivated Of these only one is commercially important, *Agaricus (Psalliota) campestris* The spawn of this fungus is planted on properly heated beds (usually underground)

of well-rotted horse manure piled in long ridges Spawn consists of bricks or flakes of prepared manure permeated with fungus mycelium After planting, this mycelium rapidly grows through the beds, which are then covered with fine earth, and left undisturbed for a time After a month or so mushrooms begin to appear on the surface of the beds They grow with astonishing rapidity, and must be cut soon after appearing, or they will reach maturity and disintegrate The food value of mushrooms is probably much overrated, as most of them are actually over 90% water, with some nitrogenous matter and no fat But they are much fancied for their palatability and fine flavor It is interesting to note that one group of tropical ants feeds largely on fungus plants, which they grow in their nests in an advanced state of cultivation

The poisonous nature of many fungi has received wide publicity, and probably accounts for th popular aversion to this group of plants The toxic substances present in the fungus are products of its **metabolism,** not substances absorbed from without It may be that these substances are some sort of waste products accumulating in the cells Some people have suggested that they are a means of protection against animals which might otherwise eat the plant However, many animals eat with impunity fungi which are violently toxic to man, so it seems difficult to maintain this explanation The toxic substances present in fungi are various Closely related species may contain quite different poisons, a single species may have more than one poison The effect of the poison on the human body varies One group of poisons is taken into the body some hours before its effects become evident Then abdominal cramps and nausea develop, vomiting occurs, thirst arises and diarrhoea These symptoms continue for hours, usually (but not always) ending in death This is the type of poisoning caused by *Amanita phalloides* *Amanita muscaria* is less violent in its action The poison of this fungus acts on the nerve centers, causing lack of coordination, illusions and delirium, as well as gastric disturbances *Amanita muscaria* is only very rarely fatal This fungus is used by native tribes of northeastern Siberia as a stimulant In addition to the *Amanitas,* many other fungi are of poisonous nature It also seems that the effect varies among different people What one finds edible may be definitely toxic to another This renders even more difficult the problem of satisfactorily determining harmful species (R M W)

FUNGUS GNAT. Insecta, Diptera Small two-winged **flies** whose larvae live on fungi and decaying vegetation Family Mycetophilidae (A W L)

FUNICULAR POLYGONS AND CATENARIES If a closed loop of cord or rope is pulled at several points by forces in various directions, it forms a figure, plane or otherwise, known as a funicular polygon The external forces acting on the loop at the vertices are, for **equilibrium,** subject to the same conditions as a set of non-concurrent forces acting on a rigid body, while the three forces concurrent at each vertex, including the tensions in the loop itself, may be represented by an equilibrium triangle, and the several triangles fitted together to form the equilibrium polygon for the external forces (Figure 1) Figure 2 gives the corresponding analysis for an open cord supported at the ends and loaded by weights hung vertically from it In Figure 3 the weights are equal, have equal horizontal spacing, and are hung close together The form of the cord in this case approximates a parabola This condition practically obtains with the cables of a suspension bridge The point O in each figure is located by drawing from the extremities of any side of the external-face polygon lines parallel to the sides adjacent to the corresponding vertex of the funicular polygon.

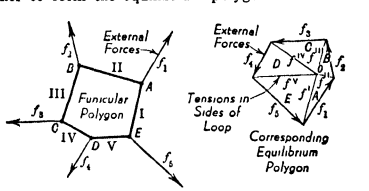


Figure 1 Closed funicular polygon with diagram of forces

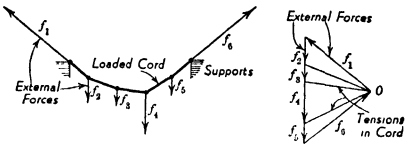


Figure 2 Suspended cable with unequal loads

If a suspended cord is loaded uniformly along its length (not horizontally), as by its own weight, it assumes the form of a **catenary.** The equation of this curve may be written

$$y = \frac{a}{2}\left(\epsilon^{\frac{x}{a}} + \epsilon^{\frac{-x}{a}}\right) = a\cosh\frac{x}{a}$$

(The hyperbolic cosine form is convenient for numerical computations) a represents the Y-intercept of the curve It is an interesting property of a catenary cable that if at any point it is hung over a pulley, and enough cable cut off to reach down to the X-axis (Figure 4), the weight of this portion will just sustain the tension on the other side of the pulley. (L D W)

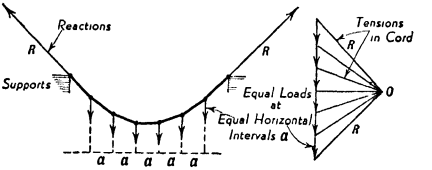


Figure 3 Suspended cable with equal loads, as in a suspension bridge

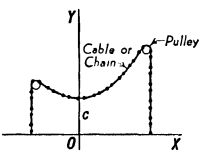


Figure 4
Tension of chain in catenary balances weight of chain hanging down to X axis

FUNICULUS. A cord Specifically 1 A structure attaching the alimentary tract of the **bryozoans** to the body wall 2 A slender segmented part of the antenna of some **insects,** just before its terminal segment 3 A bundle of nerve fibers in its sheath 4 Tracts of nerve fibers in the central nervous system of **vertebrates.** (A W L)

FUNNEL. 1 The tube leading out of the mantle cavity of the **squids** and related mollusks (**mollusca**) The siphon 2 The oral depression of **lampreys.** (A W L)

FUR. The fine soft hair of many mammals Also the pelt, the skin of the animal bearing the fur, especially when made up to be worn as a scarf

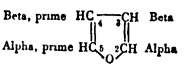
Fur shares with feathers the highest position as a protection against cold It owes this property to the insulating value of the layer of air held among the fine hairs that compose it. In many animals the vestiture

consists of a thick woolly under layer interspersed with longer and heavier hairs which form a smooth surface

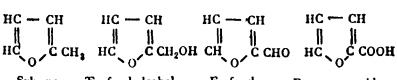
The best furs are those of animals which live in the colder latitudes and especially the semi-aquatic species Sea otter of the northern Pacific produces the most valuable fur and mink and muskrat are examples of moderately valuable and low-priced furs Fox and skunk are among the commercially important terrestrial species All of these animals should be taken in the winter to furnish durable pelts Summer fur is not only thinner but separates readily from the skin

The preparation of fur for the market now involves so many processes, such as plucking, shearing, and dyeing, that only an expert can judge skins dependably Trade names add to the confusion and give false dignity to many furs of very modest worth Many of the seals on the market, for example, are clipped and dyed muskrat or rabbit fur (A W L)

FURANE AND RELATED COMPOUNDS Furane (C_4H_4O) contains a ring of 1 oxygen and 4 carbons, with 1 hydrogen attached to each carbon:

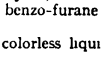


Furane is a colorless liquid, boiling point 32° C, insoluble in water, soluble in alcohol or ether Furane vapor produces a green coloration on pine wood moistened with **hydrochloric acid** Furane may be made from mucic acid ($COOH(CHOH)_4COOH$) by dry distillation into pyromucic acid (C_4H_3O COOH) and then heating the latter under pressure at 270° C Furane derivatives are known, namely, methyl, primary **alcohol, aldehyde, carboxylic acid,** in which the group attachment is at carbon number 2

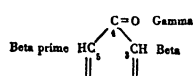


Sylvane, Alpha methyl furane, boiling point 65°C. | Furfuryl alcohol, Alpha furyl carbinol, boiling point 170°C (750 mm.) | Furfuryl "furfurol," Alpha furfuraldehyde boiling point 160°C (740 mm) | Pyromucic acid, furoic acid, furane alpha-carboxylic acid, Melting point 133°C boiling point 230°C

(See **Furfuraldehyde.**)

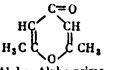
Coumarone is benzo-furane (C_8H_6O or C_6H_4CH CHO or), colorless liquid, boiling point 173° C, and diphenylene oxide is dibenzo-furane ($C_{12}H_8O$ or C_6H_4 C_6H_4 or ) white solid, melting point 81° C, boiling point 288° C

Gamma-pyrone (C_5H_4O O(4)) is a gamma-ketone (4) containing a ring of 1 oxygen and 5 carbons with 1 hydrogen attached to each of 4 carbons, namely, 2,3,5,6,

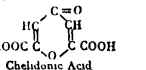


Gamma-pyrone is a colorless liquid, melting point 32° C, boiling point 218° C.

Pyrone derivatives are known, e g,



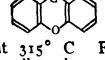
Alpha, Alpha prime dimethyl gamma-pyrone



Chelidonic Acid Gamma pyrone alpha, alpha prime dicarboxylic acid

Chromone is benzo pyrone ($C_9H_6O_2$) or white solid, melting point 59°C, and chromane is colorless liquid, boiling point 214°(750 mm.)

Flavone is phenyl chromone, melting point 97°C. white solid

Xanthone is dibenzo pyrone ($C_{13}H_8O_2$ or C_6H_4 C_6H_4 or white solid, melting point 174°C, boiling point 351°C., and Xanthene is  white solid, melting point 100° C, boiling point 315° C From chromone and xanthone a number of yellow dyes are made, which dyes also occur in nature Such dyes are chrysin, fisetin, buteolin, morin, quercetin, rhamnetin

Where oxygen of furane is occupied by sulfur, thiophene is the compound, and of coumarone, benzothiophene, and where oxygen of furane is occupied by nitrogen (group —NH), pyrrole, and of coumarone, indole (R K S)

FURCA. A pair of divergent projections at the caudal end of the body of some **crustaceans.** (A W L)

FURCULA The jumping appendage of a spring tail **Collembola.** (A W L)

FURFURALDEHYDE. Furfuraldehyde (C_4H_3O CHO(2)) is a colorless, odorous liquid, boiling point 162° C When pentoses, e g, arabinose, xylose (See **Carbohydrates**), are heated with dilute **hydrochloric acid,** furfuraldehyde is formed, recognizable by deep red coloration with phloroglucinol, or by the formation, with **phenylhydrazine** of furfuraldehyde phenylhydrazone (C_4H_3O CH $NNHC_6H_5$), solid, melting point 97° C Furfuraldehyde is formed by the treatment of corn-cobs, bran, or wood, with **sulfuric acid,** and can be used in many instances where **formaldehyde** is utilized, as a disinfectant, insecticide, and for a raw material for the manufacture of synthetic plastics and resins, also as a solvent for organic substances, and to prepare furfuryl alcohol (C_4H_3O $CH_2OH(2)$) and furoic acid (pyromucic acid, C_4H_3O COOH(2)) for furoates (R K S)

FURNACE A furnace may be said to be a chamber for **combustion.** In addition, it provides support and enclosure for the firing equipment and partial enclosure for the **boiler.** It surrounds the region where the combustion reaction takes place, confining and isolating it so that it remains a controlled force

The furnace is a relatively important component of any plant The success of a boiler installation is so dependent upon the furnace which serves it that the importance of correct furnace design can not be overemphasized The furnace converts the latent chemical energy of raw fuel into a dynamic form (heat)

There are many interesting, puzzling, and difficult problems in the field of furnace design Even when this field is limited to boiler furnaces finds a great variety of service conditions calling for an equally great variety of applications Many of the questions which arise have already been answered by scientific testing and by experience, but some points are still met by the liberal allowance method Since no part of a power plant has been developed as rapidly during the last decade as has that part having to do with combustion, it is natural that

furnace design, as an art, should have taken rapid strides.

The design of a furnace can not be carried out independently of other equipment, for its success will require coordination of several important factors, among which may be mentioned

1 Type of combustion equipment
2 Character of the fuel used, especially its ash content
3 Draft equipment employed
4 Air supply and degree of preheating
5 Boiler, and its baffling arrangement

In former years, especially when steaming equipment had been standardized for a time, and before pulverized coal firing had inspired the remarkable progress in combustion that it has, furnaces were customarily designed on the basis of certain volumetric requirements per boiler horsepower. This method related furnace volume to heating surface, and naturally became inadequate when this heating surface, under the stress of improved methods of firing coal, was required to transfer several times the heat it formerly did

With boiler ratings creeping up to three or four hundred per cent nominal capacity, furnace volumes have come to be based on heat liberation, meaning the number of B T U produced per hour per cubic foot of furnace volume To fix upon furnace dimensions by this method requires only the division of the hourly heat liberation by some acceptable volumetric rate This rate is not deductible from theory, but fortunately numerous data are available as to rates actually employed in successful designs The data of Brooks are specific and well accepted as far as pulverized coal furnaces are concerned To these the writer has added, in the accompanying table, values representative of conservative practice with other fuels

TABLE FOR CALCULATING HEAT RELEASE OF FURNACES

Design values in B T U per cubic foot per hour

For Pulverized Coal			
Ash Fusion Temperature	Below 2100° F	2100-2400° F	Above 2400° F
Solid refractory	Never used	12,500	15,000
Air-cooled refractory	12,000	15,000	17,500
Water-cooled bottom	16,000	17,500	20,000
Water walls	17,500	22,000	30,000
For Lump Coal			
Stoker firing	Very large plant		30,000–45,000
Stoker firing	Large plant		20,000–30,000
Stoker firing	Small plant		15,000–25,000
For oil or gas			25,000–50,000

Range for lump coal given to cover various ranks of coal and wall types Low ranks of coal take the lower release value Water-cooled walls permit the higher release values

There is much to be said for both theory and experience in furnace design The heat release method is hardly theoretical, but represents an enlightened approach compared with the older methods When leaving long established practices behind, and in pioneering installations, experience may usefully be employed to season theory and computation In employing the heat release data, care should be exercised to eliminate dead gas spaces and ineffective regions If ineffective regions are unavoidable, they should be excluded from the volume indicated by the above type of example Generally, wide and shallow furnaces are superior in effective volume to deep narrow ones

Furnaces classified according to their wall construction are (1) solid refractory, (2) air-cooled refractory, (3) water-cooled, either totally or partially,

Recent progress in this field, stimulated by the introduction of high capacity firing, has greatly increased our knowledge of the part played by radiant energy in the furnace Radiant energy reverberates back and forth in the furnace until gases are at their final flame temperature because flame is opaque to radiation If cold black surfaces such as water walls are met in the process of reverberation large amounts of high-level energy will be absorbed, less will be reverberated to the flame whose temperature will, in consequence, be less It is well established that a heat transfer of approximately 75,000 B T U per square foot per hour is realized Not only water walls, but water screens and those portions of the boiler heating surface that "see" the furnace, absorb radiant energy (F T M)

FURUNCLE. A boil. A localized infection of the skin and subcutaneous tissues occurring singly or multiply The usual infecting agent is the *Staphylococcus* (R S M)

FUSAIN. A term proposed by Stevenson in 1911 for what had previously been called "mineral charcoal" or "mother of coal" The highly oxidized cellulose and blackened woody fibers which form an important constituent of most true coals (R M F)

FUSE. A fuse is a common protective or circuit breaking device for low voltage electric circuits It is an over current protector, and since the current must first heat the metal, there is a time delay in fuse "blowing" that is inversely proportional to the current This characteristic is called "inverse time element" The ordinary fuse consists of a calibrated length of conductor whose resistance is so chosen that when a certain current flow through it is exceeded, it fails to lose by radiation enough of the resistance heat to keep its temperature below melting The fuse is enclosed in a protective case which forms the contact points to connect it into its circuit Sometimes the case contains a powder which helps to extinguish the arc which follows the blowing of the fuse element in high capacity fuses Sometimes, also, the case is provided with a glass cover, which allows one to discover at any time the integrity of the fuse Fuses for 110 volt house circuits usually take a form of a plug which can be screwed into a socket They are standardized at 5, 10, 15, 20, 25, and 30 amperes Cartridge type fuses have been standardized with ferrule contacts up to 60 amperes, and knife contacts above that There are a number of other types, such as expulsion fuses, thermal overload fuses, etc, that are not discussed here The National Electric Code specifies that if fuses are used for motor protection, their capacity must not exceed 125% of the name plate rating of the motor The detonating device on a shell is a fuse as is the powder-filled cord used in setting off any charge (F T M)

FUSELAGE. The fuselage is the principal structural member of an airplane, serving the purpose of housing the crew, passengers, and load, supporting tail surfaces, and being attached to the wings. To the extent that it is possible to do so in keeping with the other purposes for which it is intended, the fuselage should have a streamlined shape In construction, the fuselage may be made of triangularly framed structural members of tubing or other metal shapes, which are riveted, welded, or bolted together at the joints, and so loaded as to experience co-axial loads In this construction there are four main longitudinal members called the longerons, which really form the "backbone" of the airplane Roughly, these are the edges of a long, tapered box The longerons are properly spaced from each other, and rigidly braced on four sides with shorter web members Reinforcement is necessary at the points of attachment of landing gear, engine, and wings Another fuselage construction is known as monocoque, a variation of which is the semi-monocoque Monocoque construction is possible

with both plywood and sheet metal. Essentially, a monocoque fuselage is a hollow tube, and derives its strength in exactly the same way as a tube subjected to transverse bending (F.T.M.)

FUSEL OIL. Alcohols.

FUSION. A change from the solid to the liquid state of matter. In crystalline bodies, and, we are beginning to understand, also in many other solids not exhibiting well defined **crystal structure,** the atoms are held in positions of stable equilibrium by intermolecular forces. They of course move with thermal agitation, but their movements are oscillatory and do not carry them outside a limited range of distance from their equilibrium positions Stable equilibrium may, however, become unstable when the system is disturbed beyond a certain limit. Thus if a solid body is sufficiently heated, the molecules break loose from their stable configuration and wander about or diffuse among each other. When this condition has become general, the body exhibits the characteristics of a liquid, and we say it has undergone fusion. In some cases, such as ice, the change is quite abrupt, the substance having a well defined **melting point;** in others, like glass or pitch, it is gradual. The difference is probably due to the more uniform potential energy of the atoms in the former case, so that they all "break loose" at the same stage of thermal agitation, while in the latter case some atoms require more energy to dislodge them than others In any case the process requires a supply of energy which is recognized as the **heat of fusion.** With most substances, fusion is accompanied by an increase in volume, but with some, like ice, the volume becomes definitely less. (L.D.W.)

G

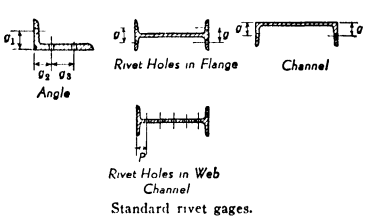
GABBRO. Gabbro is a deep seated and often very coarse grained **igneous** rock composed of **plagioclase feldspar,** usually **labradorite** or **bytownite** and **monoclinic pyroxene** with occasionally as accessories **olivine** (when it is then called olivine gabbro) **biotite, magnetite, ilmenite** and **hornblende. Norite** is a variety of gabbro carrying **orthorhombic** pyroxene, usually **hypersthene** instead of the monoclinic sort. **Troctolite** is essentially olivine and plagioclase. **Quartz** gabbros are known and have probably been derived from **magmas** somewhat oversaturated with **silica.** On the other hand **essexites** represent gabbros whose parent magma doubtless had an insufficiency of silica resulting in the formation of **nephelite.** Gabbros are frequently rich in sulphides that may be of commercial value, a notable occurrence of which is at Sudbury, Canada Here a norite carrying **chalcopyrite** and nickeliferous **pyrrhotite** forms the most important deposits of nickel known Gold, silver and platinum are also recovered from this ore. (E S C S.)

GADOLINIUM. Symbol: Gd. Atomic number: 64. Atomic weight: 157 3 Type of compound Gd_2O_3. Color of salts: Colorless Discovered by Marignac in 1886 A member of the **cerium** sub-group of the rare earth metals (R K S)

GADWALL. Aves, Anseriformes A North American **duck,** *Anas strepera* (A.W.L)

GAGE. A gage is an instrument or device the purpose of which is to measure some physical characteristic, such as pressure, temperature, water level, etc, or which measures dimensions, force, etc The term is usually, though not always, confined to instruments which have a mechanical principle of operation Electrical measuring devices are usually called instruments See **Pressure Gage, Electrical Instruments.** (F T M)

GAGE LINE. A gage line marks the limits of any standard distance used repeatedly Structural steel shapes are punched or drilled for rivets on lines called gage lines



Standard rivet gages.

as indicated in the accompanying figure. Structural handbooks contain tables giving the numerical value of these gages for different sizes of structural shapes. The gage lines may be varied to suit the details as long as the minimum required edge distance and clearance for punching, drilling, or riveting is maintained. In some fabricating shops the rivet holes in the webs of beams and channels are made with multiple punches or drills. (C.W C, F T M)

GAGE NUMBERS. In the metal trades, the word gage is used to describe thicknesses of sheets of thin metal products. Such systems are used also in connection with relatively small or light metal products, such as wires, sheets, rods, strips, etc. The use of a series of numbers, constituting a certain gage, to describe the thickness or diameter of metal sheets and wires would be very much more satisfactory if there were fewer different standard gages. However, there are several gages having a different thickness for a given gage number, so that a certain amount of experience in the usually accepted gage system is necessary before gage numbers have much usefulness. The accompanying table shows the dimensions of sizes of different gage systems in decimal parts of an inch. The table does not show the tin plate gage. Tin and terne plate are sized in pounds per base box of sheets, aggregating 31,360 square inches.

Different Standards for Wire Gages in Use in the United States. Dimensions of Sizes in Decimal Parts of an Inch.

Number of Wire Gage	American or B. & S.	Birmingham or Stubs' Iron Wire	Washburn & Moen, Worcester, Mass.	W. & M. Steel Music Wire	New American S. & W. Co.'s Music Wire Gage	Imperial Wire Gage	Stubs' Steel Wire	U. S. Standard Gage for Sheet and Plate Iron and Steel
00000000	....	..	.	0083				
0000000	.....	....	...	0087			....	
000000	.....	..	.. .	0095	004	464		46875
00000	. .. ..	..	.	010	005	432	..	4375
0000	.460	.454	3938	011	006	400	....	40625
000	.40964	425	3625	012	007	372	.....	375
00	3648	380	3310	0133	008	348	..	34375
0	32486	340	3065	0144	009	324	..	3125
1	2893	300	2830	0156	010	300	.227	28125
2	25763	284	2625	0166	011	276	219	265625
3	22942	259	2437	0178	012	252	212	250
4	20431	238	2253	0188	013	232	207	234375
5	18194	220	2070	0202	014	212	204	21875
6	16202	203	1920	0215	016	192	201	203125
7	14428	180	1770	023	018	176	.199	1875
8	12849	165	.1620	0243	020	160	197	171875
9	11443	148	1483	0256	022	144	194	15625
10	10189	134	1350	027	024	128	191	140625
11	090742	120	1205	0284	026	116	188	125
12	080808	109	1055	0296	029	104	185	109375
13	071961	095	0915	0314	031	092	182	09375
14	064084	083	0800	0326	033	080	180	078125
15	057068	072	0720	0345	035	072	178	0703125
16	05082	065	0625	036	037	064	175	0625
17	045257	058	0540	0377	039	056	.172	05625
18	040303	049	0475	0395	041	048	168	050
19	03589	042	0410	0414	043	040	.164	04375
20	031961	035	0348	0434	045	036	161	0375
21	028462	032	03175	046	047	032	157	034375
22	025347	028	0286	0483	049	028	155	03125
23	022571	025	0258	051	051	024	153	028125
24	0201	022	0230	055	055	022	151	025
25	0179	020	0204	0586	059	020	148	021875
26	01594	018	0181	0626	063	018	.146	01875
27	014195	016	0173	0658	067	0164	143	0171875
28	.012641	014	0162	072	071	.0149	.139	015625
29	011257	013	0150	076	075	0136	.134	0140625
30	010025	012	0140	080	080	0124	127	0125
31	008928	010	0132	....	085	0116	.120	0109375
32	00795	009	0128	.....	090	0108	115	01015625
33	00708	008	0118	....	095	0100	112	009375
34	006304	007	0104	.....	.....	0092	110	00859375
35	005614	005	0095	.....	.....	0084	.108	0078125
36	005	004	0090	.....	.....	0076	106	00703125
37	004468	..	... ...	.....	.....	0068	103	006640625
38	003965	....	.....	.....	....	0060	101	00625
39	003531	..	... ..	.....	. .	0052	099	.
40	003144			....		0048	097	

The practice of specifying sizes by gage numbers originated in the necessity of manufacturers of employing a marking scheme to designate the different sizes which were produced, and there grew up a large number of gages Fortunately, there has been a considerable reduction in the number in use, but there remain more than are actually needed The one thing that the gage systems have in common, is that they denote thickness in gage number, and the thinner sizes have the larger gage numbers. (F.T M.)

GAHNITE—ZINC-SPINEL. The mineral gahnite is **isometric** with an **octahedral** habit but may appear as **dodecahedrons** or modified cubes. Chemically it is **zinc aluminate** corresponding to the formula $ZnAl_2O_4$. There is a tendency for cleavage parallel to the octahedron, fracture varies from conchoidal to uneven, brit-

tle, hardness 7 5–8, specific gravity 4 –4 6, luster vitreous, color ranges from dark green through various shades of greenish or bluish black, yellowish black or grayish, subtransparent to almost opaque Gahnite is found in association with other zinc minerals at several European localities, notably in Bavaria and Sweden In the United States it is found at Franklin and Sterling Hill, New Jersey, at Rowe, Massachusetts and in Maryland, North Carolina, Georgia and Colorado Gahnite was named in honor of the Swedish chemist, J G Gahn (E S C S)

GALACTIC COORDINATES. As the modern theories regarding the structure of the sidereal **universe** became more and more firmly established, it became necessary to have a system of **spherical coordinates** for the representation of points relative to the plane of the **milky way,** or the **galactic plane.**

The galactic coordinate system is a system of spherical coordinates having as its fundamental plane the plane of the milky way (or galaxy) The adopted position of the pole of this plane is 12^h 40^m **right ascension** and 28° north **declination** The plane of the milky way cuts the plane of the celestial **equator** at an angle of 62° Galactic latitude is measured perpendicular to the plane of the galaxy along great circles drawn through the galactic poles and hence perpendicular to the galactic plane Galactic longitude is measured in the plane of the galaxy from the point where this plane cuts the plane of the equator in right ascension 18^h 40^m to the point where the great circle perpendicular to the galactic plane through the object intersects the galactic plane (W K G)

GALACTIC SYSTEM Milky Way.

GALAGO Mammalia, Primates The African **lemurs** The several species are long-tailed animals whose nearest relatives are the mouse lemurs of Madagascar (A W L)

GALAXY. Milky Way.

GALEA. Maxilla.

GALENA The mineral galena, **lead** sulfide, PbS, crystallizes in the **isometric** system, usually in cubes or cube-octahedron combinations, less frequently in **octahedrons** It is often found in cleavable masses, but may be granular or fibrous The highly perfect cubic cleavage is an important characteristic of this mineral, it may, however, sometimes show an octahedral parting Its hardness is 2 5, specific gravity, 7 3–7 6, luster, metallic, color, lead gray, streak, grayish black, opaque Galena is the most important ore of lead and in addition often carries values of **silver,** it is then known as argentiferous galena It occasionally is actually mined as a silver ore Sometimes galena contains small amounts of **zinc, cadmium, antimony, bismuth,** and **copper** as sulfides Galena is a very common and widely spread mineral, it occurs in veins and beds in various rocks, both crystalline and sedimentary Some of these deposits are doubtless replacements, others seem to show a close connection with intrusive igneous rocks Of the many foreign localities might be mentioned the classic one at Freiberg, Saxony, and the silver mines of the Harz Mountains This mineral has been found in the lavas of Vesuvius, in Italy, and fine specimens come from Cornwall and Cumberland, England Australia, South America, Chile, and Peru produce galena In the United States, Missouri, Illinois, Iowa, and Wisconsin contain large and important galena deposits In Colorado and Idaho it has been mined for its silver content Galena is usually associated with **sphalerite, smithsonite,** and at **Phoenixville,** Pennsylvania, with beautiful **pyromorphite** crystals The name is derived from the Latin *galena,* a term which was applied both to the lead ore and slag from refining (E S C S)

GALILEO (1564–1642). Galileo Galilei was born at Pisa on February 18, 1564 His father was a noble Florentine who had received an excellent education and had started life as a scientist Having become discouraged with the lack of interest shown by others in his scientific pursuits, he had turned to the textile trade He desired to have Galileo continue in this business and gave him a good elementary education Galileo indicated in his early career a fondness for poetry and music and his father, recognizing his genius, sent him to the University of Pisa At the University Galileo studied medicine, and while there noticed that the period of swing of a **pendulum** was proportional to the length of the pendulum itself and was apparently independent of the arc through which the pendulum was swinging He invented a so-called pulsimeter by means of which the period of beat of the human pulse was measured in terms of the length of a pendulum cord His studies in connection with the pendulum led him to a study of the works of Euclid and Archimedes, and from that time on Galileo could not be kept at his medical studies In the course of his studies at the University he read the forbidden works of Bruno and became very interested in the **Copernican** theory

At the age of twenty-six he was appointed Lecturer in Mathematics at Pisa While at Pisa he started in on the study of **falling bodies** and proved that the rate of fall is independent of the mass and of the path which the body takes, neglecting the friction of the air This statement was contrary to the Aristotelian doctrine and, upon defending his own thesis against that of the Aristotelians at Pisa, he became exceedingly unpopular in his native city and in 1592 accepted a professorship at Padua

During the early part of his stay at Padua, Galileo invented a thermometer While here he renewed his interest in astronomy, and for a while seems to have abandoned the Copernican theory in favor of the **Ptolemaic** In his attempt to decide between the two hypotheses he wrote to **Kepler** at Prague, and the correspondence between these two worthies developed into a warm friendship

The news of the invention of the **telescope** early in 1609, by Hans Lipperschey in Holland, spread rapidly, and by August of that year Galileo had built an instrument of his own on the Dutch pattern He immediately applied the telescope to astronomical research, and in January, 1610, announced the discovery of the **satellites** of **Jupiter** He made numerous other discoveries with his telescope, among which may be listed the **phases** of **Venus, sun spots,** and **nebulae** He also noticed changes in the appearance of **Saturn,** but the definition and resolving power of his instrument were not sufficiently good for him to determine the real character of the rings

While carrying on his astronomical observations, Galileo also worked in a variety of other fields of research in the physical sciences He determined the velocity of sound and attempted to prove that light also traveled with finite velocity The study of the period of the pendulum was continued and Galileo passed on to his son instructions as to a method of construction of a pendulum clock In the field of Hydrostatics he developed a method for determination of **specific gravity,** and in the study of Pneumatics he not only proved that air actually had mass, but determined the ratio between the masses of equal volumes of air and water

In 1610 Galileo left Padua and went to Florence After his discovery of the phases of Venus, which had been predicted but not observed by Copernicus, Galileo became convinced of the validity of the Copernican hypothesis He proceeded with great caution for many years, for he was well aware of the opposition of the Church, but in 1632, perhaps placing too much assurance in his friendships with Pope Urban VIII and with the Duke of Tuscany, he published his famous dialogues comparing the Ptolemaic with the Copernican theory This book was passed by the Censor before publication but was placed upon the forbidden list immediately after appearing and the storm burst upon Galileo with great violence For a time he stood out against the Church,

but finally surrendered and wrote and signed a recantation.

Following his recantation Galileo was released from prison and lived in seclusion in Arcetri near Florence, accompanied by his two disciples Viviani and Torricelli. During this period he did a great deal of writing, but could not get his books published, since all of his writings were banned by the Church. In 1639, probably as a result of his treatment by the Inquisition, Galileo became totally blind. During his period of retirement he was visited by the poet Milton, whose Samson Agonistes may be regarded as embodying the tragedy of the blind Galileo as well as of Milton himself. Galileo died in 1642, the same year in which **Newton** was born. (W.K.G.)

GALL. Gall is the secretion of the **liver** of vertebrates, also called bile.

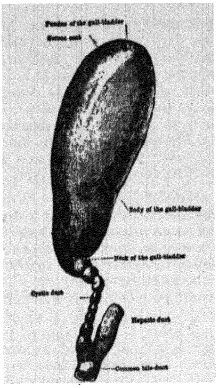
Galls are abnormal outgrowths in plants caused by plant or animal **parasites,** which attack various parts of the plant. While no part of the plant is immune, galls most frequently occur in those regions composed of actively growing **cells,** such as the leaves, or the cortical tissues of the stem, or young roots. The irritation caused by the parasite may result in a tremendous **hypertrophy** of all cells affected or may cause numerous cell divisions which result in tremendous increase in the affected tissues.

The organisms which cause gall formation are many. **Nematode worms** often enter the roots of plants and cause the formation of irregular tumorous growth. These same organisms often infect the larger brown **algae** and cause hypertrophies, or at least gall-like malformations. Many parasitic **fungi** cause galls to form in the tissues which they attack. Galls occur in the leaves and stems of blueberry and cranberry bushes, due to fungus infection by *Exobasidium vaccinii,* a **basidiomycete.** The **hyphae** of the fungus penetrate the cells of the host, which enlarge tremendously in consequence. All **chlorophyll** in these enlarged cells is destroyed, and a red pigment forms, causing the galls to appear very conspicuous. Several species of *Taphrina,* a fungus of the **ascomycete** group, cause galls in the leaves of many plants. Those caused by *Taphrina aurea* in the leaves and fruits of poplar trees are especially common. Many **rusts** also cause gall formation.

However, probably the most striking and best known galls are caused by insects. (See **Gall-Wasps and Gall-Gnats.**) A gall-producing insect lays its eggs in the tissues of the plant. Apparently as a result of the irritations caused by the young **larvae,** the surrounding cells become greatly enlarged, and the gall is formed. The galls caused by each species of insect have a very characteristic shape. The leaves and stems of rose bushes, for example, are frequently infected. One insect causes a smoothly spherical gall to form; the gall produced by another is similarly shaped but studded with stiff spines; while a third causes the formation of a dense growth of matted, branched hairs, forming a structure an inch or more in diameter. Within there may be a single insect larva, or many, feeding on the loose **parenchymatous** inner tissues of the gall and protected from enemies by the firm outer layers. Often the young buds of willow twigs are parasitized, causing bud galls to form. As the bud grows older, the internodes enlarge tremendously in diameter but elongate very little, so that a gigantic bud is formed.

The leaves of oak trees are very commonly parasitized by gall-forming organisms, both fungus and insect. Considerable value attaches to these galls, because of the large accumulation of **tannin** occurring in the developing gall. In countries where cheap labor is available these galls are gathered in quantities. They are used in tanning leather and in the manufacture of ink. (R.M.W., A.W.L.)

GALL-BLADDER. A pear-shaped organ (see accompanying figures) situated on the under side of the **liver**



The gall-bladder, moderately distended, with the cystic duct and the junction of the latter with the hepatic duct to form the common bile-duct. (Toldt.) (From Kimber and Gray, *Textbook of Anatomy and Physiology,* Macmillan & Co.)

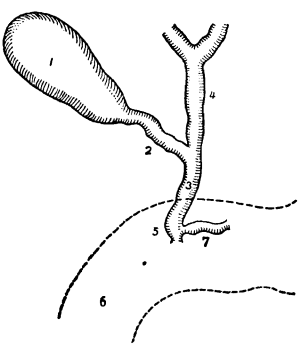
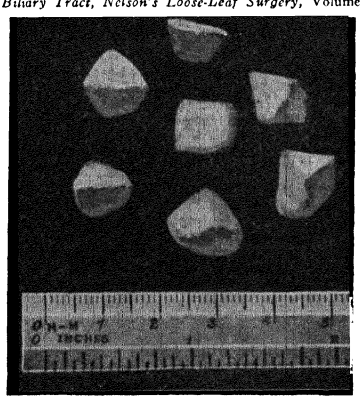


Diagram of biliary tract. 1, gall-bladder; 2, cystic duct; 3, common bile duct; 4, common hepatic bile ducts from liver; 5, splinter at opening of bile ducts into the duodenum; 6, duodenum; 7, duct from pancreas. (Whipple, A. O., *Surgery of the Biliary Tract, Nelson's Loose-Leaf Surgery,* Volume 5.)



Cholesterin-bilirubin-calcium stones, outer layer pure cholesterin. (From the *Nelson Loose-Leaf Surgery,* Thomas Nelson & Sons.)

on the right side just below the lower ribs. It serves as a reservoir for the **bile** and by means of the cystic duct it communicates with the common duct through which the bile secreted by the liver passes to the **duodenum.** The gall-bladder is about 3 inches in length and 1–1¼ inches in diameter It holds about 1½ ounces of bile When fatty substances are eaten, the normal gall-bladder empties the stored, concentrated bile into the common duct, and upon passing into the duodenum the bile aids in the **digestion** of the **fat.**

The gall-bladder under certain conditions is subject to acute and chronic infections (**cholecystitis**) and to stone formation (**cholelithiasis**) Under these conditions its function is lost and, becoming the source of infection to the body, is then removed (cholecystectomy) No ill effects follow the removal of the gall-bladder, as the common duct serves as a reservoir in its place (R S M)

GALL GNAT. Insecta, Diptera Small two-winged **flies** of many species constituting the family Cecidomyiidae Most are plant feeders as larvae and produce **galls** on the plants that they attack Others are predacious or scavengers (A W L)

GALLIFORMES. The order of birds (**Aves**) containing the more common domestic species and many game birds, such as the **quails, pheasants,** and **grouse** They are predominantly ground birds although they may fly strongly for short distances and may roost in trees (A W L)

GALLINULE Aves, Gruiformes Wading birds related to the **coots** and **rails** (A W L)

GALLIUM. Symbol Ga Atomic number 31 Atomic weight 69 72 Density 5 89 Melting point 29 75° C Boiling point 1700° C

Gallium is a white, tough metal, soft enough to be cut with a knife, fresh surface soon oxidized superficially to bluish-gray, burns in air upon being heated to 500° C The temperature range at which gallium is a liquid permits its use as a substitute for mercury in high-temperature thermometers Gallium metal is only slightly affected by water at room temperature, but reacts vigorously upon boiling, dissolves in **hydrochloric acid** and in **sodium** hydroxide, reacts vigorously with chlorine at room temperature Discovered by Boisbaudran in 1875

Gallium occurs in very small amount in **zinc blende, magnetite, pyrite, bauxite,** and **kaolin** of certain localities A few parts per million is present in Oklahoma zinc ores The recovery of gallium from zinc flue dust is effected by solution of the dust in excess of **hydrochloric acid,** addition of potassium chlorate, and distillation to remove **germanium** When the residue is converted into sulfate, fractional electrolysis of the slightly acid solution removes **zinc,** and the gallium is obtained almost free from **indium**

Hydroxide Gallium hydroxide ($Ga(OH)_3$), white, gelatinous precipitate by reaction of **ammonium** hydroxide on gallium salt solutions, precipitate is soluble in **sodium** hydroxide to form sodium gallate

Oxide· Gallium oxide (Ga_2O_3), white solid, infusible at red heat, obtained by ignition of gallium nitrate or hydroxide

Salts Gallium sulfate ($Ga_2(SO_4)_3$), nitrate ($Ga(NO_3)_3$), and chloride ($GaCl_3$, melting point 76° C) are white, soluble in water, and upon boiling the solution a basic salt is precipitated Gallium dichloride, gallous chloride ($GaCl_2$), melting point 164° C (R K S)

GALLOTANNINS. Tannins.

GALL WASP Insecta, Hymenoptera A minute **insect** whose attack on plants produces **galls** They are of many species, making up the subfamily Cynipinae (A W L)

GALVANIZING. A process wherein iron the yield protected from the corrosive effect of moistu the air, by applying to it a coating of **zinc,** is know kerosene, vanizing A very thin coating of zinc evenly age deover the whole surface of iron sheets, wires, etc acking serve to prevent its destruction by rust, or at lea ase," extend its life beyond that which it would have if un goes tected Zinc used as a protective coating has the vantage that it is positive with respect to iron, and when the zinc coat is scratched or broken, and moistur penetrates, it is the zinc that is corroded first, giving rise to a growth of zinc oxide which will protect the iron unless a considerable area has been exposed Zinc is reasonably cheap, and may be obtained in ample quantities

The two methods of galvanizing iron and steel are known as the hot galvanizing method and the electro-galvanizing method Most commercial galvanizing is done by the hot process, as it is cheaper, and, in general, as satisfactory as electro-galvanizing In the hot galvanizing process, the stock to be galvanized is first annealed and then cleaned in a pickling bath of hydrochloric acid After rinsing in hot water, the stock is immediately passed through a bath of **flux,** such as zinc chloride, or sal ammoniac, the purpose of which is to prevent rusting of the stock when it is dried, and to aid the reaction between zinc and iron The stock is now ready for the application of molten zinc, or "spelter," as it is called This is contained in a spelter pan of such size as is required for the galvanizing operation undertaken The pan is supported on a brick setting and directly fired from below The stock is dipped in the molten zinc for sufficient time to permit the zinc to alloy with the surface of the iron so that a coating of zinc will remain on the stock when it is withdrawn from the spelter pan The excess zinc is allowed to drip from the galvanized stock, or is mechanically wiped from it The galvanizing operation is now complete except for cooling the stock and cutting it into sheets, wrapping it on reels, or otherwise preparing it for commerce

Electro-galvanizing is carried out in a plating vat, usually made of wood In one portion of this vat are bus wires, to which the positive of the plating circuit is connected The vat is filled with an **electrolyte** of some zinc salt Zinc sulfate is frequently used The stock to be plated is suspended in the electrolyte by metallic supports which are connected to the negative of the plating circuit Current is supplied from a special plating generator, and the circuit is completed through the electrolyte, decomposing it and plating the zinc on the cathodes, which are the pieces being galvanized Preparations prior to electro-galvanizing are similar to those in hot galvanizing (F T M)

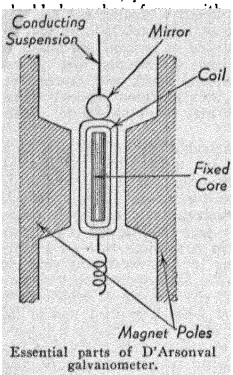
GALVANOLUMINESCENCE. Luminescence.

GALVANOMETERS. A galvanometer is an instrument for measuring electric currents, usually by means of their magnetic effect Observations are made by noting the deflection produced by the reactive **torque** exerted between an **electric circuit** and a magnet Galvanometers may be divided broadly into two classes, according to whether the coil is stationary and the magnet turns, or *vice versa*

Perhaps the most highly developed of the first type is the Kelvin astatic galvanometer This has two magnets equally magnetized but antiparallel mounted on the same suspension, one above the other, and each magnet is surrounded by a coil The two coils are joined in series and are oppositely wound, so that a current through them will turn their respective magnets in the same direction The earth's field has no effect upon such an astatic pair of magnets, but there is a large control magnet, placed above the pair, against whose field the current turns the suspended system The movement is observed by the usual mirror-and-scale or opti-

cal lever device. Galvanometers of this type are now little used in accurate work.

Among galvanometers of the second type, that of d'Arsonval is best known. The magnet in this instrument is a fixed, permanent magnet of the horseshoe or



Essential parts of D'Arsonval galvanometer.

Essential parts of D'Arsonval galvanometer.

a light, rectangular coil suspended in the strong field between its poles, the suspension carrying the feeble current. The current causes the coil to turn in the field. Often a fixed iron core is supported inside the movable coil to concentrate the field.

If these galvanometers are undamped, they will give a "throw" when a charge of electricity is sent through them, and the charge can be thereby measured. Such an instrument, with a heavy coil, called a ballistic galvanometer, is useful in capacitance measurements. The oscillations may be damped by shunting.

There are also string galvanometers, in which a straight, slender wire carrying the current is thrust to one side by a magnetic field; and vibration galvanometers, in which the string vibrates in resonance with the alternating current traversing it. (L.D.W.)

GAMBOGE. Garcinia. Guttiferae.

GAMETANGIA. Gamete.

GAMETE. A sexual reproductive cell or **germ cell** which normally unites with another to produce a new individual.

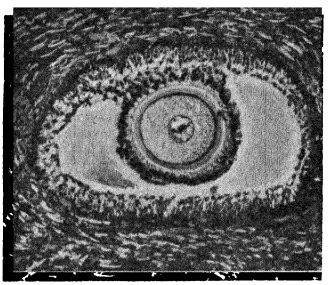
The gametes of some primitive organisms are of one form; all are single cells which swim about in the water. Such organisms are said to be isogamous and the germ cells are called isogamous. In most species, however, only the male gametes retain the power of locomotion. The female gametes are larger inert cells and the organisms are called heterogamous. The male cells of these species are known as sperms or spermatozoa and the female cells as ova or eggs. Because of its size the male gamete is also known as a microgamete, and the female gamete as a megagamete.

The union of two unlike gametes (heterogametes) is called heterogamy. The cell which is formed by the union of two gametes is called the zygote; from it new plants are formed. The cells in which gametes are formed are called gametangia. In heterogamous plants, the gametangia containing sperms are called antheridia; those containing eggs, either oögonia or achegonia. (In rare cases, a gamete does develop without two gametes having previously united.)

The development of two forms of gametes permits both the freedom of movement necessary to bring the two cells together for **fertilization** and the storage of the **protoplasm** and food necessary for the development of any body of reasonable size and complexity to a stage in which it can secure more materials for itself. By the delegation of one function to each kind of cell neither is subject to harmful restriction.

In most species of animals the sperm is a minute cell with a slender **flagellum** or tail whose undulating movements propel it through the water or the seminal fluid. The main part of the sperm is the head, which contains an apical body and the **nucleus**. Behind the head is a neck, or a middle piece of more complex structure, from which the sperm aster involved in the fertilization process sometimes develops. The sperms of some **worms** and **arthropods** lack the flagellum although many bear processes of other kinds. They are much less motile than flagellate sperms but they are said to move slowly by amoeboid action or by means of their processes.

Ova are more compact cells, often spherical in form. They contain abundant **cytoplasm** and in many species an enormous amount of food material (yolk, deutoplasm), as in the egg of a bird. Here the yolk is the egg cell or **ovum** proper but the living protoplasm is a tiny mass at some point on its periphery. Ova may also have special envelopes such as the albumen or white


Graafian follicle and ovum of the cat, within the ovary. (Photograph through the courtesy of Dr. B. F. Kingsbury.)

of the bird's egg, the shell membrane, and the shell. Insect eggs are enclosed by a shell called the **chorion** which is often beautifully sculptured and strangely shaped. Where such coverings occur, a minute opening, the micropyle, sometimes provides an entrance for the sperm. (A.W.L., R.M.W.)

GAMETOGENESIS. The formation of **gametes**. In animals usually accompanied by **meiosis**. (A.W.L.)

GAMETOPHYTE. One of the two **generations** which **alternate** with each other in the life-history of many plants is called the gametophyte generation. It is the generation in which the gametes or sexual cells are formed, and so is frequently called the sexual generation. The cells of plants in this generation have the reduced or haploid number of **chromosomes**, which is half the number found in cells of plants of the sporophyte generation. (R.M.W.)

GAMMA. a). The one-millionth part of a gram. b). a unit of magnetic field intensity.

GAMMA FUNCTION. The gamma function is a certain type of mathematical function which is met in advanced parts of **Calculus**; it is a **transcendental function**. The **infinite integral**

$$\Gamma(\alpha) = \int_0^\infty x^{\alpha-1} e^{-x} dx$$

converges for all positive values of α, and defines a **function** of α which is called the gamma function.

A few of its important properties are:

$$\Gamma(\alpha + 1) = \alpha\Gamma(\alpha),$$

$$\Gamma(n)\Gamma(1 - n) = \frac{\pi}{\sin n\pi},$$

$$\Gamma(\tfrac{1}{2}) = \sqrt{\pi},$$

$\Gamma(n+1) = n!$ when n is a positive integer.

Tables of values of the gamma function are published. (L.L.S.)

GAMMA RAYS. Gamma rays are **x-rays** of short wave length emitted by **radioactive** substances. (R.K.S.)

GAMONT. An individual in the life cycle of certain one-celled animals whose subdivision produces **gametes**. (A.W.L.)

GANGLION. In zoology, a ganglion is a small mass of nervous tissue isolated from the central system but containing cell bodies as well as fibers. Many ganglia bear special names. The brain of many **invertebrates**, for example, is also called the **cerebral ganglion**, and the more numerous centers of the molluscan nervous system bear names, such as the visceral ganglia and the pedal ganglia. The dorsal root of each nerve arising from the vertebrate **spinal cord** bears a spinal ganglion and the sympathetic system contains numerous ganglia.

In pathology, a ganglion is a tense globular cystic swelling on the back of the wrist or the hand communicating with one of the tendon sheathes or nearby joints. It is filled with a thick gelatinous fluid and is caused by injury or low-grade inflammation. The treatment is by mechanical rupturing, aspiration with a needle, or by surgical excision. (A.W.L., R.S.M.)

GANGRENE. Local death of tissue due primarily to total interference with the blood supply to the area or part involved. It is characterized by **anesthesia** of the part, loss of function, change in color, lack of warmth, and in some cases, invasion by bacteria causing decomposition of the tissue with spreading infection.

Many disease processes may terminate in gangrene. Thus in cases of injury, severe crushing of tissues may destroy their viability by interfering with the circulation. Again, inflammation, when intense, may shut off circulation by thrombosis or clotting, or by strangulation of blood vessels. Gangrene may also result from arrest of circulation, however produced, as is seen in various diseases causing obstruction of arteries or veins, for example, severe hardening of the arteries (**arteriosclerosis**), and in **diabetes**, when the channels in the vessels gradually become obliterated. Raynaud's Disease and Buerger's Disease often show the same result. Chemical and physical agents, including **phenol**, or merely prolonged exposure to heat and cold, cause local death of tissue, just as does the prolonged constriction of a part. (R.S.M.)

GANGUE. The term gangue is used to refer to the non-valuable minerals associated with a metalliferous ore deposit. Commonly the gangue minerals are nonmetallics such as **quartz** or **calcite.** (R.M.F.)

GANISTER ROCK. This term was originally applied to a **siliceous** underclay occurring in certain **coal** beds in the north of England. Now it is often applied to highly siliceous, fine-grained rocks used for refractory purposes or to a mixture of ground **quartz** and **fire clay** used for furnace linings. (R.M.F.)

GANNET. Aves, Pelecaniformes. *Sula.* Large fishing birds (**Aves**) found on the seacoasts in the higher latitudes of both hemispheres. (A.W.L.)

GANOIDEI. A division of the fishes (Class **Pisces**) used in some classifications to include the orders **Chondrostei** and **Holostei.** (See also **Fossil Fishes.**) (A.W.L.)

GAP. In geology, a gap is an opening through a ridge connecting the valleys or lowlands on either side. Gaps may be formed by a river which earlier in the cycle of **erosion** was able to cut its way through the hard rocks now making up the ridge. If the stream is still flowing through this opening it is spoken of as a water gap, if the stream has disappeared because of its diversion or for other reasons it is then spoken of as a wind gap.

An electric gap is the distance separating two **electrodes** between which a **spark** or **arc** is caused to pass. Magnetically, a gap is the distance across an air gap separating two parts of a **magnetic circuit**. The clearance between pole pieces and rotor of **dynamo** machinery is such a gap.

In **aviation** a gap is a measurement used to describe the position of biplane wings. It is the distance between the upper and lower wings, measured from the mean aerodynamic **chord** of the upper wing to the mean **aerodynamic** chord of the lower wing. If the wings are staggered, the forward tri-section points of the mean aerodynamic chords are connected to determine the gap. The gap is frequently given in terms of the chord length, thus a biplane wing cellule might be said to have a gap of 80%, which would mean that the gap was 80% of the wing chord. A gap of 100% is a relatively large one, though not considered a rarity. Small gaps, as low as 40%, have also been used. Larger gaps yield wing arrangements which are more efficient, aerodynamically, but smaller gaps lead to trimmer airplanes due to the compact arrangement of wings. (R.M.F., F.T.M.)

GARCINIA. Mangosteen; Gamboge. Guttiferae. A genus of trees and shrubs found wild in the tropics of the Old World. The leathery leaves are simple and opposite, and contain numerous oil glands. The fruit is a berry. Several species bear edible fruits. *Garcinia mangostana* is the best known of these, the fruit being the famous mangosteen, considered by many to be the most delicious of all fruits. It has been introduced into tropical America.

Several species are tapped by cutting notches in the bark, through which **resin** exudes. This is the drug gamboge, a harsh cathartic, ordinarily mixed before use with other less violent drugs. (R.M.W.)

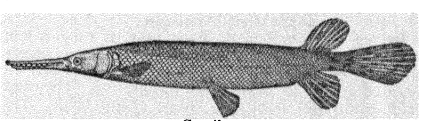
GARDENIA. Madder family.

GAREFOWL. Aves, Charadriiformes. The great **auk**, *Pinguinus impennis*, now extinct. (A.W.L.)

GARFISH. Billfish.

GARGANEY. Aves, Anseriformes. A **duck**, the summer **teal** of Europe. *Anas guerguedula.* (A.W.L.)

GAR, GARPIKE. Pisces, Holostei. Slender fishes (**Pisces**) with long, narrow jaws and sharp teeth. Three



Garpike.

species in the rivers and lakes of North America and one in Central America. The common garpike, *Lepisosteus osseus*, reaches a length of four feet, the short-nosed gar, *L. platystomus*, about three feet, and the alligator gar, *L. tristaechus*, as much as eighteen feet. They are of little value as food fishes. (A.W.L.)

Garial. (Courtesy of *N. Y. Zool. Society.*)

GARIAL, GAVIAL. Reptilia, Crocodilia. A large fish-eating **crocodile** of India with an extremely long slender snout. The name gavial is said to have been an error for the vernacular name garial but it is much the commoner term and is perpetuated in the scientific names of the genus and family. (A.W.L.)

GARLIC. Allium.

GARNET. The name garnet is now applied to a group of very important minerals crystallizing in the **isometric** system and showing the same habit of **dodecahedrons** and **trapezohedrons** They have the same general formulas, **orthosilicates,** and are to a limited degree **isomorphous** Many different elements are included in the several varieties of garnet as **calcium, magnesium, aluminum,** ferrous or ferric **iron, chromium, manganese** and **titanium** While garnets show no **cleavage** a dodecahedral **parting** is sometimes noted, fracture conchoidal to uneven, some varieties very tough and valuable for abrasive purposes The hardness of garnet is 6 5–7 5, specific gravity, 3 1–4 3, luster, vitreous to resinous, colors, red, yellow, brown, black, green, or colorless, transparent to opaque The word garnet is derived from the Latin *granatus*, a grain

In general six varieties of garnet are recognized, based on their chemical composition Grossularite (which is also called hessonite and cinnamon-stone), pyrope, almandine or carbuncle, spessartite, uvarovite, and andradite Grossularite is a calcium aluminum garnet which corresponds to the formula $Ca_3Al_2(SiO_4)_3$, the calcium may, however, be in part replaced by ferrous iron and the aluminum by ferric iron The name grossularite is derived from the botanical name for the gooseberry, *grossularia*, in reference to the green garnet of this composition found in Siberia Other shades are the well-known cinnamon brown, reds and yellows Because of its inferior hardness to zircon, which mineral the yellow crystals resemble, they have been termed hessonite, from the Greek meaning inferior Curiously enough, in the gem-bearing gravels of Ceylon both zircon and hessonite are found and indiscriminately called hyacinth, from the Greek, seemingly general term used by Pliny for the transparent varieties of corundum, later it was used for yellow zircons

Grossularite is found in crystalline limestones with **vesuvianite, diopside, wollastonite** and **wernerite** Among the many localities may be mentioned Siberia, the Urals, Italy, Switzerland, Mexico, and in the United States in Maine and New Hampshire

Pyrope, sometimes called Cape ruby, is ruby red in color and chemically a magnesium aluminum silicate with the formula $Mg_3Al_2(SiO_4)_3$, the magnesium may be replaced in part by calcium and ferrous iron The color of pyrope varies from deep red to almost black The transparent pyropes are used as gems, but some have a slight tinge of yellow The name pyrope is derived from the Greek word meaning *fire-like* A sub variety of pyrope from Macon County, North Carolina, is of a violet red shade and has been called rhodolite, from the Greek meaning *a rose* In chemical composition it may be considered as essentially an **isomorphous** mixture of pyrope and almandite, in the proportion of two molecules of pyrope to one molecule of almandite Pyrope is found at Teplitz and Aussig, Bohemia, in the Kimberley diamond mines in South Africa, in Australia and elsewhere In the United States important localities are in Arizona, New Mexico, and Utah

Almandite, sometimes called almandine, is the modern gem the carbuncle, although in Pliny's time this term was used for almost any red stone The term carbuncle is derived from the Latin *carbunculus*, meaning a little spark The name almandite or almandine is a corruption of Alabanda, a locality in Asia Minor where, in ancient times, these red stones were cut Chemically almandite is an iron aluminum garnet corresponding to the formula $Fe_3Al_2(SiO_4)_3$ The deep red transparent stones are often called precious garnet and used for gems. Almandite occurs in metamorphic rocks like mica schists usually associated with typically metamorphic minerals such as **staurolite, kyanite, andalusite,** etc Good gem material comes from India and Brazil Almandite is also found in Australia, Alaska, Africa, Norway, Sweden, Madagascar, and Japan In the United States almandite is found in the **gneisses** of the Adirondack region of New York, sometimes of very large size, in New England and elsewhere

Spessartite is manganese aluminum garnet, $Mn_3Al_2(SiO_4)_3$ The name of this mineral is derived from Spessart in Bavaria, a well-known European locality Spessartite of a beautiful orange yellow comes from the Island of Madagascar Violet red spessartite has occurred in **rhyolites** in Colorado and Maine Uvarovite is a calcium chromium silicate the formula being $Ca_3Cr_2(SiO_4)_3$ It is a rather rare garnet, bright green in color, usually in small crystals associated with **chromite** in **serpentines,** sometimes in crystalline limestones or schists Found in the Urals, South Africa, Canada, and in the United States in California and Pennsylvania Andradite, calcium iron garnet, $Ca_3Fe_2(SiO_4)_3$, is of variable composition and may be red, yellow, brown, green, or black, or of intermediate shades The subvarieties topazolite, yellow or green, demantoid, green, and melanite, a black sort, are recognized Andradite is found both in deep-seated igneous rocks like syenite as well as in serpentines, schists, and crystalline limestones Demantoid has been called the "emerald of the Urals" from its occurrence there Varieties of andradite are found in many localities in Europe, Italy, Switzerland, Norway, Saxony, etc, and in the United States at Franklin, New Jersey, Magnet Cove, Arkansas, and elsewhere (E S C S)

GAS CALORIMETER. Fuel Calorimeter.

GAS ENGINE. Internal Combustion Engine.

GASES States of Matter; **Dynamics of Gases; Kinetic Theory; Ideal Gas Law, Characteristic Equations; Avogadro's Law, Boyle's Law, Charles' Law; Joule-Thomson Effect; Dalton's Law.**

GAS GANGRENE. Infection of tissues around a wound by certain anaerobic bacilli These anaerobic bacilli grow best deep in tissues away from the air (anaerobic organisms are those that grow best without oxygen)

Most of the information on gas gangrene was obtained during the World War Many of the war wounds were infected with these gas-producing organisms and occurred from contamination either directly or indirectly with fecally contaminated soil It is occasionally seen in civil medical practice in extensive wounds with considerable crushing of tissue At autopsy, following death from gas gangrene infection, gas bubbles are often found in the tissues and organs of the body The organisms ferment muscle sugar, thereby producing gas

The most common organism of this group found in gas gangrene infections is the Bacillus Welchii It is a normal inhabitant of the human and animal intestinal tract When attacking tissue it liberates a toxic material which kills tissue with which it comes in contact This toxic production varies with the virulence of the strain of bacteria

In war or traumatic civil surgery the organisms are carried into the depths of tissues by foreign bodies or bits of projectiles In these types of injury variable amounts of tissue are destroyed or devitalized, thus furnishing the dead or necrotic material that gas organisms thrive upon It is for this reason that debridement (excision of all devitalized or contaminated tissue) is immediately done as soon as the patient is hospitalized This is one of the best methods in preventing this serious complication of wounds.

Promising results also have been obtained by injection of a polyvalent antitoxic serum against the common gas gangrene organisms. (R S M)

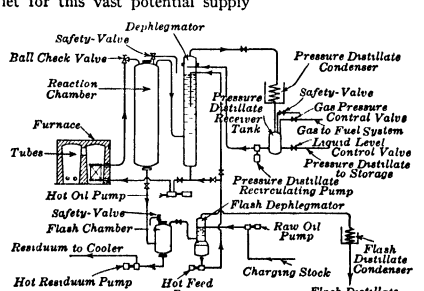
GASKET. The gasket is a layer of packing material firmly held between contact surfaces on two pieces whose joint is to be sealed with the gasket Gaskets are made in many different shapes to suit the shapes of the various mating pieces The simplest type of gasket is that used to seal the joint between two circular **flanges,** as might

be used in making a joint in piping The gasket is made of a thin sheet of material, satisfactory for the service, having through it a hole corresponding to the internal diameter of the pipe After being inserted between the flanges, flange bolts draw the latter tightly together, compressing the gasket material until it tightly seals the joint Some gaskets are **toroidal** in shape, but most are flat The services they perform range from that of sealing against leakage of the liquids in water lines to rendering gas-tight such high temperature joints as those in engine exhaust manifolds Naturally, a variety of materials would be required for these different conditions In general, gasket material is rubber for water, corrugated copper for saturated steam, soft corrugated steel for superheated steam, asbestos for hot gas (F T M)

GAS OIL. Gas oil is the residual oil left after **gasoline** and kerosene are distilled from certain crude petroleums (See **Fuels** and **Hydrocarbons paraffinic**) (R K S)

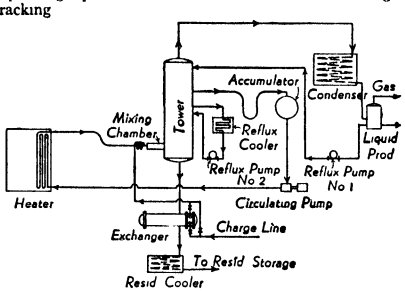
GASOLINE. Gasoline is a mixture of those **hydrocarbons** in crude oil which have relatively low boiling points Under ordinary temperatures the bulk of gasoline remains liquid, and is widely handled as such in these days on a commercial scale, since this fuel has been the most satisfactory for **internal combustion engines**, especially those used in automobiles and trucks The crude oil from which gasoline is obtained is the source of a number of commercial products, including, in order of volatility, petroleum ether, gasoline, naphtha, kerosene, **fuel** oil, lubricating oil, wax, or asphalt Crude oils are generally too heavy and viscous to use directly as fuels in internal combustion engines, moreover, they usually contain, or form on combustion, free carbon, sulfur compounds, ash and moisture, which are detrimental to engine mechanisms

When the crude oil is heated it may be separated into a number of fractions because of the great difference in boiling point (**vapor pressure**) of its constituents Of course, these fractions are themselves mixtures, since it is not economically feasible to carry the separation down to the individual hydrocarbons Instead, fractionation of the group is ordinarily carried out to produce the well-known products mentioned above It is to be noted that the result of ordinary distillation is to produce more of the other products than gasoline With the continually increasing demand for gasoline due to the widespread use of motor vehicles, the simple distillation process would have caused the accumulation of large, unused reserves of the heavier fractions of crude oil However, the various cracking processes provide an economic outlet for this vast potential supply



Dubbs cracking process flow chart (Courtesy of *Universal Oil Products Co*)

In these cracking processes, the crude is subjected to heat under pressure, in such a way as to break up, or "crack," the heavy molecules of the high-boiling hydrocarbons into smaller, lighter molecules which constitute the more volatile hydrocarbons In this way the yield of gasoline from a crude can be increased at the expense of the heavier fractions (corresponding to kerosene, lubricating oil, etc) for which there is less tonnage demand One basis of classification of the many cracking processes in use is as "liquid phase" or "vapor phase," depending upon the state of the oil when it undergoes cracking



Flow diagram "De Florez" vapor phase cracking process for gasoline

Another way of producing a high yield of gasoline from crude is by the **hydrogenation** process, in which hydrogen and low-grade crude oil react in the presence of a **catalyst**, at controlled pressure and temperature, to produce high-quality products, including a good yield of gasoline This process is operating successfully, but the present large supplies of high-grade crude oil constitute an economic barrier to extensive production of gasoline by this process

Casinghead, or natural, gasoline is obtained from certain gas wells by compressing and cooling the gas This product is richer than ordinary gasoline in the volatile constituents, and it is therefore not suited for use in the gasoline engine, except when blended with gasoline produced by one of the other processes

Under ideal combustion conditions the average gasoline requires nearly fifteen pounds of air per pound This produces between 18,000 and 19,500 B T U per pound of gasoline While the 15 1 ratio ordinarily gives the most effective combustion, mixtures as rich as 12 1 or as lean as 19 1 are explosive (See **Detonation**) (F T M)

GAS PRODUCER. The gas producer is used to manufacture **fuel** gas from coal, steam, and air It consists of a vertical cylinder which is lined with fire-brick and charged with **coal** Coal is fed at the top of the producer, and steam and air are injected at the bottom When the producer is in operation there are three distinct regions in the fuel bed it contains Above the ash in the lowest zone there is a combustion region of burning coke producing a considerable amount of heat, as it receives a strong blast of air (mixed with steam) Above that is a zone of incandescent carbon not undergoing complete **combustion** because of the consumption of the **oxygen** in the combustion region below The top zone is a layer of green coal which, upon being heated, evolves its volatile matter with formation of a crust The bed is mechanically poked to break up this crust as it forms The steam and air injected from below pass up through the combustion region, during which the oxygen combines with the carbon of the burning coke bed, forming carbon dioxide, and the steam becomes very highly superheated When these gases pass upward through the middle zone, the incandescent coke there reduces the carbon dioxide to carbon monoxide, thus

$$CO_2 + C = 2CO$$

and the steam to hydrogen and carbon monoxide, thus

$$H_2O + C = H_2 + CO$$

The composition of the gas obtained from a producer depends to a great extent on the control of these reactions by variation in the relative proportions of steam and air A typical analysis of such a gas is **carbon monoxide** 25%, **methane** 2%, **hydrogen** 15%, **carbon dioxide** 8%, **nitrogen** 50% The large nitrogen content is due, of course, to the use of air for combustion in the producer With so large a portion of the analysis contained in this inert gas, it is not surprising that the heating value of producer gas is low when compared to gases more completely composed of combustible elements The average heating value of producer gas is 150 B T U per cubic foot (F T M)

GASTEROPODA, GASTROPODA. The **snails, slugs**, and allied forms, constituting a class of the phylum **Mollusca** This group includes a large number of marine and fresh-water species and many that are terrestrial

The chief structural characteristics of the gasteropods are these 1 Most species have a dorsal visceral hump which is often spirally twisted 2 A head is present, bearing eyes and tentacles 3 The mouth is provided with a toothed organ called the radula 4 The foot is usually a broad creeping organ 5 Respiratory **ctenidia** lie in the mantle cavity of some species and in others the walls of the cavity are the respiratory organ 6 In many species a shell, conical or spirally coiled, encloses the visceral hump

Gasteropods are of relatively little economic importance Snails are eaten in Europe and the abalones of the Pacific Coast are also used as food The shell of the abalones furnish beautifully iridescent mother-of-pearl for costume jewelry and there is an extensive traffic in the shells of many species among collectors

The group is classified as follows

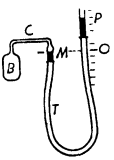
Subclass **Streptoneura** Usually with a shell closed by a horny shield, the **operculum**, when the animal is retracted
- Order **Diotocardia** (Aspidobranchiata) **Abalones, limpets**, and other marine species A few fresh water forms
- Order Monotocardia (Pectinibranchiata) **Whelk, periwinkle**, and many other marine forms and a few fresh water species

Subclass Opisthobranchiata Shell small and internal, sometimes lacking
- Order Tectibranchiata **Sea hare, sea butterflies** or pteropods with the foot expanded into winglike lobes All marine
- Order Nudibranchiata Marine species without shells Often with complex dorsal processes **Sea lemon**, nudibranchs

Subclass Pulmonata Shell usually present but without an operculum Mantle cavity sometimes the only respiratory organ Mostly fresh-water and terrestrial species, a few marine
- Order **Basommatophora** Eyes at the bases of the posterior tentacles Many common **snails**
- Order Stylommatophora Eyes at the tips of the posterior tentacles Common snails and **slugs** (See also **Invertebrate Paleontology**) (A W L)

GASTEROSTOMATA. Trematoda

GAS THERMOMETER. When the standard measure of **temperature** was fixed upon as the pressure of a gas kept at constant volume, the constant volume gas thermometer became the final arbiter of temperature measurement (See **Thermometry**) In this instrument the gas (preferably hydrogen or helium) is enclosed in a glass or fused quartz bulb that is connected to a mercury manometer, and facilities are provided to bring the gas always to the same volume and to indicate the gas pressure The most common form, designed by Jolly (1874) is shown diagrammatically by the figure, in which *B* represents the bulb, *T* the flexible tube of the manometer, *M* the constant volume mark at zero level, and *P* the level of the mercury indicating the pressure The pressure is regulated by moving the right-hand mercury column up or down the scale Slight corrections are necessary for the expansion of the bulb and for the difference of temperature between the gas in the bulb and that in the connecting tube *C* The use of this thermometer depends upon the fact that changes of pressure are accurately proportional to the changes of temperature producing them If a mercury thermometer is to be standardized between 0° and 100° C, for example, its bulb is placed along with the bulb *B* in a bath of adjustable temperature and the total pressure in *B* noted for each of these fixed points The interval between these points is then divided into 100 parts, each of which corresponds to 0 01 of the whole change of pressure Since the mercury at *P* is exposed to the atmosphere, the atmosphere pressure, taken from a good barometer, must be added to that measured by *OP* The constant pressure type of gas thermometer was perfected by Callendar and others, but proved somewhat impracticable and has fallen into disuse (L D W)



Sketch of essential parts of constant volume gas thermometer

GASTRIC FILAMENT. Slender projections on the floor of the stomach of a **jellyfish**, containing stinging cells which kill living prey taken into the stomach (A W L)

GASTRIC SHIELD A plate in the stomach of **bivalve** mollusks against which the **crystalline style** is worn away (A W L)

GASTRITIS An inflammation of the lining membrane of the stomach occurring in an acute or chronic form It results in various digestive and constitutional symptoms The common causes of gastritis are alcoholism, errors in diet, food poisoning, and irritant or corrosive poisons (R S M)

GASTRO-ENTERITIS An inflammation or irritated condition of the gastro-intestinal tract, due to errors in diet, infection or food poisoning, irritant poisons or alcohol (R S M)

GASTRO-ENTEROLOGY. The study of the diseases and functions of the **stomach** and **intestines** A gastro-enterologist is a specialist in the diagnosis and treatment of the disorders of the stomach and intestines (R S M)

GASTRO-ENTEROSTOMY A short-circuiting surgical procedure in which the stomach is made to communicate with the upper small intestine by an artificial passage or anastomosis In this way, food no longer has to pass through the **pylorus** into the **duodenum** It is done to promote healing in certain cases of **ulcer** formation near the pylorus, and when there is obstruction at the outlet of the stomach due to inoperable growths or ulcer formation (R S M)

GASTROSTOMY. An artificial, and usually permanent, opening made through the abdominal wall into the stomach This is done to prevent starvation when there is an obstruction in the **oesophagus** from a malignant growth, or scarring after drinking a corrosive chemical, etc, thus making it impossible for the normal passage of food into the stomach (R S M)

GASTROTRICHA. A group of minute animals found in fresh and salt water on the bottom and among the debris accumulated there They move chiefly by means of **cilia** and have cement glands whose secretion attaches them temporarily to supports They have a tubular alimentary tract and an excretory system consisting of

two tubules with flame cells The group is ranked by some writers as a class in the same phylum as the **rotifers** and by others as of uncertain relationship

Two orders are recognized **Macrodasyoidea**, made up of marine species with numerous cement glands, and **Chaetonotoidea**, made up of marine and fresh-water species with a single pair of cement glands at the caudal end of the body or none (A W L)

GASTROVASCULAR SPACE The central cavity (**enteron**) of **coelenterates** and **ctenophores** (A W I)

GASTROZOOID. A form of individual in **hydrozoan** colonies whose function is to digest food for the colony (A W L)

GASTRULA The stage in embryonic development in which the initial differentiation of tissues is evident The gastrula is typically a sac whose wall is composed of the two germ layers, an outer ectoderm and an inner endoderm The cavity lined by the endoderm is the archenteron and the opening to the exterior is the blastopore

The gastrula is formed from the **blastula** by the process of gastrulation Typically the wall of the spherical blastula caves in on one side and the invagination progresses until this side is in contact with the opposite wall In some **coelenterates**, however, the two germ layers appear as a solid mass of endoderm surrounded by a layer of ectoderm and the archenteron forms by the splitting of the inner mass In animals with abundant yolk, modifications also appear In birds, for example, the stage approximating the blastula is a disk of cells on the surface of the yolk and the endoderm is formed by the folding under of this layer at one point on the margin Later the folded edge undergoes a concrescent growth until it doubles on itself and fuses to form the primitive streak, equivalent to a closed blastopore

The mesodermal layer also appears in the gastrula of **triploblastic** animals Its formation is extremely variable but it usually grows out from the indeterminate zone about the blastospore where ectoderm and endoderm join (A W L)

GATES. Sluices through a dam are conduits cast in the concrete and equipped with controls called sluice gates The common types of sluice gates are the plain sliding, the gate, the butterfly, and the needle valve The purpose of the sluice is to empty the reservoir if necessary, to control the head level, and to aid in passing floods (See **Crest Gate**)

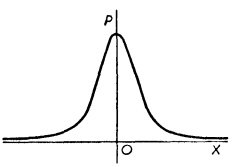
In foundry practice, the pouring spout casting, which comes from the mold attached to the casting, is called a gate (F T M)

GAUR. Mammalia, Artiodactyla A large wild **ox**, *Bibos gauras*, of India, Burma, and the Malay Peninsula It has been domesticated to a very limited extent (A W L)

GAUSS. The gauss, as now defined, is the practical c g s unit of magnetic induction (See **Magnetism**) If a straight wire is passed across a region under magnetic influence so as to cut it with a speed of 1 centimeter per second perpendicular to the direction of the induction, the value of the induction necessary to set up an electromotive force of 1 abvolt (0 00000001 volt) per centimeter length of wire is 1 gauss Or, if the induction is 100,000,000 gausses, the resulting electromotive force is 1 volt per centimeter length of this moving wire The induction in gausses is commonly represented by the number of "lines," or maxwells, per square centimeter of normal cross-section

For many years prior to 1932 the term gauss was used to designate that unit of magnetic field intensity which is now known as the **oersted** This change in terminology was introduced to distinguish between magnetic induction and magnetic intensity as physical magnitudes (L D W)

GAUSSIAN DISTRIBUTION. Wherever statistical analysis has a part in physical theory or in the treatment of chance or accidental **errors of measurement**, frequency distributions and distribution functions are of importance Probably the most common type of distribution function is the so-called Gaussian distribution whose graphical representation gives rise to the "bell-shaped" figure so frequently met with in the treatment of errors of measurement and the theory of **least squares** It may be illustrated by a study of the distribution of a large number of shots on a target ruled with parallel, equidistant vertical lines, the line bisecting the middle compartment being the "bull's eye" aimed at The distribution of the shots may be tabulated by counting the shots and recording the percentages corresponding to the numbers found in the several vertical compartments numbered out both ways from the central (or zero) compartment The outstanding characteristics of such a distribution are the tendency to a maximum at the center (zero mode), the progressive decrease of frequency with distance from the center, and the symmetry of the distribution with respect to this modal zero In dealing with all such problems we are assuming that merely chance or accidental errors are involved, i e, that the marksman honestly tried to hit the "bull's eye" and that his sights were properly adjusted, wind effects were properly compensated for, etc



Typical Gaussian distribution curve.

The mathematical analysis of the probability for distributions having the characteristics of pure chance or accident, carried out by Gauss and by Hagen along quite different lines of reasoning, result in the following form of distribution function

$$p = \frac{k}{\sqrt{\pi}} e^{-k^2x^2}.$$

In this expression p is the probability that any one of the statistical elements chosen at random (e g, one of the shots on the target) will be found in the statistical interval numbered x from the modal zero (e g, the xth vertical compartment from the center of the target) Or, it is the approximate percentage of all the elements which in the long run are found in the xth interval k is a constant which depends upon the degree of concentration about the mode, its value being greater, the greater this concentration, as indicated by the fact that $\frac{k}{\sqrt{\pi}}$ is the probability of the element lying in the zero or modal interval (i e, is the value of p for $x = 0$) In the target example k measures the excellence of marksmanship In the language of statistics k is equal to about 0 95 of the reciprocal of the interquartile range, that is, the range of variation within which the central half of the elements lie

Perhaps the most common example of the Gaussian distribution is that of the distribution of the accidental errors of varying size in measurements, in which case x is the size of the accidental error and k is the measure of precision Again the components, parallel to any one axis, of the velocities of molecules in a pure gas (gravity and convection currents excluded) are distributed in like manner, though the actual speeds of the molecules follow the unsymmetrical and distinctly different **Maxwell distribution law** Here k is dependent upon the temperature and molecular mass of the gas Other examples are numerous in statistical physics (L D W, W K G, L L S)

GAUSS' THEOREM. Green's Theorem in Space.

GAVIAL. Garial.

GAVIIFORMES. The loons An order of large birds (**Aves**) with elongate bodies, short legs with webbed feet, and a long sharp beak They are powerful swimmers and divers, and are named divers as well as loons. (A W L)

GAYAL. Mammalia, Artiodactyla A wild **ox** of northeastern India, related to the **gaur** but smaller and with less flattened horns Domesticated to a limited extent (A W L)

GAY-LUSSAC LAW. Charles Law.

GAZELLE. Mammalia, Artiodactyla **Antelopes** of moderate size which live in Africa and Asia The numerous species are mostly inhabitants of deserts They constitute the genus *Gazella* and with few exceptions are named gazelles Among these exceptions are the **springbok**, the korin, and the aoul (A W L)

GEANTICLINE. Anticlinorium.

GEARING Although this word may be taken in as broad a meaning as to apply to all combinations in which motion, especially rotative motion, is transmitted from one member to the others, in the more common usage, gearing refers in particular to toothed gearing, wherein rotation is transmitted between shafts through the medium of toothed wheels properly shaped to engage each other

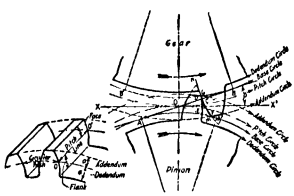
The principal classes of tooth gears are the **beveled gear**, the **spur gear**, and the **worm gear** (or screw) The principal distinguishing characteristics of these three classes are that the two shafts must be parallel when spur gears are used, must intersect for the use of beveled gears, and are neither parallel nor intersecting in the screw type gearing Gears are especially useful where the shafts are comparatively close together, and where compactness and positiveness of drive are essential requirements So varied are the possible applications of gearing, that it is one of the most common mechanisms applied to machinery Gears are susceptible of such delicacy of treatment as is required in the smallest wrist watch, but are also equally suitable in large, comparatively rough machinery, such as mining or agricultural machinery

The materials from which gears are made are either metals or such tough enduring substances as bakelite, rawhide, and fiber The softer materials are employed for one of the mating gears when silent operation or confinement of wear to one gear is desired Cast iron has been a widely used material for a variety of gears, especially the heavy, comparatively rough gears in which the teeth are used as cast These are noisier and less efficient than the cut teeth, which are machine cut after the blank has been cast Cast and forged steel, brass, and bronze have also been widely used for gears

The common methods of manufacture of **gear teeth** are molding, machine cutting, and stamping The latter method is used especially for the gears of clock machinery, counter trains, small automatic machines, etc The molding process is one of casting of the gear from a pattern This is still practiced extensively for large spur gears Machine-cut gears may be cut by milling and by generating, the latter being accepted as a suitable way of cutting helical teeth The amount of power wasted in friction between well-designed, unworn gears is so small that there is probably no other method of transmitting loads from one machine element to another that has the high efficiency of all gears Especially is this true with machined gears which revolve in a bath of lubricating oil. (F T M)

GEAR TEETH. The forms of teeth employed on mating gears must be so chosen as to result in smooth action between the gears, and an unvarying velocity ratio This condition is satisfied when the perpendiculars to the tooth surfaces at the points of contact always pass through the pitch point The pitch point may be designated as the intersection between the line of centers of the gears and their pitch circles, the latter being circles the diameters of which are the same as the diameters of a pair of **friction gears** that would replace the spur gears Among tooth profiles which will accomplish this purpose are the **involute** and the **epicycloid** As the involute tooth is the more important as far as the whole field of gearing is concerned, it is here described. However, there are many modifications of the involute profile which have been designed to suit special purpose gears A fact contributing to the popularity of the involute tooth is that the distance between shaft centers may be slightly greater or less than that for which the teeth were designed, without affecting the velocity ratio

The involute is a curve traced by a point at the end of a string wrapped around a cylinder, and held taut as the string is unwrapped from the cylinder The circumference of the cylinder is called the base circle, and the profile of an involute tooth on the outside of the base circle follows the curve of the involute Inside the base circle, the tooth profile is usually radial The accompanying figure shows the principal dimensions of a



Form of teeth

gear tooth, and the names of the circles of most importance in the laying out of a gear The pitch circles previously referred to are tangent to the line XX' at the common point O Part of a gear tooth extends outside the pitch line a distance equal to the addendum, while the remainder, the dedendum, is inside the pitch line The dedendum must exceed the addendum of the mating gear by the amount required for mechanical clearance between the tips and roots of the teeth The base circle is that imaginary circle from which the involute is unwrapped to form the tooth profile on the outside of that circle The straight line which is the locus of the successive points of contact on the faces of mating gears as they move through their angle of engagement, is designated as the line of action It passes through the pitch point and is inclined to the tangent XX' at the angle of obliquity The angle of obliquity most used is $14\frac{1}{2}°$ The pitch diameter of gear teeth is, of course, the diameter of the pitch circle, and the velocity ratio between mating gears is inversely as the diameters of the pitch circles For freedom of action, a certain amount of backlash is allowed in gears by making the spaces between teeth on the pitch circle slightly greater than the thickness of the teeth measured on the same circle

The circular pitch of a gear is the distance of one tooth to a corresponding point on the next tooth, as measured on the pitch circle This is the same as the portion of the circumference of the pitch circle occupied by a tooth and a space The circular pitch is a dimension, the diametral pitch, found by dividing the number of teeth in a gear by the pitch diameter, is simply a ratio

In action a gear tooth undergoes a pressure applied at the point of contact with the mating tooth On the assumption that only one pair of mating teeth is in contact, when transmitting power between rotating shafts,

and making the further assumption that the load is concentrated at the tip of the tooth at the beginning of contact, Lewis devised his classic formula for the strength of cut gear teeth It has become the standard for this service In deriving the Lewis formula, the tooth was considered to be a cantilever beam, with the weakest section at the root. The Lewis formula for safe tooth load is.

$$F = Spfy$$

S is the safe working stress of the material of the gear tooth. p is the circular pitch, f is the face width of the tooth, y is $\frac{2}{3}\frac{x}{p}$, in which x is a factor depending on the form of the tooth profile y is frequently called the Lewis factor, and numerical values of it are usually included in books which deal with gears The working stress of a moving gear will necessarily be less than the static stress allowable in the same material

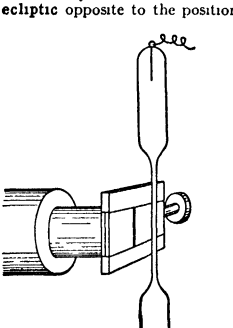
The Barth formula for speed factor may be applied to the ordinary static stresses of material to obtain a working stress suitable for use in the Lewis formula The speed factor is $\frac{600}{600 + V}$. V is the velocity of the pitch line, feet per minute This factor is multiplied by the static stress to obtain the dynamic stress (F T M)

GEAR TRAIN. Several gears connected in a series arrangement, the gear of one pair of mating gears being rigidly fixed to the same shaft as the pinion of the next pair, is a gear train A gear train is employed to effect a reduction of speed, quite beyond the capacity of any single pair of mating gears to attain One of the most frequent examples, and one which displays a rather intricate gear train, is found in the common pocket watch (F T M)

GEASTERS. Basidiomycetes.

GECKO. Reptilia, Sauria Small **lizards** of many species inhabiting the warmer regions of both hemispheres Most geckos have adhesive disks on the toes Several species are found in southern Florida and the southwestern states (A W L)

GEGENSCHEIN. The gegenschein is a slight increase in intensity of the **zodiacal light** at a point on the **ecliptic** opposite to the position of the sun The gegenschein appears as a soft glow against the sky, oval in shape, a few degrees wide and from ten to fifteen degrees in length It is so faint that it cannot be observed on a night when there is any moon or when the patch falls in the vicinity of the **milky way** (W K G)



Common form of Geissler tube, in front of spectroscope slit.

GEIGER - MÜLLER COUNTER. Counting Tube.

GEISSLER TUBE. Geissler manufactured a variety of gas discharge tubes at moderate exhaustion, which exhibited bright glow discharges and sometimes marked **fluorescence** effects A form very useful in **spectroscopy** consists of two elongated bulbs, one containing the **cathode** and one the **anode**, and connected by a straight capillary section The glow is most intense in the capillary, which is by its shape especially adapted to be placed in front of a spectroscope slit Such tubes may be conveniently operated by an induction coil or a small transformer, though the latter is likely to overheat them and may even fuse the electrodes A most practical modern form is the so-called "neon tube" used so extensively in illuminated advertising signs (L D W)

GELADA BABOON. Mammalia, Primates An Abyssinian **monkey**, *Theropithecus gelada*, of rather large size and chiefly black color, with a large mane It resembles the true **baboons** in its elongate muzzle but differs in having the nostrils set well back from the tip (A W L)

GELATINE. Aminoacids, Polypeptides, and Proteins.

GEM, GEM STONES. A gem stone is a mineral substance which because of its beauty or rarity is in demand for ornamental purposes, chiefly personal adornment The origin of such use for what we now call gem minerals is lost in the dim vistas of early human history. Ancient records describe the various gem stones, and archeologists find them in their investigations of bygone peoples When we look at a collection of minerals with their bright colors and varying degrees of transparency or light-reflecting power, we cannot doubt that primitive man was much attracted by them and valued them greatly We may imagine, too, that the occasionally found crystals with their regular geometric forms were more highly prized than broken fragments of the same minerals Later they learned to polish them Apparently the oldest form into which stones were shaped is that known as *en cabochon*, a French term derived from the Latin word for head and referring to its rounded shape The forms were either hemispherical or hemiellipsoidal The Emperor Nero is supposed to have had a large **emerald** cut en cabochon, and indeed for several centuries after his time this seems to have been the only sort of cutting employed The supposedly accidental discovery in 1475 that diamonds would mutually scratch each other began the era of modern gem cutting Previously it had been believed that diamonds were so hard that they could not be artificially shaped At first, however, little progress was made in fashioning gems other than polishing a number of facets without any definite arrangement

We owe to Vicenzio Peruzzi, a Venetian, the credit for devising the so-called "brilliant cut," the style of the modern **diamond** cutting, which, except for certain refinements due to a more thorough understanding of the behavior of minerals toward light, remains the same as in Peruzzi's day At the present time transparent stones of all sorts are usually "brilliant cut," while translucent or opaque are cut en cabochon.

Since time immemorial dealers in gems have used as the unit of weight the carat, undoubtedly introduced from the east The word is derived from the Greek meaning a small horn, referring to the pods of the locust tree, *Ceratonia siliqua*, a common Mediterranean tree whose seeds were said to have been taken as the unit of weight in buying and selling gems In the nineteenth century the actual weight of the carat differed slightly in different countries of Europe, from a little under to somewhat over one-fifth of a gram The uniform use of the metric carat, exactly one-fifth of a gram, has been urged and to some extent adopted. (E S C S)

GEMINI. (The twins) (Map, page 306) This constellation, which marks the third sign of the zodiac, has been recognized as a pair of twins from remote antiquity The twins have not always been human, however, the Egyptians considering them as a pair of kids, and the Arabians as a pair of peacocks By far the most familiar names for the two bright stars of this constellation are the names of the warrior brothers,

Castor and Pollux, sons of Jupiter and Leda. Both of these stars are interesting objects in a three-inch telescope, Castor being a fine **binary** and Pollux being a multiple star of at least six components There is also a fine star **cluster** in this constellation which can easily be seen with a field glass and can be detected with the unaided eye on a clear moonless night (W K G)

GEMMULE Reproductive bodies of **sponges** enclosed in protective capsules which enable them to withstand severe conditions of temperature and drought (A W L)

GEMSBOK Mammalia, Artiodactyla A South African **antelope** related to the **beisa** *Oryx gazella* (A W L)

GENE. A minute body or zone in a **chromosome** which governs the hereditary transmission and the development of a specific character of the individual

The gene is regarded as a hypothetical unit of **heredity** and as such its existence has been judged by indirect evidence from the study of hereditary processes In recent years the study of giant chromosomes of the salivary glands of the fruit flies has revealed fine details of structure which may be the genes These chromosomes are differentiated longitudinally into many zones whose nature and arrangement appear to be constant, barring recognized types of change, and many of these transverse bands or zones have been identified as the points occupied by the hypothetical genes of other studies

The action of genes is not definitely known, but they have been interpreted as self-perpetuating bodies that produce **enzymes** capable of influencing the action of other parts of the cell (A W L)

GENERAL PARESIS (Paretic neurosyphilis, General paralysis, General paralysis of the insane, Dementia paralytica) General paresis is a chronic **syphilitic** inflammation of the brain and its coverings It is characterized by progressive insanity and a generalized paralysis that eventually terminates fatally

About 3% of syphilitics develop paresis

Microscopically the changes in the brain are characterized by degeneration of the brain cells The lesions seen in locomotor **ataxia** are also frequently present

The symptoms may assume any form Since the onset may be sudden or insidious, this manifestation of syphilis may resemble and be mistaken for any kind of mental disease Some patients die in seizures at the onset of the disease

In the early stages, changes in personality, lack of judgment, carelessness, may lead to financial and moral difficulties These early symptoms may last weeks, months, or years Visual, auditory, and speech defects are common

During the fully developed stage of the disease characteristic symptoms are euphoria, with grandiose ideas, delusions of wealth, etc In others, depression may be marked with anxiety and fear There is also a form characterized by **dementia** or paranoia Epileptic or apoplectic seizures followed by temporary paralysis are common Progressive dementia is present with all the above syndromes

In the late stages the paralysis is marked, involving all muscles, and the patient is bedridden until death occurs either by intercurrent infection or the respiratory paralysis.

The prognosis is more hopeful at present since more cases receive early treatment During recent years remission of the disease for varying periods has been obtained by means of fever therapy together with certain arsenicals that have more effect on neurosyphilis than the common arsenical compounds

Juvenile paresis is much more common than juvenile tabes and is a form of congenital syphilis It is characterized by a rapidly progressing dementia or feeble-mindedness.

The blood Wassermann is usually positive The spinal fluid Wassermann is more apt to be positive than the blood (R S M)

GENERAL SOLUTION OF A DIFFERENTIAL EQUATION. Ordinary Differential Equations.

GENERATOR. A generator is any equipment wherein originates a vital or chemical process The two generators most frequently met are gas generators and electric generators The method of generating the gas varies greatly, and there are several different kinds of gas generators The acetylene generator, for example, has a chamber containing calcium carbide, into which water falls drop by drop, wetting the carbide, and reacting with it to produce acetylene.

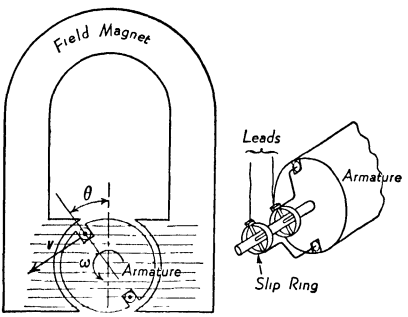


Figure 1 Elementary generator

Electric generators are built in all capacities, to suit the smallest and the largest installations They can produce **alternating current** or **direct current**, depending on the design, but the origin of the electrical energy is the same, whether the final product be alternating current or direct current To understand the action of the generator, examine Figure 1, which represents a soft iron **core** rotating between the poles of a permanent magnet, and having the slots on the surface, in which is embedded a coil of wire It is apparent that as the coil rotates, carried by the soft arm armature, it will cut across the **flux** lines extending from pole to pole When this apparatus is connected to stationary leads through the medium of slip rings, and brushes resting thereon, it becomes an elementary **alternator** If, instead of slip rings, a split segment, such as that shown in Figure 2, is connected to the ends of the coil, the reverse of the current in the coil will occur when alternate segments of the slip ring (an elementary commutator) are opposite one of the **brushes** This gives uni-directional current in the exterior leads, although it would be quite variable with only one coil in the **armature** A uniform and uni-directional current is the result of many single coil armatures so connected that the resultant current is the sum of several individual outputs With sufficient overlap, the resulting current will be uniform and uni-directional When the coil is revolving at a speed of ω radians per minute, at the position indicated, the speed of cutting vertically across flux lines is $v \cos \omega t$ The time is measured from the vertical position of the coil, and angle θ is ωt When a wire cuts a magnetic field having a flux density represented by b and has a length and velocity represented by l and v, the voltage gener-

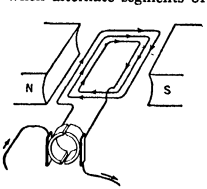


Figure 2

ated is $\frac{b}{10^8}$ volts, thus the voltage generated any instant t, t being measured from the point of minimum generated voltage, is $\frac{blv}{10^8} \sin \omega t$

The direct current generator is an ordinary dynamo machine having a multiple coil winding, the ends of the coils of which are connected to a multiple segment commutator The armature is usually rotating, and the field stationary The field sets up magnetic lines of force, which are cut by the conductors on the revolving armature, giving rise to a generated voltage which is led through the commutator to a uni-directional external circuit The iron core is built of laminations of iron insulated from each other by mill scale, or lacquer, or japanning, so that eddy currents which can be generated in the iron core, will be a minimum The field windings are usually stationary, and the armature rotating, hence low voltage is the usual condition of use of direct current generators The common direct current generator is classified on the basis of the connection of the field current circuit to the armature circuit If the field is so connected that the armature current flows through it, it is known as a series field In a series machine, all of the armature current flows through the field This type of generator is sometimes used to supply series street lamp circuits The more the armature current, the higher the generated voltage in this type of machine This characteristic serves to overcome the voltage drop in a series light circuit A shunt wound generator is a type in which the field winding has a high resistance, and is composed of a large number of coils of fine wire The terminals of the shunt field are connected across the commutator The shunt wound generator has definitely drooping voltage characteristics, for the current in the field is dependent on the generated voltage in the armature A compound wound generator, having both a shunt and a series field, partakes of the best features of both of the other types When the shunt field is connected across the commutator, only, the compounding is called short shunt, when the shunt field is connected across the series field and the commutator, it is a long shunt generator

The direct current generator may be adapted to the Edison three-wire system, in which there are 220 volts between outside wires and 110 volts between an outside and a neutral wire This dual voltage arrangement is obtained by bringing out the neutral point of the coil through slip rings mounted on the armature shaft

A direct current generator can not be operated without certain losses, both mechanical and electrical The efficiency of the generator is simply the output in electrical energy divided by the same output, to which have been added these losses mechanical friction, resistance heating, core loss due to hysteresis and eddy currents In a well designed generator, the efficiency is very high It can be of the order of 95% (F T M)

GENET. Mammalia, Carnivora *Genetta* Animals related to the **civets** but with more slender bodies and shorter legs The several species are found in Africa, Asia, and Europe (A W L)

GENITAL BURSA. A cavity lined with ciliated ectoderm at the base of each arm of the brittle stars (**Asteroidea**), into which the reproductive glands discharge (A W L)

GENITALIA. The organs of reproduction See **Reproductive system.** (A W L)

GENITAL OPERCULUM. A small plate formed of the united vestiges of a pair of appendages, which covers the openings of the genital ducts of **scorpions.** (A.W.L.)

GENITAL PORE. An external opening on the ventral surface of a flatworm, communicating with the genital atrium into which the reproductive ducts discharge (A.W.L.)

GENITAL RACHIS. A ring of tissue in the starfishes and sea urchins (**Echinoidea**) whose branches bear the reproductive organs (A W L)

GENITAL STOLON. A mass of cells associated with the **axial organ** of echinoderms (See **Echinodermata**) (A W L)

GENUS. A minor subdivision of the animal or plant kingdom composed of related **species** Genera are subdivisions of **families** and subfamilies

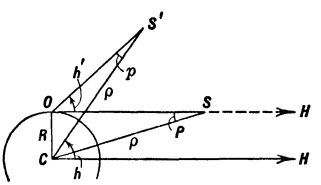
Genera are usually based on minor structural relations but in some cases superficial characters of color and pattern are made the basis of generic separation in groups of uniform structure The distinctive characters of a genus are those of a type species (genotype) which should be stated in the original description of the genus and is determined in other cases by established rules of **taxonomy.** (A W L)

GEOBENTHOS All organisms that live on the surface of land masses Aerial benthos (See **Distribution**) (A W L)

GEOCENTRIC COORDINATES. Any system of coordinates on the **celestial sphere** which uses for its origin, or reference point, the center of the earth is known as a system of geocentric coordinates Practically all coordinates published in an **ephemeris** or **almanac** are geocentric in character (W K G)

GEOCENTRIC PARALLAX. The origin of the apparent systems of **spherical coordinates** is a point on the surface of the earth, while the origin of the **geocentric** systems is at the center of the earth For obvious reasons, all observations must be taken in the apparent system For the solution of most problems, geocentric coordinates are desired The transfer from one system to the other is made by applying a correction for geocentric **parallax**

In the figure we have C the center of the earth of radius R, and O the position of an observer on the surface OC is the direction of gravity at O OH is the direction of the astronomical **horizon** and CH is a parallel direction drawn through the center of the earth S and S' represent two positions of an object at distance ρ from the center of the earth S being the position when the object is on the horizon At S' the object has an apparent **altitude** h' and a geocentric altitude h P is defined as the horizontal parallax of the object and is the angle subtended at the object by the radius of the earth For rigor the quantity usually defined is the mean equatorial horizontal parallax which is the angle subtended by an equatorial radius of the earth at the object, when the object is on the horizon, and at its mean, or average, distance from the earth The equatorial horizontal parallax is tabulated in **Ephemerides** for all members of the solar system for selected dates Inspection of the figure indicates that $\sin P = R/\rho$



Geocentric parallax in altitude

The geocentric altitude h is greater than the apparent altitude h by the angle p which is defined as the geocen-

tric parallax in altitude. In the oblique plane triangle COS' we have $\frac{R}{\rho} = \frac{\sin p}{\cos h'}$ but we have already seen that $R/\rho = \sin P$ whence $\sin P_3 \cos h' = \sin p$ Now both P and p are such small angles that, without sensible errors for most problems, except those dealing with the moon, we have $p = P \cos h'$ giving the geocentric parallax in altitude in terms of the equatorial horizontal parallax and the apparent altitude of the object For objects outside of the solar system the value of P is far too small to be appreciable in even the most refined observations

In case other spherical coordinates than altitude are to be used, the geocentric parallax in altitude may be transformed to the desired quantities by solution of the **astronomical triangle** or other triangles on the **celestial sphere.** (W K G)

GEOCHEMISTRY. Geochemistry is that branch of the science of chemistry which deals with the **chemical composition** of and the past and present chemical changes in the earth The subject matter is for convenience divided into three parts

1 Atmosphere See **Air; Atmosphere.**
2 Hydrosphere See **Water**
3 Lithosphere See **Lithosphere**

The chemical and physical weathering and transport of rock materials furnishes the inorganic portion of soils for crops Local concentration of various minerals in the crust of the earth is a matter of great economic importance (R K S)

GEODE. A geode is a hollow concretion or nodule whose inside walls are lined with crystals, commonly of **quartz** or **calcite** (R M F)

GEODESY. **Geophysics.**

GEODUCK Mollusca, Lamellibranchiata A giant **clam** found on the Pacific coast of North America It attains a weight of more than six pounds and is edible (A W L)

GEOGALE Mammalia, Insectivora *Geosale* A small animal of Madagascar which resembles the mice (**mouse**) (A W L)

GEOGRAPHICAL COORDINATES. Geographical coordinates provide a method for determining the position of a point on the surface of the earth by means of a system of **spherical coordinates.** Because of the fact that the earth is not a sphere but is in reality an oblate spheroid, technically the system of coordinates cannot be strictly spherical The geographical method of representation of the position of points on a spherical earth by means of **latitude** and **longitude** was first applied by Ptolemy in the construction of his atlas of the world during the second century of the Christian era (W K G)

GEOLOGY. The study of the composition, structure, and history of the earth The term is derived from the Latin, *geologia,* coined by Bishop Richard de Bury in 1473 to distinguish lawyers, who study "earthy things" from theologians First consistently used in its present sense in the latter part of the seventeenth century The great mass of detail that constitutes geology is classified under a number of subdivisions which, in turn, depend upon the fundamental sciences, physics, chemistry and biology The principal subdivisions of geology are **Mineralogy, Petrology, Structural Geology, Physiography** (Geomorphology), usually grouped under **Physical** or **Dynamical Geology;** and **Paleontology, Stratigraphy,** and **Paleogeography,** grouped under **Historical Geology.** The term **Economic Geology** usually refers to the study of valuable mineral (ore) deposits, including coal and oil The economic aspects of geology are, however, much more embrasive, including many subjects associated with Civil Engineering, Economic Geography and Conservation Some of the more important of these subjects are **Meteorology, Hydrology, Agriculture** and **Seismology.** Subjects which are also distinctly allied to geology are **Geophysics, Geochemistry** and **Cosmogony.** (R M F)

GEOMETRIC MEANS. **Geometric Progressions.**

GEOMETRIC PROGRESSION. A geometric progression is a succession of numbers in which each term has a constant **ratio** to the preceding term, this ratio is called the common ratio The terms "geometric progression" are often abbreviated by G P

There are two fundamental formulas for geometric progressions,—one for the general term and one for the sum of any number of terms

The general term or n^{th} term of the geometric progression whose first term is a and whose common ratio is r is given by the formula

$$l = a\, r^{n-1}$$

The sum of the first n terms of this progression is given by

$$s = \frac{a(1 - r^n)}{1 - r} = \frac{a(r^n - 1)}{r - 1} = \frac{rl - a}{r - 1} \quad (\text{if } r \neq 1)$$

The terms of a geometric progression between the first and last are called geometric means

The geometric mean of two numbers is the middle term of a geometric progression whose first and last terms are the given numbers It is given by the square root of the product of the given numbers

If in a geometric progression $a, ar, ar^2, \ldots, ar^n, \ldots$ the common ratio r is <1 in absolute value, the sum s_n of the first n terms approaches $\frac{a}{1-r}$ as a limit when n increases beyond all bounds ($n \to \infty$) In this case, we speak of the geometric progression as an **infinite** geometric **series,** and we say that its sum is $\frac{a}{1-r}$. (L L S)

GEOMETRIC SERIES The infinite series $\sum_{n=0}^{\infty} r^n$ is called a geometric series It is **convergent** when $|r| < 1$ with sum $\frac{1}{1-r}$, but is **divergent** for other values of r (L L S)

GEOMETRICAL OPTICS. This branch of physics treats light as if it were actually composed of "rays" diverging in various directions from the source and abruptly bent by **refraction** or turned back by **reflection** into paths determined by well known laws The idea that light travels in straight lines is here uppermost, while its wave character and other physical aspects are lost sight of Thus the image of a point A, if "real," is simply another point B through which the rays diverging from A ultimately pass after the several reflections or refractions produced by the mirrors, lenses, etc, of the optical system If the image B is "virtual," the rays appear to be diverging from it, but only because their direction has been so changed that if produced backward, the lines along which they now travel would intersect at B A real image of a lamp may easily be formed by a reading glass, a virtual image, by a plane mirror

The chief advantage of this mode of visualizing the behavior of light is the simplicity with which problems may be solved by geometrical constructions. The same formulae which are deduced by the methods of geometrical optics may be arrived at, but often with much more labor, by treating light as composed of waves and studying the changes of wave front See **Mirrors and Lenses, Optical Instruments, Eyepieces, Spherical Aberration,** etc (L D W.)

GEOMETRY. Geometry may be said to be a study of the properties of geometric figures Elementary Plane Geometry deals with figures composed of points, straight lines and circles, elementary Solid Geometry deals with figures composed of points, planes, straight lines, and spherical, cylindrical and conical surfaces **Analytic Geometry** is an analytic (algebraic) treatment of geometric problems There are other branches of Geometry, such as **Projective Geometry,** Differential Geometry, etc (L L S)

GEOMORPHOLOGY. This term is gradually replacing the earlier term physiography to denote the full scientific interpretation of the origin of topographic features, or the purely physical attributes of scenery This relatively distinct department of the earth sciences includes the study of the origin of all topographic features in terms of process, or processes of erosion and their effect upon geologic structure. (R M F)

GEOPHYSICS. The term "geophysics," derived from the Greek, meaning the Physics of the Earth, was probably first used by the Germans According to Dr G Angenheister, Director of the Geophysical Institute of the University of Gottingen, the word *"Geophysik"* appeared in Meyer's *Conversationslexikon,* published in 1853 The term must have been in use sometime before Both A Muhry (1863), and K Loppritz, Sr, aided in procuring its general acceptance (See A Sieberg, *"Geologische Einfuhrung in der Geophysik,"* 1927, p 1) Among the first comprehensive treatises in the English language on this subject is "The Physics of the Crust," by G Osmund Fisher, published in 1861 (O T Jones) The scope of geophysics is broad and difficult to define, especially in relation to geology During recent years geophysical techniques have been highly developed, particularly in relation to prospecting for petroleum through the mapping of sub-surface geological structures, the traces of which may, or may not, be exposed at the surface of the earth By 1925 the general field of geophysics is defined in the *"Zeitschrift fur Geophysik"* as follows

I. Motion and Constitution of the **Earth.**
   1 Rotation, revolution, precession, mutation, fluctuation of the poles (Subjects which are also directly related to astronomy and physical geography)
   2 Mass, weight, figure, density, and elasticity of the earth (frequently classified under the subject of **geodesy**)
   3 Distribution of mass in the earth's interior, **isostasy** (Intimately related to fundamental problems in geodesy, **geology,** and **cosmogony**)

II Deformations, drifts and vibrations
   1 Elevations and depressions of the crust, folding and mountain building, glaciation and glacier-movement, vulcanism. (Primarily geological problems)
   2. Tides of the **atmosphere,** of the oceans, and of the earth (Problems in meteorology, physical oceanography and structural geology)
   3 Wave-motions and currents in air and water (Meteorology and physical oceanography)
   4 Elastic deformation and seismic behavior of the earth (Usually classified under seismology, and related to structural geology)

III **Electric and Magnetic Field** of the Earth
   1 The internal permanent magnetic field, its distribution and secular variation.
   2. The external magnetic field and its **periodic** variation
   3. Earth-currents and **aurora.**
   4 Atmospheric electricity, **radioactivity** of the earth, the oceans, and the atmosphere (All of the above problems are included under the subject of **terrestrial magnetism,** a distinct and important branch of geophysics, it should be noted that the **compass** is the earliest type of geophysical apparatus)

IV Cosmic Physics in its Relation to the Earth and its Atmosphere.
   1. History of the earth, determination of the origin and age of the earth as a whole, and of its crust (Usually considered under the subjects of cosmogony and historical geology)
   2. Solar constants, radiation of the earth and the atmosphere for light, heat, and wireless waves
   3 Relation of solar activity to terrestrial radiation and to the earth's electric and magnetic field
   4 Climatic changes (meteorology)
   5. Cosmic radiation (discovered since 1925).

In terms of geophysics meteorology, hydrology, physical geography, physical oceanography, structural-inorganic-historical geology and cosmogony, are allied subjects In terms, however, of each of the "allied subjects," geophysical methods are included, among others, as contributary techniques

The greatest field for the application of geophysical methods has been in geology, both from the point of view of fundamental science and economics In the field of applied geophysics the many methods and techniques are classified as either gravitational, seismic, magnetic, electric or radioactive (Mathematics and physical chemistry are directly allied to geophysics only through experimental physics) In its purest sense, therefore, geophysics is a branch of experimental physics dealing, particularly, with the structure and, to a certain extent, the mass-composition of the earth, including its atmosphere and hydrosphere Geophysics bridges the gap between physics and geology in its broadest sense (R M F)

GEOSYNCLINE. Dana's definition of a geosyncline (1873) is a depression which has been produced by lateral compression and which is filled with **sediments.** Although Dana, in his original definition, suggested that subordinate ridges might be formed in the bottom of the geosyncline during its formation, it remained for Emile Haug, in his Traité de Geologie, to emphasize these ridges (geanticlines) in relation to the tectonics of the Alps According to L W Collet, "A geosyncline is situated between two continental masses and is destined to be filled with sediments, some of which are derived from the **geanticlines** which develop in it" According to R M Field, "A geosyncline originates in a continental block as a great trough, the locus for the accumulation of marine and terrestrial sediments, which are derived from concomitant geanticlines formed in or on the margins of the geosyncline" The geophysical and geological study of the great island arcs, such as the East Indies and West Indies (1927-1937), strongly intimates that the foredeeps in front of the arcs represent geosynclines which have not been filled with sediments while they were being formed The pronounced deficiency of gravity associated with these foredeeps suggests great down buckle of the crustal or continental type of rocks called Sial or Sima, such as are supposed to form most of the **submarine lithosphere** of the Pacific Ocean (R M F)

GEOTROPISM. Tropism, and also Movement in plants.

GEPHYREA. Large marine worms As adults they are not segmented but since the young show evidence of metameric segmentation they are placed with the segmented worms in the phylum **Annelida.** They have a large body cavity, one pair of **nephridia,** and in some species a few **setae.** The internal organs are not metamerically arranged.

This class is divided into three orders

Order Echiurida With a pair of setae near the anterior end Body cylindrical with a slender anterior protuberance, the **prostomium.**

Order Sipunculida No setae Body slender, with a protrusible proboscis and a group of tentacles near the mouth

Order Priapulida No setae or tentacles (A W L)

GERANIOL Alcohols and Ethers.

GERANIUM OIL. Volatile oils.

GERBIL. Mammalia, Rodentia Small burrowing animals of Asia and Africa They resemble **rats** but have long hind legs and large eyes and move about by jumping In these points they resemble the **jerboas** but they are less extreme (A W L)

GERENUK. Mammalia, Artiodactyla An **antelope,** *Lithocranius walleri,* of eastern Africa with a very long neck and moderate spiral horns, turned forward sharply at the tips Also called Waller's gazelle but not a true gazelle (A W L)

GERM. I Any microbe or **bacterium** II A **spore** III The substance from which the **embryo** develops (R S M)

GERMANIUM. Symbol Ge Atomic number 32 Atomic weight 72 60 Density 5 46 Melting point 958 5° C

Germanium is a silver-white, lustrous, hard, brittle metal, when heated in oxygen to 730° C is partially oxidized to dioxide, unaffected by solutions of acids and bases but soluble in fused **sodium** hydroxide, in the form of powder is of dull gray color, combines with **chlorine** to form volatile tetrachloride Discovered by Winkler in 1886, but predicted by Mendeleeff in 1871 as an element to be discovered with properties resembling **silicon.**

Germanium occurs in very small amount in many **sulfide** ores, such as American zinc ores (0 25% GeO_2), and the rare mineral **argyrodite** (silver germanium sulfide) of Saxony, and Bolivia Separated from accompanying metals by fractional **distillation** of volatile germanium tetrachloride, then converted to dioxide, and then reduced to germanium metal by heating with **hydrogen, carbon, or aluminum.** Chemically related to **silicon** and **tin.**

Chlorides Germanium dichloride ($GeCl_2$), white solid, germanium tetrachloride ($GeCl_4$), colorless liquid, boiling point 86° C, from the acid solution zinc metal precipitates germanium metal

Hydroxide Germanous hydroxide ($Ge(OH)_2$), yellow precipitate turning red on heating, formed by reaction of sodium hydroxide solution and germanous salt solutions, soluble in excess sodium hydroxide, germanic hydroxide not known

Oxides Germanous oxide (GeO), gray-black solid, soluble in hydrochloric acid, or sodium hydroxide solution, germanic oxide (GeO_2), white solid, by ignition of germanium metal or sulfide

Sulfides Germanous sulfide (GeS), brown to red precipitate, germanic sulfide (GeS_2), white precipitate, both by hydrogen sulfide with the respective salt solutions

Germanomethane (GeH_4), melting point —165° C, boiling point —90°C, germanoethane (Ge_2H_6), melting point —109° C, boiling point 29° C

Germanium tetramethyl ($Ge(CH_3)_4$), boiling point 43° C, germanium tetraethyl ($Ge(C_2H_5)_4$), boiling point 163° C

Germanochloroform ($GeHCl_3$), boiling point 75° C (R K S)

GERMAN MEASLES. Rubella.

GERMAN SILVER Alloys.

GERMARIUM. I A division of the ovary (See **Gonad**) of **rotifers** in which the eggs are formed 2 A division of the follicles in the testes of insects in which the germ cells are formed but not completely differentiated (A W L)

GERM CELL. A sexual reproductive cell **Gamete.** (A W L)

GERMICIDE Any substance or agent, physical or chemical, which is destructive to germs (**bacteria**) (R S M)

GERMINATION. Seed.

GERM LAYER The three tissues resulting from the first differentiation in the embryonic development of multicellular animals They are usually in layers at their first appearance and are the source of all tissues and organs developed later The three are an outer ectoderm, an inner endoderm, and between the two the mesoderm

Animals of the phyla **Porifera, Coelenterata,** and according to one interpretation the **Ctenophora,** develop only the first two germ layers and are said to be diploblastic Multicellular forms of all other phyla have all three and are therefore **triploblastic.**

The chief parts of the body formed from the various germ layers are as follows In these lists the terms are chosen to embrace both vertebrates and invertebrates and so do not all apply to the same animal

Ectoderm Outer cellular layers of the integument, their glandular derivatives, and the cuticula Exoskeleton and exoskeletal structures such as setae, scales, feathers, hair, claws, hoofs, and nails Parts of sensory organs including the cornea and lenses of all types of eyes, external and internal ears of vertebrates Lining of oral cavities and salivary glands, and in vertebrates the enamel of the teeth Lining of the posterior part of the alimentary tract The entire nervous system of most animals, including the nervous structures in the sense organs A limited amount of muscular tissue Organs of reproduction of some animals Lining or covering of organs of respiration of many invertebrates

Mesoderm Lining of body cavity, circulatory system, water vascular system of echinoderms, and parts of excretory system Muscular tissue Bone Teeth, except the enamel The mesenchymal tissues such as cartilage, connective tissue, adipose tissue, and tendon Blood A limited part of the nervous system of starfishes Reproductive organs

Endoderm Lining of the enteric cavity, including most of the alimentary tract of vertebrates and the limited mid-intestine of arthropods Respiratory epithelium of vertebrates Lining of parts of vertebrate excretory system Reproductive organs and cells (A W L)

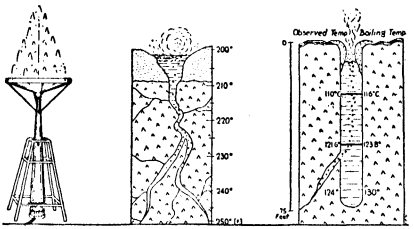
GERM PLASM. The essential reproductive tissue and the germ cells that it produces

The concept of the germ plasm has been emphasized chiefly in the field of organic **evolution.** Since the germ cells of one generation produce both the body (soma, somatoplasm) and the germ plasm of the next, the continuity of this material is evident It had been interpreted as the perpetual living substance, while the material of the body appears as an offshoot in each generation In the one-celled animals, however, there is no differentiation (A W L)

GESTATION. The condition of being with child See **Pregnancy** (R S M)

GEYSER. Derived from the Icelandic word *geysa,* meaning gush and descriptive of hot springs which at regular, or irregular, intervals throw a column of steam and hot water into the air Geyser waters usually build up tubes or conduits of **siliceous** sinter Geyser waters have been proved to be mainly **vadose** with approx-

imately 10 per cent of juvenile or magmatic water. Geyser action is the result of vadose water coming in contact with steam arising from the solidifying **magma,** and periodically returning to the surface through the



The mechanics of geyser action, as illustrated by laboratory experiment, and the hypothetical cross-sections of natural geysers. (Field, *Outline of Geology,* Barnes and Noble.)

geyser tube, for the same reason that water is suddenly expelled from a test tube when heated too rapidly. The mechanics of geyser action are illustrated. The principal geyser fields are in Wyoming (Yellowstone Park), New Zealand, and Iceland. (R.M.F.)

GEYSERITE. A loose or compact, sometimes concretionary, **siliceous** deposit, formed by geysers and hot springs from the material held in solution by the thermal waters. (R.M.F.)

GHOSTS. Diffraction Grating.

GIANT AND DWARF STARS. With the **absolute magnitudes** and **spectral classes** of a number of stars known, a diagram may be plotted showing absolute magnitude as ordinates against spectral class as abscissae. Such a diagram was first published by Russell at Princeton in 1913. He found a number of stars of approximately the same absolute magnitude of all spectral classes running as a horizontal line across the top of the diagram and a series of stars of steadily decreasing absolute magnitude with spectral type changing from B to M. From the shape of the original diagram it became known as the "Figure 7" diagram. In 1905, Hertzsprung had noticed that there was a sharp distinction between M-type stars of high and low luminosity which he referred to as giant and dwarf stars. With

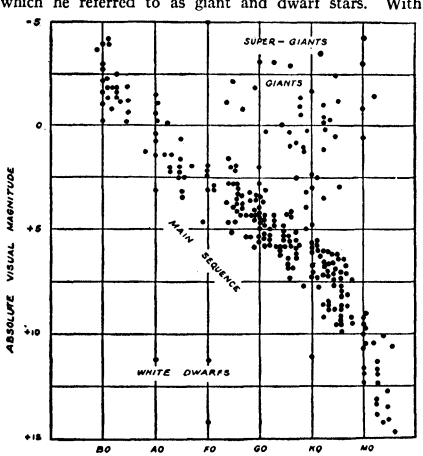


Figure 1. Spectrum-luminosity diagram.

the publication of the figure 7 diagram it became apparent that the distinction between giant and dwarf existed for all spectral types except for blue B-type stars which were apparently all of high luminosity, or giant stars.

As the number of parallax determinations increased and more and more stars were added to the figure 7 diagram, it became evident that the distinction between giant and dwarf was sharply marked only for the M-type stars. Figure 1 indicates the plot for a large number of stars with accurately determined distances. It will be noticed that the great majority of the stars are found in a narrow region extending diagonally across the figure. This is known as the main sequence. The stars which fall above this main sequence are known as giant stars. Among the giant stars the scattering of points is much greater than in the main sequence. Those stars which have greatest luminosity are frequently referred to as the super-giants. The stars which are found below the main sequence are known as the **white dwarfs.** The sun, of spectral class G_0 and absolute magnitude 4.85, is a member of the main sequence. The sun is about 100 times brighter than an M-type star of the main sequence and 100 times fainter than an A-type star.

While the term giant star was originally intended to refer solely to the great luminosity of this sort of star, nevertheless, the term has a far more striking meaning. Since the spectral types of both a giant and a dwarf M-star are approximately the same, the temperatures and hence the brightness per unit area must be approximately the same. However, the total intrinsic brightness of a giant M is of the order of a million times that of a dwarf. Hence, their areas must be in the same ratio and the diameter of the giant M is of the order of magnitude of one thousand times that of the dwarf. Calculations of relative diameters of stars of differing spectral types is a more complicated task, but the diameter to be expected for any type in terms of the known diameter of the sun may be computed. By means of the **interferometer** the diameters of a number of stars have been measured. The close agreement between observed diameters and those calculated from the giant and dwarf hypothesis provides a striking example of the validity of astrophysical theory.

Returning now to the comparison of the giant and dwarf M-types. Studies of the masses of the stars indicate that the ratio of mass of the heaviest to the lightest star is probably not much greater than 300. Using as an assumption that the giant M has a mass 100 times that of the dwarf M, we find that the density of a dwarf M is at least ten million times that of the giant M.

It must be realized that the case we have just been discussing is the extreme to be expected, but even in types other than M the range of densities between the giant and dwarf stars must be enormous. Since difference in density of a gas produces differences in relative intensities of **spectral lines,** we should expect to find differences between the line spectra of giant and dwarf stars of the same spectral type. Such differences have been found and form the basis for the determination of **spectroscopic parallaxes.**

Modern theories regarding the evolutionary sequence of the stars and the conditions in the interior of a star, based upon the giant and dwarf hypothesis will be found in the article on **stars.** With this same article a table will be found giving the physical characteristics of typical giant and dwarf stars. (W.K.G.)

GIBBER. Glyptolith.

GIBBON. Mammalia, Primates. Several species of man-like **apes,** highly adapted for arboreal life. They live in the forests of southeastern **Asia,** especially in the region of the Malay Peninsula.

Gibbons are smaller and of more slender build than the other apes and are among the most agile of all primates in the trees. They have extremely long arms

with which they swing long distances from bough to bough, and their movements are said to be very rapid They differ from the other anthropoid apes in the presence of ischial callosities

Three of the species are known as the siamang, *Symphalangus syndactylus*, hoolock, *Hylobates hulock*, and the wou-wou, *H leuciscus* (A W L)

GIBRALTAR SKULL. Paleontology of Man.

GILA MONSTER. Reptilia, Sauria A poisonous lizard, *Heloderma suspectum*, of the southwestern deserts It attains a length of eighteen inches and is thick bodied, with a stubby tail The skin bears rounded tubercles instead of flat scales and is black or blackish with pink to yellow markings (A W L)

GILBERT. Magnetic Circuit.

GILL. A respiratory organ for the extraction of oxygen from the water and for the liberation of carbon dioxide

Many small aquatic animals absorb oxygen through the surface of the body generally but the more complex forms have localized respiratory organs formed to present an adequate surface They are usually thin plates of tissue or slender tufted processes and with the exception of some aquatic insects they contain blood or coelomic fluid which absorbs oxygen through their thin walls In the insects a unique type of respiratory organ is the tracheal gill which contains air tubes. The oxygen of these tubes is renewed in the gills

Gills are developed in starfishes and sea urchins (See **Echinoidea**) as thin protuberances on the surface of the body containing diverticula of the water vascular system In the **crustaceans, mollusks,** and some **insects** they are tufted or plate like structures at the surface of the body in which blood circulates The gills of other insects are of the **tracheal** type and also include both thin plates and tufted structures, and in the larval dragon fly the wall of the caudal end of the alimentary tract (rectum) is richly supplied with tracheae as a rectal gill. Water pumped into and out of the rectum supplies oxygen to the closed tracheae

Gills of vertebrates are developed in the walls of the **pharynx** along a series of gill slits opening to the exterior Water taken into the mouth passes out of the slits, bathing the gills as it passes In some of the **amphibians** the gills occupy a similar position on the body but protrude as external tufts. (A W L)

GILL BOOK. A series of many thin respiratory plates associated with the jointed appendages of the horseshoe crabs (See **Xiphosura**) (A W L)

GILL CHAMBER. A partially enclosed space containing **gills** In many invertebrates external gills project from the surface of the body Such structures are very delicate and in many species are protected by folds of the body wall The **crayfish** offers a good example, with the **carapace** extended down on each side of the body to form the outer wall of a chamber in which the gills lie (A W L)

GILL FILAMENT. A threadlike component of a **gill.** Also the ciliated ridges of the gills of **bivalve** mollusks. (A W L)

GILL PLATE. The respiratory organ of some **bivalve** mollusks It is formed of two thin plates or lamellae, each made up of united ctenidial filaments (**ctenidium**), and contains passages communicating with the mantle cavity and with the chamber above the **gills.** Water passes into these passages from the mantle cavity. (A W L)

GILL RAKER. A combline structure along the inner margin of the **gill arches of fishes (Pisces).** These combs prevent the passage of food into the gill slits and direct it toward the **oesophagus.** (A W L)

GILL SLIT. A perforation of the body wall of **vertebrates** opening into the **pharynx.** In the fishes (**Pisces**) and **amphibians** the slits are associated with the **gills** but in terrestrial vertebrates they occur only in the embryo and in mammals they usually fail to open The gill slits are paired, opening as a series on each side of the body In the **lampreys** and most cartilaginous fishes (**sharks,** etc) the openings are externally separate but in the bony fishes those of each side are covered by an **operculum.** (A W L)

GILSONITE. Uintaite. The mineral Gilsonite named for S H Gilson of Salt Lake City, is a variety of **asphaltum** that occurs in Uinta County, Utah It is found in black lustrous masses which ignite easily A less frequently used name for it is uintaite (E S C S)

GILT-HEAD. Pisces, Teleostei Marine fishes (**Pisces**) whose heads are marked with gold spots (A W L)

GINGER. *Zingiber officinale* Zingiberaceae Ginger is the **rhizome** of a perennial **monocotyledonous** plant, probably native to tropical Asia The plant apparently no longer exists in the wild state, but is extensively cultivated in tropical countries and islands of both hemispheres In China, the cultivation of ginger has been carried on since earliest times

The plant has a fleshy, irregularly branched rhizome from which arise erect leafy stems two to three feet in height The leaves are grass-like, the flowers, borne on a separate stem, are yellow and of a distinctive shape resembling that of orchids The inside tissues of the rhizome are white and richly spotted with resin dots The plant is propagated by means of rhizome-cuttings, each cutting having an eye or bud which produces an erect stem

When the leaves begin to turn yellow the plant is ready to harvest The rhizomes are dug up and cleaned, then immersed in boiling water to kill the buds or eyes, and also to loosen the periderm or outer portion The rhizomes are then peeled and dried

Ginger is used principally as a condiment and as an aromatic stimulant A volatile oil, gingeral, is responsible for the characteristic odor, while a resinous substance produces the hot biting taste Much ginger is used in preparing ginger ale Formerly quantities of the rhizome were used in making Jamaica ginger Ginger also appears on the market in another form, preserved ginger, a Chinese product made from uncured rhizomes (R M W)

GINGIVITIS. Inflammation of the gums (R S M)

GINKGO. Paleobotany; Maidenhair Tree.

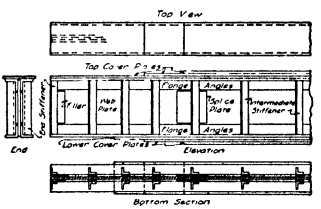
GINKGOALES. Paleobotany.

GINSENG. *Panax Ginseng* and *P quinquefolium* Araliaceae The thick roots of the two species of ginseng, the first a native of Manchuria, the second of North America, are of curious interest because of the significance attached to their use The plants are low-growing perennial herbs having compound leaves and compound **umbels** of small white flowers They grow best in rich shady woods of hardwood trees Even in cultivation they are usually grown in such localities When mature, the thick fleshy roots are removed from the ground very carefully to avoid any damage They are then dried, and marketed Their chief users are the Chinese, who attribute to the roots wonderful curative properties, which modern research has failed to verify Especially valuable, from the primitive viewpoint, are roots having the general form of the human body, two lateral branch roots near the top simulating the arms, and a **dichotomy** in the lower half resembling two legs Formerly such a root would be worth its weight in gold, but today the Chinese are becoming gradually educated by modern science away from such beliefs (R M W)

GIRAFFE. Mammalia, Artiodactyla. *Giraffa* Large African animals with unusually long necks and legs The head bears a pair of stubby hornlike structures, covered with skin Giraffes are marked with large irregular brown spots on a lighter ground but this pattern is said to be inconspicuous in their natural habitat. (A W L)

GIRDER. A girder is a large heavy beam capable of carrying both concentrated and uniformly distributed loads Large rolled steel beams are frequently called girders although the name is generally applied to large beams which are made up of rolled steel sections connected by rivets or welding In concrete construction the large beams which are used to support smaller beams are called girders A girder, like a beam, resists transverse bending, and is loaded, ordinarily, by gravity load which is transferred by the girder to its supports The common plate girder is a compound steel structure composed of plates and angles, bound together in one structure by the use of rivets or welding **Plate girders** are used where strength requirements cannot be met by the largest available rolled steel sections Due to their adaptability, plate girders are to be found in almost every form of construction embodying steel **Bridges, cranes,** and buildings, show many examples of the plate girder

The built-up plate girder roughly resembles an **I-beam** in shape Its area may be thought of as subdivided into area of flanges and area of web The flange sections are most useful in withstanding the bending, and the web resists most of the **shear** to which a girder is subjected The arrangement of plates and angles in a plate girder is shown in the accompanying figure



Principal parts of a plate girder

As shown in the figure, the girder is built up of a web plate whose depth is nearly equal to the full depth of the girder, flange angles which are riveted near the top and bottom of the web plate and cover plates that are riveted to the flange angles Since the flange chiefly resists bending, and bending moment is greatest at the center of a girder (for ordinary load conditions) the cover plate could be of a thickness increasing from minimum at the abutment to maximum at midspan It is not practicable to specify a tapered plate, but the same effect is achieved by subdividing the total maximum required cover plate area into a number of plates in laminar arrangement, and achieving the taper effect by cutting off the plates where reduction of bending stress permits Localized buckling of the web must be resisted in order to permit the girder to develop its full strength For this purpose stiffeners, consisting of angles arranged vertically, and riveted to the web and to the flange angles, are spaced periodically along the length of the girder These are called stiffener angles, and may be smaller than the flange angles

As the girder carries load by beam action, the **flexure** theory applies The problem of design of plate girders begins with the computation of bending moment and shear Generally, bending moment governs the design. A cross-section of the girder is then assumed, and the **moment of inertia** of the same computed. This moment of inertia must be such as to fit into the common flexure formula

$$\frac{M}{p} = \frac{I}{y}$$

and give a value of p which is within the safe working stress, but which is not uneconomically low In the above equation, I is the moment of inertia of the section of the girder about its neutral axis, M is the bending moment, p is the working unit stress of the metal, and y is the distance from the neutral axis at the most stressed fiber of the girder, generally, at the extreme edge of the flange

Most authorities require that the design of an important girder be carried through with an exact computation of the moment of inertia of some assumed section If a determination of an economic section is made by trial and error, this moment of inertia method of design may become quite tedious The number of trials can be greatly shortened if some approximation, which would guide the designer towards a correct selection of the proper structural shapes, could be employed Such a method is outlined below It is based on the assumption that a girder is made up of a simple rectangular web connecting rectangular flanges Let the area of the web be w, and the area of each flange f, while the distance between the centers of gravity of the area of the flanges is h The moment of inertia of this assumed area about the neutral axis which is taken to be on the axis of symmetry, is

$$I = \frac{h^2}{2}(f + w/6).$$

If this expression be substituted in the flexure formula mentioned above, and note be taken of the fact that $y = \frac{h}{2}$, the flange area f is found to be given by the following equation

$$f = \frac{M}{ph} - \frac{w}{6}$$

As ordinarily given in structural texts, this formula represents the net flange area (area with rivet holes deducted) Consequently it has w divided by 8 instead of 6, the difference being accounted for by deduction of a certain amount of web area to account for rivet holes If the flexure is obtained by some rapid estimating system, such as this flange area method, an arrangement of commercially procurable steel shapes can be set up, and the exact **moment of inertia** accurately established by the principles of **mechanics.**

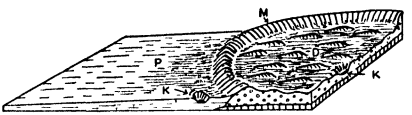
The complete design of a steel plate girder includes also such problems as determining the riveting pitch in the flanges, the design of splices in the web plate, the spacing and riveting of stiffeners, and the strengthening of the ends by end stiffeners where the girder bears on its supports (F T M)

GIRDLE 1 The part of the mantle of a **chiton** which surrounds the shell plates 2 The skeletal structures of **vertebrates** by which the appendages are associated with the trunk **Skeletal system** (A W L)

GIZZARD. A region of the alimentary tract (See **Digestive system**) with thick muscular walls and some adaptation for grinding food The gizzards of birds are the best known examples They have a tough lining and their grinding action depends on the movements of hard particles such as gravel contained in them One of the fishes, the **gizzard shad,** has a stomach of similar nature Many insects also have a gizzard but in this organ the supposed grinding structures are chitinous folds and teeth projecting into the cavity The grinding action of the organ has been questioned by some **observers.** (A W.L.)

GIZZARD SHAD Pisces, Teleostei. A widely distributed North American fish (**Pisces**) whose stomach is developed like the **gizzard** of a bird. It occurs in both fresh and salt water (A W L)

GLACIAL DEPOSITS DRIFT. The general term for glacial deposits, or sands, gravels, boulders, etc, which are the result of mountain or continental glaciation, is drift Drift is classified as either stratified drift, the result of deposition by waters from the melting glacier, or, till (unstratified drift) which is apt to be coarsely graded sediments composed of clay, sand, gravel and boulders Till may grade, in places, into stratified drift, but is principally transported and deposited by the ice Both stratified drift and till also form distinctive topographic features, to such an extent that both mountain ranges and even broad continental areas which have been subjected to glaciation can not be described as having been subjected to the normal cycle of **erosion** When a glacier advances over old drift it may form cigar-shaped hills, called **drumlins,** whose longer axes are relatively parallel with the movement of the ice **Till,** which is built up into long mounds and ridges at the frontal margin of the ice sheet forms significant topographic features called mo-



Block diagram showing a terminal moraine, M, an outwash plain, P, drumlins, D, and kettle holes, K (Modified after A Penck)

raines The waters coming off from the front of a melting ice sheet deposit great sheets of stratified gravels, sands and clays If ice-blocks have been covered by the outwash, when these ice-blocks finally melt they leave depressions in the outwash plain which fill with ground water to form ponds and lakes These depressions are called kettle holes (R M F)

GLACIER Wherever upon the earth's surface the temperature is sufficiently low and there is sufficient precipitation to produce a permanent snow field, there may glaciers be found Other things being equal, perpetual snow is more likely to be found in high latitudes and high altitudes, as examples we have the extensive snow and ice field on Greenland and the Antarctic continent as well as valley glaciers of the Alps, of Alaska, the Rocky Mountains, the Andes, the Himalayas and elsewhere Repeated thawing and freezing of the snow in perpetual snow fields permit the formation of coarse granular ice called nevé which passes into ice of the usual sort On slopes, the accumulated ice will eventually begin to move, and as it fills a mountain valley, becoming literally a river of ice, it may be called a valley glacier Even in the absence of great slopes ice will only accumulate to a limited thickness before it commences to spread out in all directions from its place of accumulation Such a mass of ice is called a continental ice sheet or continental glacier, Greenland is an example of such a sheet of continental ice The exact mechanics of ice movement is not definitely known, but the general process is frequently spoken of as regelation. (R M F)

GLAND. An organ of epithelial structure that produces secretions necessary to the system, or that excretes waste materials from the system Glands vary greatly in form and complexity and in the nature of their products

The simplest glands are unicellular In the glandular lining of the intestine (See **Digestive System**) for example, are isolated cells which secrete mucus They are known as goblet cells because the mucus accumulates in a clear ovoid mass above the constricted base of the cell, approximating the form of a goblet

Multicellular glands develop from the epithelial layers by local increase of cells and consequent expansion of

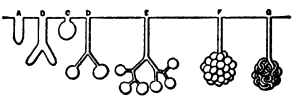


Diagram showing development of glands, *A*, a mere dimple in the surface or a simple tubular gland, *B*, enlargement by division or a branched tubular gland, *C*, enlargement by dilatation or a saccular gland, *D*, a combination of *B* and *C* or a branched saccular gland, *E*, a compound saccular or a racemose gland, *F*, development of method of *E*, *G*, a single tube intricately coiled or a convoluted tubular gland (From Kimber and Gray, *Textbook of Anatomy and Physiology,* Macmillan & Co)

the layer into adjacent spaces or tissues They include tubular, acinous, and alveolar structures Tubular glands are slender tubes lined with glandular epithelium, acini are rounded groups of cells with a small central cavity, and alveoli are larger rounded chambers lined with glandular cells Tubular glands may branch or coil Many of the larger glands of the body, including the **pancreas** and **salivary glands,** are made up of great numbers of acini borne by complex branching ducts These glands are said to be compound In the most complex forms the secretion may leave the cells by minute canals, or similar canals between the cells may conduct it to the cavity of the acinus This cavity empties into a short thin-walled intercalated duct, followed by a short secretory duct lined with gland cells, and this in turn by the excretory duct These smaller ducts join to form larger and larger passages, ultimately reaching the main duct which delivers the secretion of the entire gland to its destination

Glands may be divided into three kinds

Glands of External Secretion
Glands of Internal Secretion
Glands having both External and Internal Secretion

Glands which produce cells are known as cytogenic glands They include the reproductive glands (See **Gonad**) which produce germ cells and the **spleen, lymph** glands, and red bone marrow, in which blood cells develop

Special glands are derived from all germ layers and are associated with all organic systems They serve for lubrication, to prevent drying, for defense, in reproduction, and in many other ways (See also **Endocrine Glands.**) (A W L, R S M)

GLANDERS (MALLEUS, FARCY). A chronic or acute infectious disease of horses which is occasionally communicated to humans Multiple abscess formation, especially of the skin and mucus membranes characterize the disease

This disease is rarely seen at present as contrasted with the past, when horses were more common

The acute form is usually fatal

The disease is caused by the *actinobacillus mallei* (R S M)

GLASS. Glass is defined as "a liquid whose rigidity is great enough to enable it to be put to certain useful purposes" (Morey) The term "rigid liquid" includes the naturally occurring rock glasses, such as **obsidianite,** and the industrially formed metallurgical **slags.** Glasses, glazes of pottery, enamels on steel, obsidianite, fused quartz ware, and slags are all formed by rapidly cooling a previously molten mass without allowing sufficient time for crystallization to occur during the cooling process (undercooling) The viscosity characterizing liquids is absent, and the material appears to be solid

Common glass is essentially a sodium calcium **silicate** in composition. In preparing the raw materials for the charge, **sodium** is supplied as soda ash (sodium carbonate, Na_2CO_3) or salt cake (sodium sulfate, Na_2SO_4), with **carbon** to reduce the **sulfate, calcium** as **limestone** (calcium carbonate, $CaCO_3$) or burnt lime (calcium oxide, CaO), and **silicon** as **quartz,** usually in the form of silica sand (silicon oxide, SiO_2), along with "cullet" or broken glass to assist in the fluxing and melting.

A representative charge for common glass is 100 parts by weight of silica sand, 35 of soda ash, 12 of lime, and 10 of niter (**sodium** nitrate, $NaNO_3$), which supplies some of the sodium and serves to oxidize ferrous to ferric. For plate glass one of the charges used is 100 parts by weight of silica sand, 32 of soda ash, 6.5 of salt cake, 0.3 of charcoal, and 32 of limestone. All materials of the charge that are not volatilized in the process remain in the glass produced. The green color due to the presence of ferrous iron, of much common glass is accounted for by the presence of **iron** in some of the materials of the charge. To produce colorless glass when iron is present, sodium nitrate or manganese dioxide is usually added. To produce colored glass small amounts of the desired coloring materials are added to the charge, for example, **cobalt** oxide for blue glass, **manganese** oxide for violet, **gold** or **selenium** for red, **uranium** oxide or **silver** for yellow, **ferric** oxide for brown. Addition of **calcium** fluoride, **arsenic** trioxide, **aluminum** oxide, **zinc** oxide, **calcium** phosphate, one or more, produces opalescent white glass, while black glass is produced by **iridium** oxide or mixtures of other oxides, such as those of cobalt, iron, nickel, manganese.

The raw materials are heated to a high temperature in a furnace either in individual pots or in hearth or tank furnaces. When the whole mass has been fused, time is allowed for the escape of gases, and then the liquid is withdrawn and worked. The working depends upon the unique property possessed by glass of being shaped while in a heated state, by blowing, molding or rolling, and retaining the shape upon being cooled. The range of temperature through which glass is thus workable, and its viscosity in this range are important considerations.

For special purposes the composition of glass may be varied considerably. **Potassium** may be substituted for **sodium, lead** or **barium** for **calcium;** the ratio of these to silicon may be decreased markedly; and, finally, **boron,** which functions somewhat as **silicon,** is available. Illustrative analysis of various glasses are the following:

ANALYSES OF VARIOUS GLASSES

Kind of Glass	Silicon Oxide	Sodium Oxide	Potassium Oxide	Calcium Oxide	Barium Oxide	Zinc Oxide	Lead Monoxide	Aluminum Oxide	Boron Oxide	Remainder
Common bottle—3 samples	70–73	11–18	.....	7–17	.....	.....	.....	.....	.....	1.6–2.8
Window and plate—4 samples	71–73	12–14	.....	11–16	.....	.....	.....	.....	.....	0.1–1.3
Tableware and electric bulbs —2 samples	54–57	11–2	1–10	0.1–1.3	.....	.....	30–33	.....	.....	0.3–1.6
Optical instrument—										
n_D = 1.6555	20.0	.....	.....	.....	.....	.....	79.9	.....	.....	0.1 arsenic trioxide
1.5905	39.6	.....	.....	2.0	44.0	7.7	3.0	.....	5.0	0.4 arsenic trioxide
1.5179	68.5	12.0	5.0	.....	9.7	1.0	.....	.....	3.5	0.2 arsenic trioxide
Chemical and heat resistant:										
Pyrex (n_D = 1.47)	80.6	3.8	0.6	0.2	.....	.....	.....	2.0	11.9	0.9
Jena	64.4	7.3	.....	0.1	.....	11.7	.....	6.3	10.0	0.2

Blast furnace slag has an approximate analysis somewhat as follows: **calcium** oxide 43%, **magnesium** oxide 2%, **aluminum** oxide 15%, **silicon** oxide 35%, residue—chiefly **ferrous** oxide plus **manganous** oxide plus **calcium** sulfide—5%.

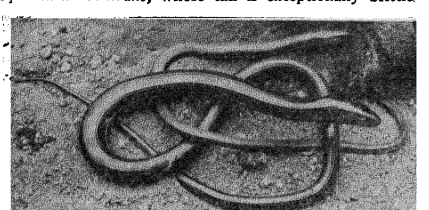
Obsidianite has the following approximate analysis: calcium oxide 1%, **sodium** oxide 4%, **potassium** oxide 4%, aluminum oxide 14%, silicon oxide 75%, ferric oxide 1%, ferrous oxide 0.5%, iron disulfide 0.5%, water 0.5%.

When glass is cooled rapidly strains are set up in it but up to a certain point the resistance to shock, and to rapid, moderate changes of temperature is increased; but on scratching it is subject to shattering. To increase this effect, glass is sometimes cooled rapidly by immersion in oil, as for lamp chimneys. To decrease this effect, glass is usually cooled slowly or annealed as for lenses. Very slow cooling, and aging cause devitrification of glass. Such glass crystallizes and is readily shattered.

Quartz glass, unlike ordinary glass, is transparent to **ultraviolet rays,** and is, therefore, used in the **mercury arc lamp.** Sodium vapor lamps require a boro-silicate glass. Heat absorbing glass, useful for sky lights, is made so that it is effective in removing one-half of the infrared or heat rays of sunlight. Safety or laminated glass is made by cementing together sheets of hardened glass by a thin layer of **cellulose** acetate or some other plastic. Such glass does not scatter when it fractures.

The system sodium (or potassium) oxide—calcium oxide—silicon oxide has been determined by Morey and coworkers. The lowest melting mixture, namely 5% sodium oxide, 20% calcium oxide, 75% silicon oxide, was found by them to have a melting temperature of 725° C. The system calcium oxide—aluminum oxide—silicon oxide, has been determined by Rankin and coworkers. (See **Cement.**) (R.K.S.)

GLASS SNAKE. Reptilia, Sauria. A legless **lizard,** *Ophisaurus ventralis,* **whose tail is exceptionally brittle.**



Glass snake, *Ophisaurus ventralis.* (Courtesy of *N. Y. Zoological Society.*)

Although snakelike it may be recognized as a lizard by its small ventral scales and its eyelids. Central and southern states. (A.W.L.)

GLAUBER'S SALT. Sodium sulfate decahydrate.

GLAUCOMA. A common disease of the eye which usually occurs in later life The exact cause of this disease is unknown There is frequently an hereditary history **Arteriosclerosis** and cardiac disease are often present

The symptoms of glaucoma are due to an increase of the pressure within the eye-ball and the accompanying venous congestion In the acute form there is diminishing or failure of vision, pain in the eye and severe headache

The disease may be rapid or insidious in onset Untreated, the disease terminates in blindness of both eyes. (R S M)

GLAUCONITE. Glauconite is a hydrous **silicate** of **potassium** and **iron** of somewhat variable composition It has a dull green color and is often a constituent of marine deposits forming "green sand" It is believed to have been produced through the alteration of iron-bearing silicates chiefly **biotite** and possibly **augite** and **hornblende.** It occurs along the Coastal Plain of the Atlantic and Gulf States Frequently found filling the interiors of the shells of globigerina, a common genus of the **foraminifera** (protozoa) Since globigerina occurs as a deep sea deposit many European geologists have claimed that glauconite is only found in deep water On the other hand typical "greensands" occur associated with sand and clays which are certainly of shallow marine origin Glauconite derives its name from the Greek word meaning bluish green (R M F)

GLAUCOPHANE. Glaucophane, essentially a complex **silicate** of **sodium,** and **iron** or **aluminum** $Na(Al,Fe)(SiO_3)_2$, is a rather rare mineral although it has been noted from widely separated occurrences It is **monoclinic** and ordinarily is fibrous or granular It is brittle, hardness, 6–6 5, specific gravity, 3–3 1, color, azure blue, blackish blue or gray, luster, vitreous to pearly, translucent to opaque Glaucophane is found only in the **metamorphic** rocks sometimes forming glaucophane schists It is found in Switzerland, Italy, Siberia, Japan and in the United States chiefly in the rocks of the Coast Ranges in California and Oregon The name glaucophane is derived from the Greek words meaning *bluish green,* and *appear* (E S C S)

GLIDER. The glider is an **aircraft** obtaining its sustension from **aerodynamic** forces created by a wing of **airfoil** section Unlike the airplane, the glider has no engine, and must depend either on gravitational energy obtainable by gliding down a slope, or upon a tow furnished by an automobile or other surface vehicle The sailplane, or soaring glider, a refinement of the glider, is a more expensive, less rugged, and aerodynamically more efficient craft It is so light and is built with so low a wing loading, (i e, pounds per square foot wing area) that in the presence of upwardly directed air currents, such as are present along the windward slopes of mountain ranges, its sinking speed being lower than the upward component of air velocity, it is able not only to remain aloft, but actually to mount upwards considerable distances

The glider appears to have two definite spheres of usefulness first, like yachting, it furnishes, to a high degree, an entertainment of a sporting nature This is especially true of the sport of soaring Secondly, since its controls are the same as those of the conventional airplane, it offers a means of preliminary pilot training at a minimum cost It is said that one unable to coordinate the controls in a glider, can not master a power plane The United States Navy is outstanding in its use of the glider in determining piloting caliber of new recruits

There are two classes of gliders, primary and secondary The primary glider is relatively heavy, and crudely constructed. It is built around a keel or backbone rather than a fuselage, and there is no attempt to streamline the pilot's seat. Due to its steep gliding angle, flights in it are necessarily short This type of glider has but little usefulness, and is not frequently built nowadays The secondary glider, sometimes called dual purpose or trainer glider, is more ruggedly built than the sailplane, and stands rougher usage, but will soar when subjected to the best wind conditions Usually it is constructed as a single place, high wing monoplane, with steel tube or wooden fuselage covered with fabric The forward end is smoothly rounded and a detachable cockpit cover is slipped into place before soaring flights The landing gear may consist either of a skid or a single wheel, aided by skids fore and aft The controls are exactly the same as those of an **airplane,** but the light wing loading makes the glider much more sensitive to wind currents Consequently, it is provided with extra large control surfaces in the form of aileron, elevator, and rudder.

To describe the operation of a glider, an example might be made of elementary training with auto tow A tow rope varying from 75 to 200 feet in length, depending on the height of the flight, is attached to a special release hook in the nose of the glider The pilot takes the seat, and is strapped in The instructor rides on the tow car The car is then started, and until flight control is attained, an assistant must run alongside, steadying a wing tip As the car accelerates to the take-off speed of the glider, usually 15 to 25 miles an hour, the glider is taken off the ground by depressing the tail with the use of the elevator This increases the **angle of attack** of the wing, causing the lift provided by it to overcome the dead weight of the glider After a short climb to a moderate height, the glider is leveled off, and by means of a latch, the pilot releases his craft from the tow rope, and executes a normal glide to the ground Depending on the altitude he attains, and his proficiency in handling of the glider, he may elect to make a straightaway glide, S turns, a 180° turn, or a complete 360° circuit of the field (F T M)

GLOBIGERINA OOZE. Oceanic Deposits.

GLOBULINS. Aminoacids, Polypeptides and Proteins.

GLOCHIDIUM. A larval form of fresh-water bivalve mollusks which lives as a parasite in the gills or skin of fishes (A W L)

GLOMERATE. The textural term, proposed by R M Field, for a **sedimentary rock** with a coarse and poorly graded texture, when the origin of the shape of the larger constituents has either been undetermined or is indeterminable. (R M F.)

GLOSSA. Labium.

GLOSSITIS. Inflammation of the tongue. (R S M)

GLOSSOPTERIS. Paleobotany.

GLOTTIS. The opening from the **pharynx** or throat of vertebrates into the **trachea.** (A W L)

GLOW DISCHARGE. Ionized Gases.

GLOW WORM. Insecta, Coleoptera. Wingless females of certain **beetles.** They resemble larvae throughout life and are luminous (A W L.)

GLUCINUM. Beryllium.

GLUCOSE. Carbohydrates.

GLUCOSIDES. Glucosides are substances that by reaction with water, either in presence of certain **enzymes** or of dilute acids or alkalis, yield a sugar, commonly **glucose**, as one of the products, plus a principal characteristic of the individual glucoside Most glucosides are soluble in cold or hot water, and in alcohol (95% C_2H_5OH), and insoluble or slightly soluble in ether (used to separate from alcohol solution) Most optically active glucosides are laevo-rotatory The di- and polysaccharides are to be considered as glucosides Glucosides occur in plants, especially in leaves, buds, young shoots where **metabolism** is active, and in the bark and seeds **Anthocyanins,** the plant colors of flowers, are glucosides, as are also some **tannins.**

SELECTED REPRESENTATIVE GLUCOSIDES

Glucoside	Formula	Melting Point, °C.	Hydrolysis	
			Sugar	Principle
1. Aesculin in horsechestnut bark	$C_{15}H_{16}O_9$ $1\frac{1}{2}H_2O$	205	glucose	aesculetin
2 Amygdalin in peach kernels, cherry laurel leaves, bitter almonds	$C_{12}H_{16}O_7$ $3H_2O$	200 (anhyd)	glucose glucose	mandelocyanides glucoside benzaldehyde + hydrocyanic acid
3 Arbutin in bearberry leaves	$C_{12}H_{16}O_7$ $\frac{1}{2}H_2O$	165	glucose	hydroquinone
4 Coniferin in sap of coniferous trees	$C_{16}H_{22}O_8$	185	glucose	coniferyl alcohol
5 Dhurrin in sorghum seedlings, millet	$C_{14}H_{17}O_7N$		glucose	para-hydroxy-benzaldehyde + hydrocyanic acid
6 Digitalin in digitalis	$C_{35}H_{56}O_{14}$	217	glucose	digitaligenin, digitalose
7 Digitonin in digitalis	$C_{55}H_{90}O_{29}$	235 approx decom	glucose galactose	digitogenin
8. Digitoxin in digitalis	$C_{34}H_{54}O_{11}$	240 (anhyd)	digitoxose	digitoxigenin
9. Helleborein	$C_{27}H_{46}O_{18}$	200–230 decom	glucose	helleboretin
10 Hesperidin in unripe oranges	$C_{50}H_{60}O_{27}$	251	glucose rhamnose	hesperetin
11. Indican in natural indigo	$C_{14}H_{17}O_6N$ $3H_2O$	100 (anhyd)	glucose	indigo
12. Phloridzin in bark of fruit trees	$C_{21}H_{24}O_{10}$ $2H_2O$	108 Remelts 170 decom	glucose	phloretin
13 Quercitrin	$C_{21}H_{22}O_{12}\cdot 2H_2O$	168 decom (anhyd)	glucose rhamnose	quercitin
14. Salicin in willow trees, used in medicine	$C_{13}H_{18}O_7$	201 Remelts 235 approx	glucose	saligenin
15 Saponin in soapwort root, forms foam with water, toxic to cold blooded animals	$C_{32}H_{52}O_{17}$	195 decom	sugar	sapogenin
Tannins in nut galls			glucose	gallic acid
Anthocyanins Red (with acids), violet (free), blue (with alkalis) pigments of flowers		.		anthocyanidins
Cyanin	$C_{15}H_{10}O_6$		glucose	cyanidin
Idaein			galactose	cyanidin
Pelargonin	$C_{15}H_{10}O_5$			pelargonidin
Delphinin	$C_{15}H_{10}O_7$	. .	glucose	delphinidin + para-hydroxy-benzoic acid (R K S)

GLUE. Glue is the product of **hydrolysis** of **proteins,** usually of animal origin Waste products of slaughterhouses (i e hide clippings, hoofs, etc) are the source of most commercial glue (R K S)

GLUME. A glume is an empty **bract,** often chaff-like, which occurs at the base of the **spikelet** in grasses Usually there are two to each spikelet (R M W)

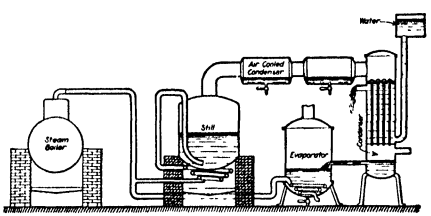
GLUTELINS. Proteins.

GLUTTON. Wolverine.

GLYCEROL. Glycerol, propantriol, glycyl alcohol, "glycerine" (CH_2OH $CHOH$ CH_2OH) is a colorless, viscous liquid, of sweetish taste, odorless, boiling point 290° C , or at 12 mm. pressure 170° C , gradually solidifies at 0° C to solid, melting point 18° C , miscible in all proportions with water or alcohol, insoluble in ether or chloroform, absorbs water on exposure to the atmosphere Glycerol reacts (1) with **phosphorus** pentachloride to form glyceryl trichloride (CH_2Cl $CHCl$ CH_2Cl), (2) with **acids** to form **esters,** e g glycerol monoacetate (CH_2OH $CHOH$ CH_2OOCCH_3), glycerol diacetate ($C_3H_5(OH)(OCOCH_3)_2$), glycerol

triacetate, triacetin ($CH_2OOCCH_3 \cdot CHOOCCH_3 \cdot CH_2OOCCH_3$), glycerol mononitrates (alpha, $CH_2OH \cdot CHOH\ CH_2ONO_2$, beta, $CH_2OH\ CHONO_2\ CH_2OH$), glycerol dinitrates (1,2, $CH_2OH\ CHONO_2\ CH_2ONO_2$, 1,3, $CH_2ONO_2\ CHOH\ CH_2ONO_2$), glyceryl trinitrate, "nitroglycerine" ($CH_2ONO_2\ CHONO_2\ CH_2ONO_2$), glyceryl tristearate, tristearin ($CH_2OOCC_{17}H_{35}\ CHOOCC_{17}H_{35}\ CH_2OOCC_{17}H_{35}$), indirectly, glycerol monophosphates (alpha, $CH_2OH\ CHOH\ CH_2OPO(OH)_2$, beta, $CH_2OH\ CHOPO(OH)_2\ CH_2OH$) (3) with oxidizing agents, e g, dilute **nitric acid**, to form glyceric acid ($CH_2OH\ CHOH\ COOH$), tartronic acid ($COOH\ CHOH\ COOH$), mesoxalic acid ($COOH\ CO\ COOH$), (4) with **phosphorus** plus **iodine**, to form allyl iodide ($CH_2\ CHCH_2I$), which with **hydrogen iodide** yields propylene ($CH_3\ CHCH_3$) and then iso-propyl iodide (CH_3CHICH_3), (5) with **sodium** or sodium hydroxide to form alcoholates, (6) with **sodium** hydrogen sulfate or **phosphorus** pentoxide heated, to form **acrolein** ($CH_2\ CHCHO$) Glycide alcohol ($CH_2OH\ CH\ CH_2$) is obtained by treatment of glycerol alpha-monochlorohydrin ($CH_2OH\ CHOH\ CH_2Cl$), which is made by reaction of hypochlorous acid and allyl alcohol with barium hydroxide With **hydrogen chloride**, glycide alcohol yields epichlorohydrin ($CH_2Cl\ CH\ CH_2$)

Glycerol is obtained (1) from vegetable and animal oils and fats, most of which are mainly glycerol esters



Apparatus used in the recovery of glycerol

of **stearic, palmitic** and **oleic acids** by treatment with alkali (**sodium** hydroxide commonly used), **acid** (sulfobenzone—or naphthalene—stearic acid, "Twitchell's reagent"), superheated steam, or an **enzyme** (lipase of castor beans) Glycerol is recovered from the water solution by **evaporation** under diminished pressure, and purified by treatment with decolorizing **carbon** followed by **filtration**, (2) by **fermentation** of glucose in the presence of **yeast** and **sodium** sulfite

Glycerol may be detected by the characteristic odor of **acrolein**, found on heating with **potassium** bisulfate

Glycerol is used (1) in the manufacture of high **explosives**, e g, glyceryl trinitrate ("nitroglycerine"), which is the main component of dynamite, (2) in antifreeze solutions, especially for automobile radiators

% Glycerol by Weight	Specific Gravity 60° F	Freezing Point, °F.
20	1 040	23
40	1 103	4
60	1 158	−28

(3) to maintain a moist condition in fruits and tobacco, (4) in cosmetics and skin preparations, (5) to prepare glycerol phosphoric acid, used in medicine, and "boroglyceride" used as a preservative (R K S)

GLYCINE. Aminoacids, Polypeptides, and Proteins.

GLYCOCOLL. Aminoacids, Polypeptides and Proteins.

GLYCOGEN. Carbohydrates.

GLYCOL. Glycol, ethylene glycol, ethandiol, ($CH_2OH\ CH_2OH$) is a colorless, viscous liquid, of sweetish taste, odorless, boiling point 197° C, miscible in all proportions with water or alcohol, slightly soluble in ether Glycol reacts (1) with **sodium** to form sodium glycol ($CH_2OH\ CH_2ONa$) and disodium glycol ($CH_2ONa\ CH_2ONa$), (2) with **phosphorous** pentachloride to form ethylene dichloride ($CH_2Cl\ CH_2Cl$), (3) with **carboxy acids** to form mono- and di- substituted esters, e g, glycol monoacetate ($CH_2OH\ CH_2OCOCH_3$), glycol diacetate ($CH_3COOCH_2\ CH_2OOCCH_3$), (4) with nitric acid (with sulfuric acid), glycol mononitrate ($CH_2OH\ CH_2ONO_2$), glycol dinitrate ($CH_2ONO_2\ CH_2ONO_2$), (5) with **hydrogen chloride**, heated, to form glycol chlorohydrin (ethylene chlorohydrin, $CH_2OH\ CHCl$), (6) upon regulated oxidation to form glycollic aldehyde ($CH_2OH\ CHO$), glyoxal ($CHO\ CHO$), glycollic acid ($CH_2OH\ COOH$), glyoxalic acid ($CHO\ COOH$), **oxalic acid** ($COOH\ COOH$) In the preparation of glycol derivatives, important substances are (a) the sodium glycols, (b) ethylene dichloride (1,2-dichloroethane), best prepared by reaction of **ethylene** and **chlorine**, (c) ethylene chlorohydrin (1-hydroxy-2-chloroethane), best prepared by reaction of ethylene and **hypochlorous acid** From these are readily made respectively, (a) **ethers**, e g, glycol monoethyl ether ($CH_2OH\ CH_2OC_2H_5$), glycol diethyl ether ($CH_2OC_2H_5\ CH_2OC_2H_5$), (b) ethylene diamine ($CH_2NH_2\ CH_2NH_2$), ethylene dicyanide ($CH_2CH\ CH_2CN$), glycol itself, (c) hydroxyethylamine ($CH_2OH\ CH_2NH_2$), ethylene cyanhydrin ($CH_2OH\ CH_2CN$), ethylene oxide (by sodium hydroxide $\left.\begin{matrix}CH_2\\ |\\ CH_2\end{matrix}\right\rangle O$) Glycol is made by reaction of ethylene and chlorine or hypochlorous acid to form ethylene dichloride or ethylene chlorohydrin, respectively, followed by treatment of either of these with sodium carbonate solution heated under pressure Glycol is also formed when ethylene is treated with **potassium** permanganate Glycol is used (1) in antifreeze solutions, especially for automobile radiators, (2) in the preparation of **ethers** and **esters**, especially nitrate for explosive, (3) as a solvent, substitute for glycerol (R K S)

Percentage of Glycol by Volume	Specific Gravity, 60° F.	Freezing Point, °F.
17	1 026	20
32 5	1 048	0
44	1 063	−20

GLYCOLLIC ALDEHYDE. Aldehydes, Ketones, and Related Compounds

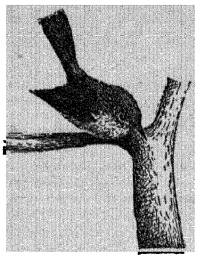
GLYCOSURIA The presence of excess **sugar** in the **urine** It is a normal accompaniment of the ingestion of large amounts of sugar—the excess being passed off by the **kidneys.** This is termed alimentary glycosuria In some people extreme emotional stress or fright may produce an excess of sugar in the urine Another form of glycosuria occurs with injuries or tumors of certain parts of the brain Still another form occurs in some individuals in whom, regardless of the sugar intake, a certain amount of sugar is passed into the urine Here the kidneys are said to have a low threshold for sugar The condition is called renal glycosuria and is without pathological significance Glycosuria is also seen in certain disorders of the thyroid and pituitary glands

In **diabetes,** of course, sugar is a constant finding in the urine in conjunction with other manifestations of the disease (R S M)

GLYPTOLITH. Dreikanter.

GNAT. Insecta, Diptera Loosely applied to many small two-winged **flies.** In such names as **buffalo gnat, gall gnat,** and **fungus gnat** it applies to specific groups. (A W L)

GNATCATCHER. Aves, Passeriformes. Small birds related to the **kinglets.** One, the blue-gray gnatcatcher, *Polioptila caerula*, ranges over North America east of the Rockies and two other species occur in the southwestern states. (A.W.L.)



Blue gray gnatcatcher. *Polioptila caerulea.* Bluish gray above, grayish white below. Outer tailfeathers white; inner ones black. Narrow black border on front and sides of head. Four and one-half inches long.

GNATHOBASE. The base of an appendage of the **arthropods**, formed for crushing food. **Spiders,** horseshoe crabs, and **scorpions** chew their food by such means. The gnathobases of a pair of appendages act together like the **mandibles** of other arthropods. (A.W.L.)

GNATHOCHILARIUM. The posterior element of the mouth parts of **millipedes.** It is formed of a pair of appendages and is similar to the **labium** of insects. (A.W.L.)

GNATHOPOD. Appendages of crustaceans (**Amphipoda**) used for grasping food. (A.W.L.)

GNEISS. The gneisses are common and widely distributed rocks which have been derived by **metamorphic** processes from pre-existing formations that were originally either **igneous** or **sedimentary** rocks. Gneissic rocks are coarsely laminated and largely recrystallized but do not carry excessive quantities of the **micas,** chlorite or other platy minerals. Gneisses that are metamorphosed igneous rocks or their equivalent are termed **granite** gneisses, **diorite** gneisses, etc.; however depending upon their mineralogical composition, they may be called **garnet** gneiss, **biotite** gneiss, **albite** gneiss and so on. Orthogneiss designates a gneiss derived from an igneous rock; paragneiss, one from a sedimentary rock. The word gneiss is from an old Saxon mining term which seems to have meant decayed or rotten, or possibly worthless material. (R.M.F.)

GNETALES. Paleobotany.

GNOMIC PROJECTION. This type of projection is used in producing, especially for use in navigation, what are frequently referred to as great circle charts, because of the fact that great circles (geodesic lines) on the surface of the earth are projected as straight lines. In the gnomonic projection the chart is constructed by placing a plane tangent to the surface of the earth at some selected point and then projecting the surface features by extending radii from the center of the earth out until they meet the plane.

In the gnomonic projection the distortion, both of shape and of size, is very severe except for a very limited area immediately about the point of tangency with the earth. The great value of the charts lies in the fact that the shortest distance, even between very widely separated points, will be projected as a straight line. The government issues a series of charts on this type of projection for all of the principal cruising areas of the world and they are of immense value to navigators for determining at a glance whether or not the following of the shortest course between two points (**great circle course**) is practicable. (W.K.G.)

GNU. Mammalia, Artiodactyla. African **antelopes,** *Connochaetes gnu,* of large size and ugly appearance. Also called wildebeests. These animals have a large head, strong curved horns, an erect bristly mane and a bristly muzzle. The withers are high and the tail hairy throughout its length. (A.W.L.)

GOAT. Mammalia, Artiodactyla. Hoofed animals belonging to the same family as the cattle, sheep, and antelopes, and not sharply distinct from the sheep. The males are usually bearded. The group includes numerous species of the Old World. One species occurs in North America, two in northern Africa, and the remainder in Europe and the more northern parts of Asia. They are primarily mountain animals.

In addition to goats named as such, the group includes the turs of the Caucasus, the Persian pasang, the **ibexes,** the **markhor,** and the **tahr.** The American species is found in the Rockies and Cascades, north to Alaska. It is called the mountain goat, *Oreamnos americanus.*

Wild goats are fine game animals and the domestic goat, *Capra hircus,* is valuable for its milk and hide, and as a source of mohair. (A.W.L.)

GOATSUCKER. Aves, Caprimulgiformes. All birds (**Aves**) of this order, characterized by weak legs, a short weak beak and very wide mouth, and crepuscular habits. They catch insects while on the wing. The **frog mouths, oil bird,** and **nightjars.** Generally distributed excepting the Australian region.

The North American goatsuckers are the chuck-will's-widow, **poor-will, whip-poor-will, nighthawk,** and parauque. (A.W.L.)

GOBLET CELL. Gland. (A.W.L.)

GOBY. Pisces, Teleostei. Shore fishes (**Pisces**) of the tropics. Many species of which a few enter fresh water. Family Gobiidae. (A.W.L.)

GODWIT. Aves, Charadriiformes. *Limosa.* Wading birds (**Aves**) allied to the sandpipers, with long legs and a long slender beak. The several species nest in the far north but migrate to the southern hemisphere in winter. (A.W.L.)

GOETHITE. The mineral goethite is a hydroxide of **iron** corresponding to the formula FeO(OH) crystallizing in the **orthorhombic** system. It occurs in prisms, but is often found in **foliated** or other massive forms. When observable it shows one good **cleavage** parallel to the **prism;** fracture, uneven; hardness, 5–5.5; specific gravity, 4.28; luster, adamantine to dull; color, yellowish, reddish, brownish to nearly black; translucent to opaque. It is found associated with **hematite** and **limonite,** being perhaps in part an alteration product of the latter mineral. Goethite is used as an ore of iron. There are many European localities including Bohemia, Saxony, Westphalia, and Cornwall. In the United States it is found in the **hematite** mines of the Lake Superior region, and in Colorado. This mineral was named in honor of the German poet Johannes Wolfgang von Goethe. (E.S.C.S.)

GOITRE. Thyroid Gland.

GOLD. Symbol: Au (aurum). Atomic number: 79. Atomic weight: 197.2. Density: 19.3. Hardness: 2.5–3. Melting point: 1063° C. Boiling point 2600° C.

Gold is a yellow metal—the color is markedly affected by the presence of traces of other metals—very malleable and ductile—the ductility is diminished by the presence of other metals—soft—the softness is counteracted when desired by the addition of other metals—unattacked by air, water or **hydrogen sulfide,** not dissolved by **hydrochloric** or **nitric acid,** but soluble in **aqua regia** and converted into chloride by **chlorine** used either as gas or solution, soluble in solutions of cyanides in the presence of air. Very thin sheet gold is translucent and transmits greenish light. Discovery prehistoric.

Gold is one of the most ancient metals used in the arts, about one-third of the present output being so used, and the remaining two-thirds in coinage or in bars. The lettering of books and the decoration of porcelain utilize important amounts of gold. It occurs chiefly as native

gold alloyed with silver, copper, lead, or other metals (60%–98% Au), in certain sands and quartz veins from which it is obtained (1) by mechanical methods, such as "washing," (2) by dissolving in sodium or potassium **cyanide** solution followed by precipitation of the gold by zinc metal, (3) by dissolving in **mercury** (quicksilver) and later distilling off the mercury.

Auricyanide: potassium aurocyanide ($KAu(CN)_2$) and sodium aurocyanide ($NaAu(CN)_2$), by treatment of gold with **potassium** and **sodium** cyanide solutions, respectively, in the presence of air.

Bromide: aurous bromide (AuBr) yellowish-gray solid, by heating auric bromide to a maximum temperature of 200° C.; auric bromide ($AuBr_3$) brownish-red soluble solid by reaction of gold with **bromine** solution.

Chloride: aurous chloride (AuCl), yellow solid, by heating auric chloride to a maximum temperature of 175° C. for several days; auric chloride ($AuCl_3$), reddish-brown soluble solid, by reaction of gold with **chlorine** as gas or in solution, sublimes at 265° C. in a current of chlorine, is changed to aurous chloride as stated above, and when heated to temperature higher than 175° C. decomposes into gold metal and chlorine gas; chlorauric acid ($HAuCl_4 \cdot 3H_2O$), brown soluble solid, used in identifying certain organic bases.

Chloroaurates: sodium chloroaurate, "sodio-gold chloride" ($NaAuCl_4 \cdot 2H_2O$), yellowish-red crystals, soluble, as also lithium chloroaurate ($LiAuCl_4$) and potassium chloroaurate ($KAuCl_4$).

Hydroxide: aurous hydroxide (AuOH), purple precipitate, by treating aurous bromide solution with **sodium** hydroxide solution in the cold; auric hydroxide ($Au(OH)_3$), brown precipitate, by treating auric chloride solution with sodium hydroxide solution.

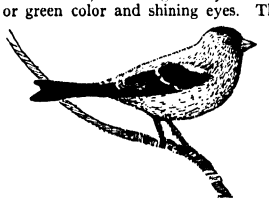
Oxide: aurous oxide (Au_2O), purple precipitate, by treating aurous bromide solution with a slight excess of sodium hydroxide and boiling the mixture; auric oxide (Au_2O_3), dark brown solid by heating auric hydroxide to 100° C.

Purple of cassius is precipitated when a solution of auric chloride is treated with a solution of **stannous** chloride of the proper concentration. The product is used in the preparation of ruby **glass.**

The occurrence of gold in sea water has attracted much attention. The various sources and reports show there is present from 5 to 250 parts by weight of gold per 100,000,000 of sea water. Although the *quantity* present is enormous, the cost of recovering the same has hitherto been greater than the value of the gold obtained. (R.K.S.)

GOLDCREST. Aves, Passeriformes. A European **kinglet.** (A.W.L.)

GOLDEN-EYE. 1. Insecta, Neuroptera. The lacewing, adult of the **aphis-lion.** These insects are small and delicate, with large many-veined wings of yellowish or green color and shining eyes. They have a disagreeable odor. 2. Aves, Anseriformes. A North American **duck.** *Glaucionetta.* (A.W.L.)



Goldfinch. *Astragalinus tristis.* Bright yellow, with top of head, wings, and tail black. Two white bands on wings. Female duller. Male also much duller in winter. Length, five inches.

GOLDFINCH. Aves, Passeriformes. **Finches** of several species. The American goldfinches, *Astragalinus tristis,* are predominantly yellow in the male sex and mostly olive in the female, while the European species is more brilliantly colored, with a red face. The latter species has been introduced into the United States but is apparently not established. (A.W.L.)

GOLDFISH. Pisces, Teleostei. A species, *Carassius auratus,* related to the carp, often bright reddish golden in captivity. It is a native of Europe and Asia and is now established in some of the lakes and streams of the eastern half of the United States. As an aquarium fish it is available in many varieties of different form. (A.W.L.)

GOLGI APPARATUS. Cell.

GOMPHOTHERIUM. Fossil mammals.

GONAD. An organ in which sexual reproductive cells (**gametes**) are produced. In some of the simpler animals gonads develop as temporary organs during the breeding season and in more complex forms they are permanent. They are ectodermal in the fresh-water polyps (*Hydra*), endodermal in the jellyfishes, and mesodermal in the higher forms. The gonads which produce male germ cells are called testes and those which produce egg cells are ovaries. In some snails the gonad produces both kinds of cells and is called an ovotestis. (A.W.L.)

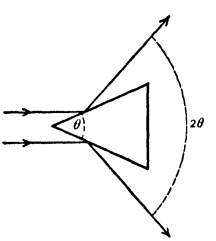
GONANGIUM. A term applied both to the reproductive members of hydroid colonies and to the sheath which envelops them. Usually the reproductive **polyp** is called a blastostyle and the sheath a gonotheca. (A.W.L.)

GONAPOPHYSIS. Appendages of the insect **abdomen** which serve as accessory organs of reproduction. Copulatory organs of the male and egg-laying organs of the female. They are probably derived from jointed appendages. (A.W.L.)

GONDWANA LAND. Permian.

GONIATITE. Invertebrate Paleontology.

GONIOMETER. An instrument for measuring the angles between the reflecting surfaces of a crystal or a prism. Parallel rays from a **collimator,** impinging upon the polished surfaces, are reflected in different directions. Two methods may be used. In one the crystal or prism is held stationary and the angle between the reflected beams from the two faces, received in succession by a telescope moving around a graduated circle, is measured on the circle; the angle between the two faces is then one-half of this (See figure). In the other method, the telescope is clamped in some convenient position and the crystal or prism is rotated so that first one and then the other face reflects light into it; the angle between the faces is the supplement of the angle through which the prism mounting is turned. An ordinary spectrometer may be used for the purpose (See **Spectroscope**). (L.D.W.)



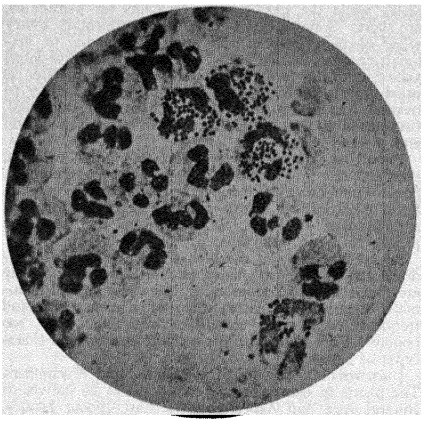
Angle between reflected rays is twice angle between prism faces.

GONOPOD. Modified jointed appendages of **centipedes,** used as accessory organs of reproduction. (A.W.L.)

GONORRHEA. An acute or chronic infectious disease, involving primarily the passages of the external genital organs and the **urethra.** Frequently, there is secondary involvement of more distant body structures, causing systemic manifestations.

Gonorrhea is the most common venereal disease. It is rarely a killing disease but due to its late complications, its obstinacy and its ability to cause permanent damage, it ranks next to syphilis as one of the most serious of infectious diseases.

Gonorrhea is as old as the human race. References to it are found in old Egyptian, Chinese and East Indian writings. It is mentioned in the Old Testament. Gonorrhea was not differentiated from syphilis until the early nineteenth century. Albert Neisser discovered the gonococcus as the causative organism in 1879.



Gonococci in urethral pus (× 1000). The gonococci appear as small dots. The cells with stained nuclei are pus cells. (From Todd and Sanford, *Clinical Diagnosis by Laboratory Methods*, W. B. Saunders Co.)

There are no figures as to the incidence of gonorrhea in the human race, as many infected never consult a physician and the disease is not ordinarily reported. At least 20% of those having gonorrhea suffer from complications.

The adult form of the disease results from sexual intercourse with an infected party. Gonorrhea of the new born results from infection of the eye during birth passage through the infected vagina. It has always been the great cause of permanent blindness in the new born. It is for this reason that antiseptics are applied to the eyes of every new born child. Accidental infection can occur through contaminated articles such as towels, etc., but is not especially common, although blindness in the adult has occurred in this manner.

The primary infection involves the mucous membrane of the urethra in both male and female, and the mucous membrane of the **vagina** and cervix in the female. This lasts in its acute form for a relatively short time. It is marked by local swelling, burning, and pain of the regions involved. Urination is painful and frequent. There is a copious discharge of pus.

The serious complications of gonorrhea develop from direct spread of infection upward from the primarily infected local parts. In the male the upper portions of the urethra, the prostate, seminal vesicles and the testicular organs are commonly involved in the acute form. The infection later becomes chronic and may remain chronic for a considerable time. The infection may later flare up and become acute. In the female, infection of the cervix, various local glands, uterus and ovary and fallopian tubes (salpingitis) are common. General **peritonitis** is a frequent complication of acute gonorrheal salpingitis. Later the salpingitis becomes chronic and many operative procedures may be necessary. Salpingitis is frequently the cause of sterility. The rectum may also become involved in the gonorrheal process.

Gonorrhea is also a general systemic disease in many instances, the organism being carried to distant organs by the blood stream.

Gonorrheal arthritis is quite common and is a severe crippling disease. Any or several joints may be involved. Fever is usually present with other constitutional symptoms. Pain is very acute. In a similar manner tendon sheathes, muscles and bones may be involved. Neuritis and various neuralgia occur. Gonorrheal septicemia is rare but has a definitely bad outlook as the mortality is high. Gonorrheal infection of the **heart** lining and valves (endocarditis) usually results fatally.

Various nervous system manifestations as **neuroses, psychoses,** are common, especially causing sexual neurasthenia, frigidity and impotence.

The treatment of gonorrhea involves local treatment of the primary disease and medical and surgical treatment for the various sequelae or complications. (R.S.M.)

GONOSOME. The medusoid (See **Medusa**) of a hydrozoan (See **Hydrozoa**). This is the sexual stage in the alternation of sexual and asexual generations of these animals. (A.W.L.)

GONOTHECA. Gonangium.

GONOZOOID. 1. The attached medusoid (See **Medusa**), such as is borne by the **blastostyle** in some hydrozoan (See **Hydrozoa**) colonies. 2. Sexual individuals in the **salpian** colony. (A.W.L.)

GOOSANDER. Aves, Anseriformes. A merganser (**duck**) of the northern Hemisphere. *Mergus merganser.* (A.W.L.)

GOOSE. Aves, Anseriformes. Large swimming birds (**Aves**) with webbed feet and thick, strong beaks. They live chiefly on vegetation. Geese are found on all continents. They are strong fliers and some species migrate from their nesting grounds in the north to the southern hemisphere. Among the several North American species the Canada goose, *Branta canadensis,* is sometimes called brant and a related species is the black brant, *B. nigricans.*

Geese are excellent game birds and good food. The domestic goose is also valuable for its smaller feathers and down, which are preferred for filling pillows and cushions. (A.W.L.)

GOOSEBERRY. Berry.

GOOSEBERRY STONE or **GROSSULARITE. Garnet.**

GOPHER. Mammalia, Rodentia. 1. The pocket gophers. Stout bodied burrowing animals of several species, found throughout the United States. They have fur-lined cheek pouches opening at the sides of the mouth. 2. Slender burrowing species of the central and western states, also called ground squirrels. The suslik or sisel is a European species.

Gophers are injurious to crops. The pocket gophers eat roots and the ground squirrels are more injurious to grain. In the prairie regions they are sometimes so abundant that they have to be destroyed by shooting or poison. (A.W.L.)

GORAL. Mammalia, Artiodactyla. *Urotragus.* Animals of several species related to the **goats.** They are slender and beardless and have small curved horns. They are distributed from the Himalayas to northern China. (A.W.L.)

GORDIACEA. Nematomorpha.

GORDIOIDEA. Nematomorpha.

GORILLA. Mammalia, Primates. The largest of the man-like **apes.** The gorillas are terrestrial animals with an enormous trunk, short bent legs, and long powerful arms. In walking they rest partly on the backs of the bent fingers. According to Akeley's observations they

are poor climbers The head of the gorilla is distinguished by the strong jaws and large teeth, the heavy ridges over the eye sockets, and the small ears There are two species, the common gorilla, *Gorilla gorilla* and the mountain gorilla *G beringei*

Gorillas live in the forests of Africa and our knowledge of them has come mostly from field observations Several have been taken alive but they do not thrive in captivity They are apparently less intelligent than the chimpanzee

The male gorilla was long regarded as a creature of the utmost ferocity Since he may reach a height of more than five feet and a weight of four hundred pounds he would, indeed, be a formidable opponent, but Akeley reported the gorillas of his experience to be very shy and difficult to approach so the older idea must be abandoned (A W L)

GOSSAN. This term is applied to the decomposed upper parts of mineral veins and ore deposits It usually consists chiefly of hydrated **iron** oxide resulting from the weathering of **pyrite, chalcopyrite,** etc Gossans have been important sources for the release of the relatively insoluble precious metals and gems which are washed away to form **placer** deposits Many valuable gold ore bodies have been traced to their source by means of their derived placers Also **secondarily enriched** sulphide ores of copper have been discovered beneath gossans which were originally prospected for the more precious metals (R M F)

GOUJON. Pisces, Teleostei A large **catfish,** *Opladelus olivaris,* common in the larger streams of the Mississippi basin Also called the mud cat It sometimes attains a weight of 100 pounds (A W L)

GOURAMI. Pisces, Teleostei *Osphromenus* Brightly colored fishes (**Pisces**) of the fresh waters of the Old World tropics The pelvic fins bear a long slender filament, apparently sensory One species is valued as food and several small species are kept in aquaria (A W L)

GOURD FAMILY. Cucurbitaceae A small family, largely restricted to tropical or warm climates, with representatives in both the Old and the New Worlds Most of its 650 species are climbing or trailing herbaceous plants which grow very rapidly They are mostly annuals The stems are hollow and in most species abundantly supplied with stiff bristly hairs The large leaves are borne alternately on the stem, have a distinct, often long, **petiole,** and show a variety of shapes The **tendrils,** which are a conspicuous feature of many members of this family, appear in the **axils** of the leaves and have been variously interpreted as stems or leaves, or other plant parts, modified greatly They are very sensitive organs, responding to the lightest touch of any solid substance, and often show a change in the direction of twining in the middle of a single tendril In many species the nutating or circling movement of the tendril is very rapid The flowers are axillary, either borne singly or in various types of **inflorescence,** and are usually yellow or white The plants are either **monoecious** or **dioecious** The **calyx** is adnate to the inferior **ovary,** the **corolla** is five-lobed and inserted on the calyx The **stamens** are typically five, but show great variation in number through fusions The inferior ovary is one- to three-celled and usually contains many flattened seeds The latter lack **endosperm** The fruit is a variety of berry called a **pepo,** differing from a berry in that the receptacle enters into the formation of the rind or outer wall The germination of the seeds of the commonly grown members of this family exhibits one rather striking peculiarity When the arched **hypocotyl** emerges from the seedcoats a small peg forms on its lower end This peg prevents the seedcoats from sticking to the **cotyledons,** which are withdrawn and carried into the air by the straightening of the arched hypocotyl Many members of this family are grown in cultivation, as for example squashes, pumpkins, and cucumbers, and certain ornamental species, like *Echinocystis, Momordica,* and some of the gourds

Cucurbita, pumpkins and squashes These are rather coarse annual vines having very rough bristly stems, large, long-stalked leaves and axillary (**axil**) flowers of two kinds The staminate (**stamen**) flowers have long stalks while the pistillate flower stalks, or **peduncles,** are short Staminate flowers have a rudimentary **ovary** while pistillate flowers have three staminodia, or vestigial stamens, in both kinds of flowers the five-lobed yellow **corolla** is conspicuous Insect-**pollination** is usual It is probable that these plants are native to tropical America, where they have been long cultivated Cultivation is now widespread in both the New World and the Old

Pumpkins, *Cucurbita pepo,* are of many varieties, sizes and shapes Included here are the Field Pumpkin, Sugar Pumpkin, Pie Pumpkin and Mammoth Pumpkin, Fordhook, Scallop (Petty-pans), Crookneck Squashes, and Marrow Squashes In this group the stems are prickly as a rule, and more or less five-angled

Squashes, *Cucurbita maxima,* are plants having cylindrical stems which are hairy rather than bristly Here are found Hubbard squashes, turban squashes and mammoth squashes, the latter often of immense size and frequent occurrence, sometimes weighing over 100 pounds *Cucurbita moschata* includes cushaw and cheese types of squashes.

Cucumis, Muskmelons, Cantaloupes and Cucumbers The plants in this genus are considered to be natives of tropical Asia and Africa and the East Indian Islands, where they have been in cultivation for many centuries In these plants the tendrils are unbranched, the staminate flowers are borne in small clusters in the axils of the leaves, while the pistillate flowers are solitary Many more staminate flowers are formed than pistillate, to insure successful pollination, which is almost entirely by insects

Cucumis melo includes melons of various kinds, among them muskmelons and cantaloupes Many varieties bear inedible fruits, some of which may be used in making preserves Few of these are cultivated in American gardens The fruits have a warted or ribbed skin, but never hairy or spiny They are probably native to southern Asia

Cucumis sativus is the cucumber This is a native of the East Indies There, and in Asia, cucumbers have been cultivated since earliest times Many varieties have been developed Certain varieties, grown under glass, are often seedless Others are largely grown for pickling The best pickling fruits are grown in regions having a cool climate For pickling, the fruits are picked while still young and small They are first salted in brine, after which they are bottled in vinegar, often with the addition of various spices or other flavorings, such as dill, or mustard, or peppers .

Gherkins, *Cucumis anguria,* are native to the West Indies Small cucumbers are also frequently called gherkins

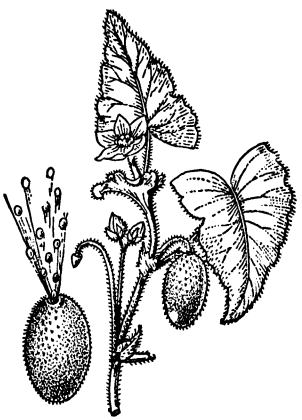
Citrullus Watermelons, Citron and Colocynth These are natives of Asia, Africa and southern Europe They are coarse trailing vines with branched tendrils and lobed leaves

Citrullus vulgaris includes the watermelon and citron as varieties It is native to Africa, where it has been cultivated since the time of Egyptian supremacy. Watermelons are grown for the juicy tender flesh In contrast to them, the flesh of the citron is firm and inedible when raw It is grown largely for preserving or for pickling Preserved citron is used in cakes and in the making of certain kinds of bread Because the juice of the citron is rich in pectin, it is much used in making jellies, especially with fruits naturally lacking in pectin and hence not capable of "jelling" Another kind of citron is made from the fruit of **Citrus media.**

Many members of this family are grown as orna-

mentals or for their curious and sometimes useful fruits. Many such are classed as gourds. One of these, *Lagenaria vulgaris*, a native of the Old World tropics, is known as the calabash gourd or bottle gourd, from the shape of its fruit. Excellent flasks are made from the woody pericarp.

Luffa cylindrica, the "bath sponge," is frequently seen in gardens. The **vascular** tissues of the **pericarp** form an intricate net which is sometimes used as a sponge. Many species of *Luffa* have edible fruits. Mostly they are natives of the Old World. Another gourd, a native of tropical America, is *Sechium edule*, grown for its edible fruit. Many other species of gourds have curiously ornamental fruits.



Squirting cucumber. Pressure develops inside the fruit, and as it is detached a hole is torn through which the seeds are violently discharged with the juice. (From Mottier's *Textbook of Botany*, P. Blakiston's Son & Co. After Jenkins.)

Ecballium elaterium, the squirting cucumber, found in Mediterranean regions, has a fruit which when mature is very turgid. When the fruit is broken, the seeds are forcefully ejected by the contraction of the pericarp. From the fruit is obtained a powerful purgative.

Citrullus colycynthis is another Cucurbitaceous plant, the fruit of which yields a drug. In this species the fruit gives colocynth, used as a general tonic, an insecticide, a fungicide, a cathartic and as a treatment for certain forms of dropsy.

Echinocystis lobata, a native American plant, is frequently grown for ornament, and as a vine to cover unsightly places quickly. Its small white flowers are pleasantly fragrant. The staminate flowers are borne in long-stalked many-flowered inflorescences, while the pistillate are borne singly and are very short-stalked. The tendrils of this plant are especially sensitive to touch and move very rapidly. (R.M.W.)

GOUT (PODAGRA). A form of **arthritis** due primarily to a disturbance of the **uric acid** metabolism of the body. Gout was first differentiated from other forms of arthritis by Syndenham (1624–1689). Excess uric acid in the body may be due to certain foods (purine foods), or it may be due to destruction of the nuclei of the body cells. This destruction is a **metabolic** disturbance of which the cause is unknown, but there are many predisposing factors such as **heredity**, over-indulgence in fermented liquor, over-eating, etc. It is more frequent in certain countries than in others.

The joints involved in gout are exceedingly painful, reddened and swollen. The first joint of the great toe is the most frequently involved, but the ankle, in-step or other joints may be involved. The attack may last for several days. Other seizures occur after months or years.

Chronic gout differs from acute gout in that there are no free intervals and the pain is much less severe and less persistent.

Tophi are commonly found in gout and are a late manifestation. They are commonly located on the ears and are small nodular accumulations of uric acid salts. (R.S.M.)

GOVERNOR. Ordinary governing consists of varying the power of a prime mover in accordance with the demands made upon it by the power user. By governor is generally understood the mechanical governor, used to effect a change of throttle position, spark advance, etc. The **centrifugal** force of rotating masses is the most common principle underlying governors. Fluid pressure produced by fans or centrifugal pumps, the rotors of which revolve with the prime mover shaft, have also been used, but greater dependence is laid upon the principle of rotating masses. A governor of this type is diagrammed in Figure 1. The rotating fork *R* carries in its ends the pivots upon which are mounted the weights *MM*. By means of the bell-crank linkage and the sliding yoke *S*, the weight *W* tends to keep the flyballs in equilibrium in the position shown under the influence of the mass of the weight, transmited through the connecting links, and the centrifugal force acting at the center of the gravity of the governor weight. Considering that the rotative speed of the governor is ω, the magnitude of this centrifugal force in weight units is:

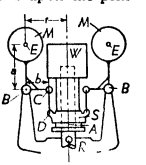


Figure 1.
Fly-ball governor.

$$\frac{Wr\omega^2}{g}.$$

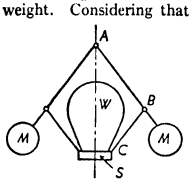


Figure 2.
Pendulum governor.

Heavier, slower speed governors are constructed with the heavier masses arranged as shown in Figure 2, this type being known as the pendulum governor. In general, the higher the rotative speed of the prime mover being governed, the lighter will the governor weights be.

Governor action on **internal combustion engines** for the purpose of regulating the speed to some normal value is undertaken in a number of ways. For example, the governor may hold the exhaust valve open, preventing any power stroke from being accomplished, or it may interrupt the ignition circuit, causing explosions to be missed by failure to ignite. Or the passage supplying the inflammable fuel air mixture may be throttled mechanically by a valve to vary the amount of fuel with which the cylinder is charged. In **Diesel engines**, governing is accomplished by varying the amount of oil pumped into a cylinder during that portion of the power stroke given over to the combustion of a fuel. This is done by a governor which either regulates the stroke of the fuel oil pump, or operates a variable by-pass in the discharge from the fuel oil pump. The steam engine may be governed with mass governors of two types, depending on the particular system of governing employed. The smaller, cheaper engines are governed by altering the throttle pressure through imposing an artificial pressure drop created by a governor valve between the boiler and the cylinder. This is known as a throttling governor, and is simplest, but least efficient. Governing of a **steam engine** consists of varying the amount of steam admitted to the cylinder per stroke. As just indicated, this can be done by throttling the steam pressure entering, but it can be accomplished, still allowing full pressure steam to enter, by varying the portion of the stroke during which the admission valve remains open. This

is governing by changing the point of cut-off, and is known as cut-off governing It is more efficient, but more complicated than the throttled governing A throttling governor may be simply a flyball type, as already described, arranged so that the motion of the sleeve at *a* can be transmitted through a forked lever to the stem of the governor valve in the steam line The automatic cut-off is usually built into the flywheel It is a weight on the end of an arm which is pivoted to one of the flywheel spokes Any motion of this arm in the direction of the centrifugal pull is opposed by a leaf or coil spring built into the governor A mechanical link connects the governor with the eccentric, which drives the steam valve Motion of the governor under varying centrifugal forces set up by variable power alters the position of the eccentric driving the valves, and thus alters the timing of the event of admission of steam to the cylinder It can do this, for the various events of the steam engine cycle are under the control of the slide valve

Governing of **steam turbines** is accomplished by three methods, viz · (1) throttling at inlet, (2) varying number of inlet nozzles in action, (3) varying duration of full pressure puffs (blasts), of which there are several per second In addition, some turbines are provided with hand-operated by-pass valves which, by admitting high-pressure steam to low-pressure stages, enable the turbine to carry more overload, though, of course, at reduced economy Of these methods, the first is widely used on small turbines In the large turbine field, the second is applied to the Curtis type, and the third to the Parsons type The basic actuation of governors will always be found to employ a change brought about by change of centrifugal force during change of speed, the latter brought about by increasing or decreasing load Usually the centrifugal force is opposed, mechanically, by governor springs which give the turbine a drooping speed characteristic A single turbo-alternator not paralleled with any other and not expected to be paralleled with another may have this curve as flat as is consistent with governor hunting—a fault induced by an oversensitive governor The unit would operate back and forth over its range of load from $P = O$ to $P =$ full load with a speed regulation of $(s_1 - s_2)/s_2$ The speed regulation should, in no case, exceed 4% But if the alternators are to be paralleled, their characteristics should have considerable droop as too flat a characteristic would exaggerate the effect of slight variations in the slopes and make apportionment of the load a difficult matter Shifting of tension on governor springs (usually done by remote control) has the effect of shifting the speed-load characteristic nearly parallel to itself

Consider two equipolar **alternators** with speed characteristics Each has full load speed of 3600 r p m The first, a 10,000-kw unit, has o 8% speed regulation, the other, a 15,000-kw unit, has o 6% speed regulation If the system load is 20,000 kw the speed is 3605 r p m, at which *A* unit has 8400 kw and *B* unit 11,600 kw Now let it be required to adjust the load on *B* to its most economical point, 12,000 kw, with the system frequency at 60 17 cycles The speed would be $3600 \times \frac{60\ 17}{60} = 3610$ r p m Referring to Figure 3, it is seen that the governor spring tension on *B* unit is adjusted and the characteristic moved until it passes through 3610 r p m at 12,000 kw *A* is similarly adjusted to where it carries 8000 kw at that speed The no-load speeds of the two units have now become: on *A*, 3633 r p m, on *B*, 3627 5 r p m

To permit speed adjustment, the speed of a turbine at no load should be adjustable within 5% above or below the rated no-load speed Within this range the emergency governor should be inoperative Furthermore, the governing characteristic of a turbine should be such as to hold the speed rise upon instantaneous drop of full load within the operating limit of the emergency overspeed trip

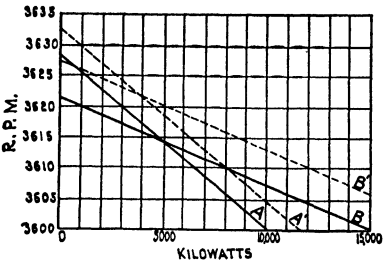


Figure 3 Governor characteristics

The gates of the **hydraulic turbine** require an operating force for their movement that is far greater than in the steam turbine, so the mechanism of a hydraulic turbine governor does not bear any resemblance to the delicate parts of the steam-driven machine Indeed, the force is so large that the hydraulic governors are rated on the basis of the foot-pounds of energy they will produce in completing an operating stroke A 30,000-foot-pound capacity is a small governor Large ones may develop as much as 200,000 foot-pounds Naturally, the force developed by sensitive flyballs operated by centrifugal force can be used only to control a relay which, in turn, will control the actual gate-shifting mechanism An oil pressure governor consists of a governor proper and an oil-supply system An oil pump, a pressure storage tank, a sump into which released oil can be drained and into which the suction of the pump dips, and suitable strainers to keep the oil clean are the principal elements of the oil-supply system The governor consists of the flyballs, the control valve, the servomotor, and such accessories as overspeed trips, and load-limit blocks

The operation of a governor can be understood by reference to Figure 4, which is a simplified diagram of the governor mechanism The servomotor piston rod is

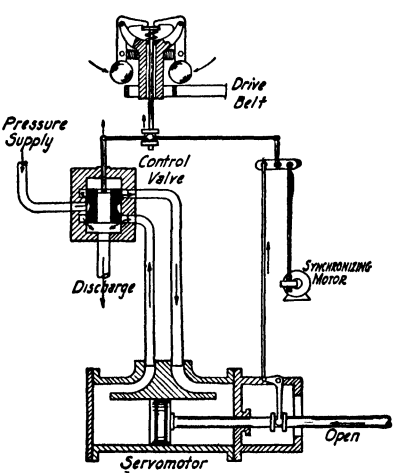
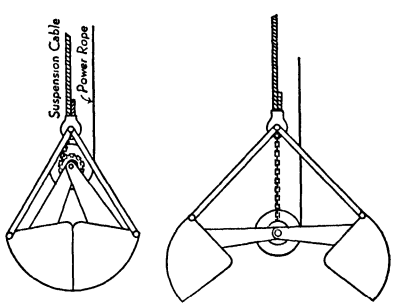


Figure 4

the operating rod of the turbine gate-shifting ring Oil is admitted to and drained from the servomotor by the control valve This control valve is connected to the governing flyballs, and also indirectly to the servomotor

rod The operation is as follows: The change in speed of the turbine resulting from change of load is communicated to the governor through the drive belt The flyballs seek a new position of equilibrium and move the control valve from closed position Oil pressure is then admitted to the servomotor piston and it completes the motion required to adjust the gates to the new operating position While completing this motion, the servomotor, through the medium of the bell-crank and connected rod, closes the control valve Some large governors have a pilot valve to control the main control valve Quick governor action is secured through using as large control valve lifts and oil passages as possible, and using heavy oil pressure The natural tendency is then to cause the servomotor to override its correct position and leave the gates too far open or closed, consequently, there must be another movement of the whole system in search of the equilibrium point Resonant conditions may be set up and a steady speed impossible to maintain Stability of the system is unsatisfactory if the governors are too sensitive, yet there is need for close regulation so that the frequency will not suffer Ordinary governors will complete a closing stroke, upon sudden release from full load, in from 2 seconds to 5 seconds. (F T M)

GRAB BUCKET. A grab bucket is an apparatus which is able to pick up a load of a bulk material by "biting" into the surface of the material The particular usefulness of the grab bucket is that it may be lowered from the end of a **boom** onto the surface of the material to be moved, where it is operated to bite into this material, picking up a load, which can then be raised and deposited where wanted The figure shows



Grab bucket (Hayward type)

a grab bucket in open and closed positions The procedure by which this bucket is caused to close upon a load of material is based on the differential action of a two-step drum A rope, to which power may be applied by winding it around a drum, passes to the bucket and has its end wrapped around the larger drum of the bucket After power is applied to this rope, it unwraps from the drum on the bucket, turning that drum and wrapping the chain on the smaller diameter portion The added leverage thus attained is sufficient to enable the drum to wind itself up on the chain, thus closing the bucket The axis of the drum is pivoted to the center arms of the bucket The digging power of a grab bucket of this kind is a function of the weight of the bucket, the sharpness of its cutting edges, the power applied to the operating rope, and the resistance of the material which it digs Buckets of this type are not suitable for hard-packed material such as earth in original embankment, but are suited to handling grain, coal, ore, etc They are built in capacities varying from one-half to five cubic yards (F T M)

GRABEN. Fault.

GRACKLE. Aves, Passeriformes In North America, several species of birds (**Aves**) with black plumage and iridescent metallic luster, related to the orioles and blackbirds The great-tailed grackle, *Cassidix mexicanus*, which ranges from Texas into South America, is also called the jackdaw It should not be confused with the European jackdaw In India the hill mynas and related species are called grackles (A W L)

GRADE. In geology, the term refers to the slope of the bed of a stream such that the water has just velocity enough to carry its load without either **erosion** of deposition A stream valley is said to have become graded when its longitudinal profile is a smooth curve without waterfalls or rapids The term grade is also used by students of **sedimentary rocks**, in a textural sense, to designate those grains of any sediment or sedimentary rock which are of the same size. The classification grade-sizes is as follows:

Name of Grade		Range of Diameters
Pebbles		Greater than 10 mm
Gravel		10 mm to 2 mm
Sand	Very Coarse	2 mm to 1 mm
	Coarse	1 mm to 0 5 mm
	Medium	0 5 mm to 0 25 mm
	Fine	0 25 mm to 0 1 mm
Silt		0 1 mm to 0 01 mm.
Clay		Less than 0 01 mm

(R M F)

GRADED BEDDING. A geological term denoting a type of bedding or stratification characterized by a cyclic or rhythmic deposition of coarse to fine sediments A helpful criterion for determining the original position of the strata after they have been deformed Graded bedding is generally supposed to be characteristic of offshore rather than in-shore deposition (R M F)

GRADIENT. In geology, this term is applied to streams to refer to the slope of their beds, as steep, gentle, or in terms of so many feet per mile. (R M F)

GRADIENT OF A SCALAR FUNCTION. The gradient of a scalar function is a type of mathematical expression which occurs frequently in mathematical physics

Let $\phi(x, y, z)$ be a **scalar function** of position Form the **partial derivatives** $\frac{\partial \phi}{\partial x}, \frac{\partial \phi}{\partial y}, \frac{\partial \phi}{\partial z}$, they may be regarded as the rectangular components of a **vector** This vector is defined as the gradient of ϕ, and is denoted by grad ϕ

In terms of the unit vectors $\hat{\mathbf{i}}, \hat{\mathbf{j}}, \hat{\mathbf{k}}$, the gradient may be represented by

$$\text{grad } \phi = \hat{\mathbf{i}}\frac{\partial \phi}{\partial x} + \hat{\mathbf{j}}\frac{\partial \phi}{\partial y} + \hat{\mathbf{k}}\frac{\partial \phi}{\partial z}.$$

This may be written symbolically

$$\text{grad } \phi = \left(\hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}\right)\phi.$$

If we consider the expression $\hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}$ as a symbolic vector, denoted by ∇, we may write

$$\text{grad } \phi = \nabla\phi$$

This symbolic vector ∇ is often called "del," (sometimes "nabla")

Grad ϕ represents both in magnitude and direction the greatest space rate of change of the function ϕ, or in other words, it has the direction and magnitude of the maximum **directional derivative** of ϕ

The vector grad ϕ is normal to the ("level" or "equipotential") **surfaces** $\phi(x, y, z) = c$. where c is any constant.

Let $\hat{\mathbf{r}}$ be a unit vector with **direction cosines** l, m, n, so that $\hat{\mathbf{r}} = l\hat{\mathbf{i}} + m\hat{\mathbf{j}} + n\hat{\mathbf{k}}$ The component of grad ϕ (or $\nabla\phi$) in the direction of $\hat{\mathbf{r}}$ is

$$\hat{\mathbf{r}} \cdot \nabla\phi = l\frac{\partial\phi}{\partial x} + m\frac{\partial\phi}{\partial y} + n\frac{\partial\phi}{\partial z},$$

a scalar, which is the directional derivative of ϕ in the direction of $\hat{\mathbf{r}}$

If $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$ and $\nabla = \hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}$, we have

$$\nabla r = \operatorname{grad} r = \hat{\mathbf{r}}, \quad \nabla\left(\frac{1}{r}\right) = \operatorname{grad}\left(\frac{1}{r}\right) = -\frac{\hat{\mathbf{r}}}{r^2},$$

$$\nabla r^n = \operatorname{grad} r^n = nr^{n-1}\hat{\mathbf{r}}$$

If $\mathbf{r}$ is a variable vector, $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$, and if $\mathbf{a}$ is a constant vector, then

$$\operatorname{grad}(\mathbf{r} \cdot \mathbf{a}) = \nabla(\mathbf{r} \cdot \mathbf{a}) = \mathbf{a},$$

$$\mathbf{a} \cdot (\operatorname{grad} r) = (\mathbf{a} \cdot \nabla)r = \frac{\mathbf{a} \cdot \mathbf{r}}{r}$$

If u and v are scalar functions of position, then

$$\operatorname{grad}(u + v) = \nabla(u + v) = \nabla u + \nabla v = \operatorname{grad} u + \operatorname{grad} v,$$

$$\operatorname{grad}(uv) = \nabla(uv) = v(\nabla u) + u(\nabla v) = v \operatorname{grad} u + \operatorname{grad} v.$$

If $\mathbf{u}$ and $\mathbf{v}$ are vector functions of position, then

$$\operatorname{grad}(\mathbf{u} \cdot \mathbf{v}) = \nabla(\mathbf{u} \cdot \mathbf{v}) = (\mathbf{u} \cdot \nabla)\mathbf{v} + (\mathbf{v} \cdot \nabla)\mathbf{u} + \mathbf{u} \times (\nabla \times \mathbf{v}) + \mathbf{v} \times (\nabla \times \mathbf{u})$$

In **spherical coordinates**, if $\hat{\mathbf{r}}$, $\hat{\boldsymbol{\theta}}$ and $\hat{\boldsymbol{\phi}}$ denote unit vectors in the direction of increasing r, θ, ϕ, we have

$$\nabla = \hat{\mathbf{r}}\frac{\partial}{\partial r} + \hat{\boldsymbol{\theta}}\frac{1}{r}\frac{\partial}{\partial\theta} + \hat{\boldsymbol{\phi}}\frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}.$$

An alternative definition of the gradient is the following

Let ϕ be a scalar function of position, let δ be a small region of space and also its volume, surrounding a point P, and let ω be the bounding closed surface of δ, and let $d\sigma$ be an element on ω, let $\hat{\mathbf{n}}$ be a unit normal to ω (outward drawn) at any point of ω Then the gradient of ϕ at the point P may be defined by

$$\operatorname{grad}\phi = \lim_{\delta \to 0} \frac{1}{\delta}\int_{\omega} \hat{\mathbf{n}}\phi\, d\sigma \qquad \text{(L.L.S)}$$

GRAFTING AND BUDDING. Grafting is the process of inserting a part of one plant into another in such manner that the two unite and the inserted piece continues to grow The part which is inserted is called the scion, the plant into which it is inserted is the stock Budding is a similar process in which the part inserted consists of a bud with some of the bark adjoining it

This process is possible because of the **cambium** cells The successful union of the two pieces is caused by the formation of callus tissue by the cambium cells Callus tissue is composed of a mass of **parenchyma** cells which fill in or grow over wounds, thus repairing the injury In graft unions, the cells of the **callus** tissue soon begin maturing into cells of various types, as **xylem** and **phloem** cells, while others become typical cambium cells joining the cambium layer of stock and scion In grafting, the cambium layers of the two parts are to be brought as closely together as is possible

There are several methods of grafting A very common method is known as cleft grafting In this method a small twig having several buds is removed from the plant which is selected as desirable The lower end of this twig is cut wedge-shaped A branch of the plant used as stock is cut off, and a vertical cut made in the end Into this cut the prepared scion is inserted in such position that its cambium layer and that of the stock come together To prevent drying of the tissues the entire cut surface is covered with a prepared wax Usually several scions are inserted in a branch of the stock When union has taken place and the scion started to grow, all but one may be cut off

Another method is whip grafting, which is used when the stock is too small for successful cleft grafting In whip grafting, both stock and scion are cut in a long oblique cut In the cut surface of each a vertical cut is made They are then fitted together so that the parts of one slide into and against those of the other, with the cambium of one in contact with that of the other The two parts are then bound firmly together and the whole covered with wax

In budding a small bit of bark bearing a bud is removed from the selected plant Usually, little wood is taken with this In the stem of the stock a T-shaped cut is made in the bark and the flaps so formed loosened The prepared bud is inserted under the flaps, which are then pressed down over it and bound tightly in place to insure contact between the two cambium layers Wax is used here also to prevent loss of water

In modern horticulture, grafting is a very important practice Many plants, for instance, do not come true when grown from seed It becomes necessary, therefore, to propagate such desirable plants vegetatively This may be done in two ways One is by means of cuttings, pieces of the plant which are rooted and grown into new plants The other method is grafting, which is now done on an immense scale Vegetative propagation must be used also in those plants which do not bear seed, as seedless oranges and seedless grapes

Commonly the stock used in such cases is not a mature plant but a seedling This is often chosen for its hardiness or its resistance to diseases and pests The seedlings are allowed to grow until their roots are well established The graft is then inserted at the base of the stem As soon as union has taken place and the scion started to grow, the shoot of the stock is cut off, so that all substances absorbed by the root are sent into the scion Grafting of this sort is used in producing nursery stock for rubber plantations, as well as nearly all common fruit trees

Successful grafting can only take place between plants of the same kind or closely related Others fail entirely to develop any union between the two parts In nearly all cases the nature of the scion is constant after grafting, so that one can be sure of the product which will result Because of this it is possible to graft several different scions on a single stock Not infrequently one sees an apple tree bearing many different kinds of apples maturing at different times of the year Grafting also hastens the time of fruiting, grafted plants coming into bearing earlier than those growing from seed

Bridge grafting is done for a very different reason Often trees are completely girdled by rodents, especially during the winter months Damage of this sort is fatal to the tree unless quickly corrected Correction is done by bridge grafting This is done by trimming the edges of the girdled region and inserting small twigs across the gap in the bark in such a way that the cambium region of the strips is in contact with that of the tree in which it is inserted Long sloping ends greatly increase the probability of such contact These "bridges" unite with the damaged tissues and allow movement of materials to occur Gradually the damaged tissues fill in the gap, and the damage is repaired (R.M.W.)

GRAIN. Fruit and Wood.

GRAM. A metric unit of mass or of weight, equal to about 1/28.35 of an avoirdupois ounce Originally the gram was defined as the mass of one cubic centimeter of pure water at its maximum density (4° C.) But since the actual metric standard of mass is now the **kilogram** at Sèvres, the present gram is one-thousandth of this standard, this exceeds the original value in the approximate ratio 1.000027 : 1 One unfamiliar with metric weights may find it helpful to remember that a silver dime weighs about two grams The avoirdupois pound is about 453.6 grams (L.D.W.)

GRAM-MOLECULAR VOLUME. Chemical Composition.

GRAMPUS. Mammalia, Odontoceti A large **dolphin**, *Orcinus orca*, of very vicious habits, also known as the killer They hunt in groups and attack even large whales (A W L)

GRANITE This name is applied to a common and widely occurring group of deep-seated igneous rocks consisting of **orthoclase, plagioclase, quartz, hornblende, biotite, muscovite** and minor accessories such as **magnetite, garnet, zircon** and **apatite** Rarely a **pyroxene** is present Ordinary granite always carries a small amount of plagioclase, but when this is absent the rock is then referred to as an alkali-granite An increasing proportion of plagioclase feldspar causes granite to pass into granodiorite A rock consisting of equal proportions of orthoclase and plagioclase plus quartz may be considered a quartz **monzonite** A granite containing both muscovite and biotite micas is called a binary granite

The word granite comes from the Latin *granum*, a grain, in reference to the grained structure of such a crystalline rock

Granite occurs as **stock**-like masses and as **batholiths** often associated with mountain ranges and frequently of great extent Granite has been intruded into the crust of the earth during all geologic periods, except perhaps the most recent, much of it is of pre-Cambrian age Granite is found extensively in Canada, New England, New York, the Appalachian region (especially the Piedmont), Wisconsin, Minnesota, South Dakota, Missouri, Oklahoma, Texas, the Rocky Mountains in general and the Pacific Coast States There are innumerable foreign localities (E S C S)

GRANITOID A textural term derived from **granite** and signifying the relatively uniform and coarse grain of **batholithic** rocks, such as granite, **syenite, anorthosite**, etc In a typical granitoid rock each species of mineral occurs as a single generation, the **silicates** crystallizing first, and any surplus of free silica crystallizes last in the form of **quartz**, or is finally driven off with the surplus water to form quartz veins (R M F)

GRANODIORITE. Granite.

GRANULE Cell.

GRANULITE (LEPTITE) This is a general term for a group of rocks that vary considerably in composition but for the most part seem to be derived by **metamorphic** processes from **quartz-feldspar** rocks The classic locality for granulite is in Saxony, where there occurs a granular **gneiss** of quartz and feldspar plus such accessory minerals as **pyroxene** and **garnet**, with occasionally small quantities of **kyanite, spinel** and similar minerals The Saxon granulites have a decided banded structure and seem to resemble **injection gneisses** It appears reasonable to suppose that these and other granulites may have been derived from sedimentary formations severely altered by igneous processes **Leptite** is a term used in the Scandinavian countries for fine-grained granulites that originally were rhyolitic tuffs and lavas

Besides the Saxon and Scandinavian granulites these rocks are found in the northern highlands of Scotland, India, West Africa, and Canada (E S C S)

GRAPE. *Vitis* sp Vitaceae Grapes are climbing plants many of which have long been cultivated by man for their fruits and the various products obtained therefrom

Climbing in grapes is made possible by tendrils, modified stems which coil tightly around any suitable support These tendrils are usually interpreted as terminal portions of the stem which have been pushed to one side by the more rapid growth of an axillary (See **Axil**) bud The leaves of grapes are simple, palmately lobed and alternate, with small stipules. The stems elongate rapidly and are of a coarse porous nature, the internodes of young stems are frequently hollow, the **nodes** solid The flowers are borne in compact **panicles** Each flower is small and inconspicuous The **calyx** is a mere rim around the tip of the **pedicel**; the **corolla** five-parted and greenish When the flower opens, the petals, united at their tips but free at the base, are forced away from the base of the flower and drop off There are five stamens and a single pistil The fruit is a two-celled berry

Commercial grapes are largely derived from three species, *Vitis vinifera*, the wine grape of Europe, a native of Asia, *Vitis Labrusca*, the northern fox grape of eastern North America, and *Vitis rotundifolia*, the southern fox grape Many varieties and hybrids of these exist, as well as hybrids with other wild species In commercial vineyards, grapevines are variously pruned to increase yield and improve quality Pruning cuts are made through the nodes, to prevent the leaving of hollow internodes in which disease might gain entrance to the plant Propagation of the grape is mainly by means of stem cuttings, a method which has been used in Europe for centuries

Grapes are grown mainly for raisins and for wine Both of these products come from the fruit of *Vitis vinifera*, which is much sweeter than other cultivated grapes For the best raisins, selected ripe fruit is carefully sun-dried, after which the stems are removed, and the product packed More commonly, grapes for raisin-making are first dipped in weak lye, then rinsed and dried either in the sun or, if necessary, artificially After drying, the stems and seeds are removed and the product packed, entirely by machinery

For wine-making the grapes are crushed and the juice allowed to ferment with yeast If a dry wine is desired, fermentation is continued until all the **sugar** of the grape is changed to **alcohol** Using both the skins and pulp of grapes with a colored flesh gives a red wine Using colorless grapes, or those with colorless pulp and removing the skins, gives white wine In sweet wine-making, fermentation is stopped before all the sugar is changed to alcohol, by adding alcohol, a procedure called fortifying the wine Distilling wine produces brandy

In addition to these two main uses, many grapes are eaten fresh More are crushed to prepare fresh grape-juice, which is bottled without fermenting Grapes are sometimes grown merely for ornamental purposes (R M W)

GRAPEFRUIT. Citrus fruits.

GRAPE-LEAF FOLDER. Insecta, Lepidoptera A **moth**, *Desmia funeralis*, whose larva eats the leaves of grape vines and lives in a fold fastened with silk It is not an important pest Arsenical sprays used for other insects destroy it (A W L)

GRAPE-LEAF SKELETONIZER. Insecta, Lepidoptera A **moth**, *Harrisina americana*, whose larvae, working in groups, destroy the soft tissues of the grape leaf, leaving the network of veins Rarely an important pest, and easily destroyed by arsenical sprays. (A W L)

GRAPH OF A FUNCTION. The graph of a function $y = f(x)$ is the **locus of the equation** $y = f(x)$ (L L S)

GRAPHICAL STATICS. The **equilibrium of forces** is often treated graphically in such practical problems as the stresses in the members of a framed structure If three concurrent forces are in equilibrium, the three vectors drawn to a common scale to represent them may be made to form a closed triangle (Figure 1); or if more than three, a closed polygon (Figure 2). The principle may

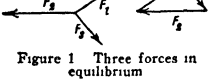


Figure 1 Three forces in equilibrium

be extended and is much used in the calculation of the forces in a truss by means of the so-called stress diagram A simple example is shown in Figure 3, which represents a small roof-truss with equal loads resting on it at the joints *A, B, C, D, E,* and supported by the upward reactions of the walls at *A* and *E* The several compartments of the figure are numbered, and both the external forces and the forces acting along the members between these compartments are represented, both in magnitude and direction, by the lines joining the corresponding numbers in the stress diagram. For example,

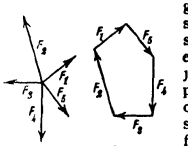


Figure 2 Five forces in equilibrium

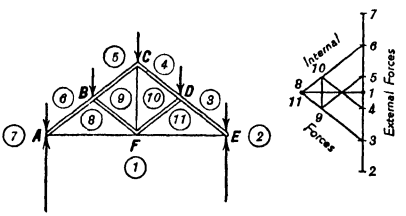


Figure 3. Elevation of truss with corresponding stress diagram

the compressive force in the strut *BF* is represented by the line 8–9, while the tension in the vertical rod *CF* is given by 9–10 The closed figure 5–4–10–9–5 in the stress diagram indicates the equilibrium of the forces acting at the joint *C* This method of analysis is attributed to Maxwell (See **Statics**) (L D W)

GRAPHIC GRANITE. A coarsely crystalline variety of **granite** or **pegmatite** composed almost entirely of **quartz** and **feldspar** which have intergrown in such a manner as to simulate semitic or cuneiform characters (R M P)

GRAPHIC REPRESENTATION OF EQUATIONS. An equation in two variables determines a **function** of one variable, and the **graph** of this function gives at the same time the graphic representation of the equation, which will be a **curve**

An equation in three variables determines a function of two variables, which is represented by a **surface** in space (L L S)

GRAPHIC REPRESENTATION OF FUNCTIONS. A function of one **variable** $y=f(x)$ may be represented graphically by plotting as points in a plane pairs of corresponding values of the variable and the function as **rectangular coordinates** or **polar coordinates**, and drawing a smooth curve through these points This graph of the function $y=f(x)$ is the same as the **locus of the equation** $y=f(x)$ (L L S)

GRAPHIC SOLUTION OF EQUATIONS. The real **roots** of an **equation** with one unknown are represented graphically by the **abscissas** of the points where the **graph** of the equation or corresponding **function** cuts or touches the X-axis

Sometimes the roots of an equation with one unknown can be found graphically by arranging the equation as an equality of two properly selected functions, plotting the graphs of these functions on the same diagram and finding their intersection points This method can be used to great advantage frequently in **quadratic** and **cubic equations** and certain **transcendental equations** (L L S.)

GRAPHITE (PLUMBAGO). Graphite is an allotropic form of **carbon** It is produced artificially by heating **coal** or, more commonly, **coke** in the electric **furnace** Graphite is also found in nature as a mineral It crystallizes in the **hexagonal** system, often in the form of scales or plates, or in large foliated masses It has a perfect **basal cleavage**, is soft, hardness 1–2, and feels greasy to the touch, specific gravity 2–2 2, luster metallic, color black to steel gray, **streak** black, opaque Graphite is a rather widely distributed mineral and is found in a variety of rocks It occurs in marbles, gneisses or schists, granites and other igneous rocks often carry graphite It has been noted in pegmatites It is likely that graphite has been formed by different processes, by magmatic separation of the graphite as an original constituent or as the result of assimilation of carbonaceous rocks, by pneumatolytic action, or by the metamorphism of sedimentary rocks that contained original carbonaceous matter Well-known localities are in Siberia, on the Island of Ceylon, which is the chief producing district at present, England, Madagascar, Mexico, and Canada In the United States it is found in the Adirondack region of New York State, in Massachusetts, Rhode Island, Pennsylvania, Alabama, New Mexico, and Montana Graphite is important as material for crucibles, lubricants, paints, pencil "leads," etc Graphite has been called black lead, but there is no connection between lead and graphite The German mineralogist, A G Werner, devised the name graphite from the Greek meaning *to write*, with reference to its use in pencils (E S C S)

GRAPHS The graph of an equation is the **locus** (or totality) of all points whose **coordinates** satisfy the equation The graph of a **function** of one variable is the locus of all points whose coordinates are the values of the variable and of the function (L L S)

GRAPHS OF TRIGONOMETRIC FUNCTIONS. **Trigonometric Curves.**

GRAPNEL. Broadly speaking, a grapnel is any device used to grapple with an object which is obscured to view, such as a submarine object Grapnels generally take the form of grapnel hooks, which have several flukes, so that they will be certain to hook into any object with which they may come in contact (F T M)

GRAPTOLITES. **Invertebrate paleontology.**

GRASS FAMILY. Gramineae Of all plant families the Grass Family is the most important economically Including many thousand species, the family is one of the largest in the plant kingdom Members of the grass family were probably the first plants to be cultivated by the human race Grasses are found everywhere plants can grow, from the coldest polar regions to the tropics, from the coasts to the upper limits of vegetation on mountains

Most grasses are herbaceous plants of low stature A few, notably the **Bamboos**, become woody plants of great height, and a small number are of clambering or trailing habit The cereals, and many other grasses, are annuals, completing their growth in a single growing season, others are perennial plants Some of the former are winter annuals, plants which start growth in one season, remain dormant over winter, and complete growth and fruit in the following season. Winter wheat is an example.

The root system of a grass plant is made up entirely of fine fibrous roots, which enlarge but little, remaining about the same diameter throughout their length These roots are mainly **adventitious**, arising from the lowermost nodes of the stem The roots of many grasses penetrate deep into the ground, so reaching supplies of moisture which enable the plant to live in dry regions where surface moisture is rare.

The stems of grasses, frequently called culms, are cylindrical and in most genera hollow except in the region of the nodes, where solid plugs occur. When young the stem is solid, but as growth continues the central portion fails to keep pace with the outer and gradually becomes hollow. Corn is an exception, the stems being permanently solid in that grass. In most grasses the stem grows erect, but frequently falls over during the growing season, due to climatic disturbances or to lack of suitable nutrient sources to give it strength. Such fallen stems do not remain so but gradually become erect through renewed growth in the nodal regions of the stem. The cause of such a growth is not definitely known. In many species of grass the lowermost nodes normally give rise to a number of buds which develop into lateral branches which give the plant a tufted appearance. Such basal branches are known as tillers, stools, and the habit of forming them as tillering or stooling. It is a valuable property of many cereals, and undesirable in others, for example, corn, where it causes a considerable reduction in yield. In a few grasses, the basal portion of the stem becomes enlarged by an accumulation of reserve food material, the plant being known as a bulbous grass. Many grasses develop underground stems known as rhizomes, from the nodes of which erect branch stems may develop, as well as numerous adventitious roots. These rhizomes may be short and the erect branches numerous, producing a tufted grass, or they may be long and wide spreading, as in the case of witch grass, *Agropyron repens*, also called quack grass. Due to the readiness with which the joints of the rhizomes of the latter grass strike root and develop to erect stems, it becomes a pestiferous weed. Eradication by chopping up the rhizome with a hoe only serves to increase its numbers, each joint or node producing a new plant. Only by preventing the green tops from forming can the plant be controlled and eliminated, or of course by complete removal of the entire underground rhizome. In some grasses the stem grows out over the surface of the ground, being then known as a stolon. Rhizomes and stolons form an effective way of propagating the plant, and in many species insure considerable dispersal over a limited area.

The leaves of grasses are composed of two parts, a basal sheath which enwraps the stem and a flat elongate blade. The veins of the leaf are all parallel to one another, with few inconspicuous interconnecting veinlets. The blades of grasses grow from the bases, so that the apical portion is older and the cells of the basal portion retain for some time the ability to divide and increase. Because of this property grasses can be mowed by machines or cropped by animals, the upper portions of the blades being removed and the basal portion growing to renew the blade. Each node bears a single leaf, which is often reduced to a small scale, especially in the lowermost nodes, and in modified stems, such as rhizomes. At the junction the sheath with the blade there occurs in many grasses a distinct structure called the ligule. This appears on the stem side of the leaf, and is a membranous or cartilaginous fringe or ring.

An **inflorescence**, in grasses, is composed of large numbers of groups of flowers, called spikelets, attached to the main stem or rachis. These spikelets are variously arranged. If they grow directly from the main stem and the latter is unbranched, the inflorescence is said to be a spike. If the main stem produces many branches, which in turn branch, the resulting inflorescence is a panicle. The nature of the branches, whether long or short, spreading or appressed, determines the nature of the panicle. In other grasses the inflorescence is a raceme, the spikelets being borne on short unbranched lateral branches.

The individual spikelet of a grass is composed of a short axis called a rachilla from which arise a series of opposite overlapping **bracts**. The two lowermost bracts are called glumes; these are empty, that is, have no flowers formed in their axils. The next bract above the glumes is the lemma, in the axil of which is borne a flower. In many grasses each spikelet contains several

A grass, red top (*Agrostis alba*). 1, panicle of flowers, ½ natural size; 2, single flower, consisting of three stamens and one pistil with two branching feathery styles, all enclosed by scales; × 15.

lemmas, each with its associated flower. Opposite the lemma is the palea, which is not borne on the rachilla, but on a short pedicel, or flower-stalk. Opposite the palea and at the base of the **ovary** appear two minute scales, the lodicules. Three **stamens**, each with a long slender filament and a large **anther**, come next, while a single **pistil** grows at the apex of the pedicel. The pistil is composed of a one-celled, one-seeded ovary, two **styles** and two feathery stigmas. Many variations from the typical spikelet described occur in different species, the number of parts being increased, or parts being completely absent. In many species of grass, conspicuous prolongations on the glumes or the lemmas are noted—these are the **awns**.

Pollination in grasses is almost entirely by wind, the light dry pollen being scattered from the open anthers, often in conspicuous clouds. Grass pollen is a particularly common cause of hay-fever.

The fruit of grasses is one-seeded, dry and indehiscent, tnat is, does not split open at maturity to liberate the seed. The ovary wall, or **pericarp**, is attached to the seedcoat. Within the latter is an abundant starchy **endosperm**. Such a fruit is known as a grain or a karyopsis.

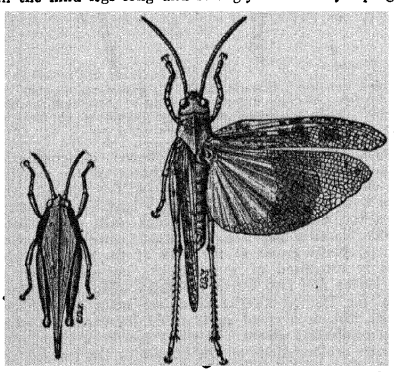
Considerable speculation has been advanced as to the probable origin of grasses, whether they are primitive **monocotyledonous** plants from which others such as lilies may have developed, or whether they are reduced plants. To many the available evidence indicates reduction from lily-like ancestors, a reduction in which two of the three pistil lobes of the ancestral form have been lost, also an entire whorl of stamens, and many of the **perianth** parts. The anatomy of the floral parts lends support to this conception; the vascular bundles suggesting that reduction has occurred. For example, in the pistil there are three vascular bundles, two passing to the styles, and the third bearing the ovule.

The vast importance of grasses to mankind has been previously noted. Grasses supply an important part of

the food of the more valuable of man's domestic animals. Many of the forage grasses occur in the wild state, forming extensive ranges on which stock may be pastured. Others are cultivated, and used directly as forage or dried and stored as hay. The search for improved hay grasses has led to the introduction of many valuable species. Notable among them is Timothy, *Phleum pratense*, a grass particularly adapted for cool, moist climates. Another group of forage grasses is that of the millets, lush-growing annual grasses used not only as green forage and cut for hay, but also occasionally grown for their "seeds," used in poultry foods. Millets grow very rapidly and are drought-resistant, and are therefore valuable in regions where the rainfall may be deficient. Another source for bird seed is *Phalaris canariensis*, a grass which is not extensively grown in the United States, but widely in Argentina.

Vast in importance, but few in number, are the grasses grown for their fruit or grain; these are the cereal grasses. These are particularly important in regions of cooler climates, where the grain they produce during the short growing season is a valuable crop which can be stored and used as food during the remainder of the year. The principal cereals are **wheat, corn, oats, rye, barley,** and **rice.** (R.M.W.)

GRASSHOPPER. Insecta, Orthoptera. **Insects** of moderate to large size, usually with four wings, and with the hind legs long and strongly built for jumping.



Grasshoppers. The figure at the left is a grouse locust, that at the right a common grasshopper.

The mouth parts are formed for biting and the front wings are thickened tegmina which conceal the hind wings when folded. The long-horned grasshoppers include the **katydids** and related species, which have very long many-jointed antennae. Short-horned grasshoppers have short antennae with a moderate number of joints and are the grasshoppers or **locusts** of common usage. The term locust applies properly to these insects, although it is also used for the cicadas.

The family Tettigoniidae, to which the long-horned grasshoppers belong, contains the katydids, **meadow grasshoppers, cone-headed grasshoppers,** and a number of wingless forms, including the cave or **camel crickets,** the **mormon cricket,** and the **sand cricket,** none of them true crickets.

The family Locustidae includes insects of more uniform appearance. The only members that differ strikingly from the grasshoppers of common experience are the little grouse locusts or **pigmy locusts.** They are less than an inch long and have the dorsal shield of the thorax prolonged over the entire body in an acute point.

In the plains and prairie states grasshoppers are sometimes a serious pest, destroying green crops completely. They are destroyed by the use of poison baits made of bran (25 pounds), molasses (2 quarts), Paris green or arsenic (1 pound), and six finely chopped lemons or oranges, mixed with two to four gallons of water, according to the prevailing humidity. The mixture should break apart slowly when squeezed into a ball. It is sown broadcast in the fields, preferably late in the day so that it may remain moist as long as possible.

In low crops, such as clover, a hopper trap has been used with great success. It is drawn through the field by horses. The hoppers are shoveled into sacks and when dead are spread out to dry in the sun before they are stored. They are an excellent winter food for poultry, hence this method of control is doubly profitable. (A.W.L.)

GRASSQUIT. Aves, Passeriformes. A Jamaican name for certain of the small birds more commonly called **buntings.** (A.W.L.)

GRATE. Bars which are arranged to support solid **fuel** for **combustion** are grates. The purpose of a grate is not only to support the fuel bed, but also to allow air to pass into it evenly throughout. Service conditions of grates call for considerable structural strength, resistance to temperature and oxidation, and a shape serrated or rough edged, so as to leave air openings between adjacent grate bars. Furthermore, since ashes are generally dumped through the grate bar system, a means for increasing the spacing between bars so as to pass ash between them must be provided in such a way that motion of a shaking crank or lever will clear ash over the entire grate surface. Because of its cheapness and its resistance to oxidation, cast iron has been the material most used for the construction of grates. (F.T.M.)

GRATE EFFICIENCY. The efficiency of a grate is a measure of the effectiveness with which the grate or its equal prevents combustible from reaching the ashpit. Too frequent slicing of the fire-bed, a poorly maintained fuel bed, and a clinkering type of ash, are sources of combustible in the refuse. Analysis of ashpit contents shows that the combustible is practically all carbon, having a heating value of 14,540 B.T.U. per pound. If the asphalt contents analyze Z% combustible, the fraction of a pound of carbon per pound of coal thus represented is:

$$\frac{Z}{100 - Z} \times \frac{\text{(Percent ash in the coal)}.}{100}$$

The grate efficiency is found by subtracting from 100% that per cent of the heating value of the coal represented by the combustible in the refuse at the rate of 14,540 B.T.U. per pound. (F.T.M.)

GRATING. Diffraction Grating.

GRAVE'S DISEASE. Thyroid Gland.

GRAVID. Pregnancy.

GRAVITATION AND GRAVITY. The distinction between these two terms is that between a universal property of matter and the special manifestation of that property exhibited in the vicinity of the **earth** or other celestial attracting mass and modified by the **centrifugal force** of planetary rotation.

Newton's conception of gravitation was expressed by his statement, to the effect that every particle of matter attracts every other particle with a force proportional to the product of the masses and to the inverse square of the distance. We are thus left to picture an infinitely complex network of attractions joining every two particles in the universe and tending to pull them together. Newton did not specify what the "particles" were assumed to be, whether atoms or otherwise. Faraday introduced a somewhat different picture in the form of a stressed medium, with its curved lines and tubes of

force The Einstein concept, again, envisages a space so warped by the presence of surrounding masses that a particle, which if projected into an empty space would follow a straight line, actually follows a more or less complicated curve, a geodesic line of this warped space, which represents physically the most direct path between any two points of the space Furthermore, **Einstein's equivalence principle** makes no distinction between gravitation and centrifugal force

The Newtonian law may be expressed by the equation $f = Gm_1m_2/r^2$, in which m_1 and m_2 are the masses of two particles, r the distance between them, and G the **gravitation constant** For practical purposes the "particles" may be homogeneous spheres, r being the distance between their centers Other bodies of finite size, such as cubes or cylinders, would not do, as they are not "centrobaric", that is, there is no one point toward which their attraction is directed The planets and stars being sensibly spherical, they may be treated approximately as particles It was from the study of the **two-body problem** as applied to such objects that Newton deduced the conclusion expressed in his law

At any point on the earth's surface, the earth's gravitational attraction is directed approximately toward its center But since the earth rotates, the "weight" of a body is somewhat less than the earth's attraction for it, because of the centrifugal force, and is, furthermore, not in general directed toward the earth's center A plumb line ten feet long in the **latitude** of New York departs about a quarter of an inch to the south from a line in the direction of the earth's geometrical center This same influence accounts for the oblateness of the earth, and these two facts together, for the variation of gravity from equator to poles Thus at the equator the weight of a gram mass is 977 09 **dynes,** while at the poles it exceeds 983 dynes These facts are ascertained by observations with such instruments as **Kater's pendulum,** and the Eotvos balance (a kind of **torsion balance** used for gravity measurements), by means of which the acceleration that would be given to a freely falling body is indirectly determined Various more or less complicated formulas expressing the intensity of gravity as a function of latitude and altitude have been proposed by Clairaut, Helmert, Hayford, and others, but these must always be modified to suit local conditions of topography and density of the crust (L D W)

GRAVITATION CONSTANT. The constant G in the equation expressing **Newton's** law of **gravitation,** which gives the attraction between two particles of masses m_1, m_2 at distance r as

$$f = G\frac{m_1m_2}{r^2},$$

is called the Newtonian constant or the constant of gravitation Newton himself was ignorant of its value Not until 1798 did Cavendish utilize the **torsion balance** in the measurement of this important quantity The obvious procedure is to place two known masses m_1, m_2 at a known distance r and measure the force of attraction f between them, from which $G = fr^2/m_1m_2$ The constant might be interpreted as numerically equal to the force between unit masses at unit distance In the actual experiment, large metal balls weighing several pounds each exert a torque on smaller balls mounted at the ends of the torsion balance beam This torque, and hence the forces producing it, can be measured The most recent determinations, made by P R Heyl at the Bureau of Standards in 1928, gave the value of G as $6\,67 \times 10^{-8}$ dyne cm^2/g^2 The attraction between two small spheres of one gram mass each with their centers one centimeter apart would thus be $6\,67 \times 10^{-8}$ dynes The exceedingly small magnitude of the quantity sought accounts for the difficulties in technique and the relatively low precision attained (L D W)

GRAVITY. Gravitation and Gravity.

GRAVITY FAULT. Fault.

GRAYLING. Pisces, Teleostei *Thymallus* Fishes (**pisces**) of the northern hemisphere, found in cold lakes and streams Related to the salmon and trout Two species in North America (A W L)

GRAYWACKE or GRAUWACKE. This term is of British origin and is not used extensively outside of western Europe As originally defined graywacke designates hard, dark colored, coarse sandstones and grits having an **argillaceous** matrix or cement and occurring among the lower **Paleozoic** formations of Wales, England Many typical graywackes are similar to **basic arkoses,** the dark color being due to a preponderance of the **femic** minerals and **plagioclase feldspar** (R M F)

GREAT CIRCLE CHART. Among navigators the **gnomonic projection** is commonly known as a great circle chart, because of the fact that on this type of projection, great circles are projected as straight lines (W K G)

GREAT CIRCLE COURSE. The shortest distance between any two points on the surface of a sphere is a great circle For all practical purposes of navigation the earth may be considered as a sphere, and, hence, the shortest course which a vessel may follow between any two ports is a great circle course

The great circle course between two ports is frequently impractical for a ship to follow, because of the fact that it may lead across land or into dangerous waters For example, the great circle course between two points in the same **latitude,** but separated by 180° of **longitude,** will lead across the pole of the earth Before deciding whether or not the **great** circle is practicable it is necessary to compute the course, computing a sufficient number of points so that the track may be plotted on a chart Such computation is laborious and, to avoid the necessity of doing the computing, a **great circle chart** may be used On such a **chart** any great circle appears as a straight line and all that is necessary for the purpose of studying a great circle course is to draw a straight line between the two points on the chart and examine it

Even though the great circle course does not lead the ship into danger, it is very difficult to follow such a course for it makes a different angle with each successive meridian and would require the helmsman to continually change his course To avoid this difficulty, as well as to avoid dangers, and still approximate as closely as practicable to the shortest distance between the ports, the **composite course** is the type almost universally followed by vessels (W K G)

GREBE. Aves, Colybiformes Swimming birds (**Aves**) with lobed toes, short legs and neck, and a sharp beak, in some species quite long The grebes are found in temperate regions of both hemispheres and members of the same species may have a very wide range The pied-billed grebe is also called the **dabchick.** (A W L)

GREENBACK. Pisces, Teleostei A species of **trout,** *Trutta smaragda,* reported from the headwaters of the Arkansas and South Platte rivers (A W L)

GREENOCKITE. The mineral greenockite is **cadmium** sulfide and is used as an ore of that metal It is found rarely in **hexagonal** crystals, sometimes as earthy coatings on other minerals Its hardness is 3-3 5, specific gravity, 4 9–5 0, luster, adamantine to earthy, color, yellow to yellowish orange, subtransparent It is found in Scotland, Bohemia, and France Also in the United States at Franklin Furnace, New Jersey, and Marion County, Arkansas, where it occurs as a yellow coloring matter in **smithsonite,** and in Mono County, California It was named for Lord Greenock (E S C S)

GREENSAND. Glauconite.

GREENSHANK. Aves, Charadriiformes A European **sandpiper**, *Tringa nebularia*, related to the **willets** of North America It migrates into South Africa and Australia (A W L)

GREEN'S THEOREM IN THE PLANE. The English mathematician and physicist Green (1793–1841) discovered a number of mathematical results concerning transformations of various types of **integrals** into other useful types Green's theorem in the plane, which is one of several so-called Green's theorems, expresses a **line integral** in the plane in terms of a **double integral** in the plane, or vice versa

Let $P(x,y)$ and $Q(x,y)$ be two functions of x and y, which, together with their first **partial derivatives**, are **continuous** within and on the boundary C of a region S, then

$$\int_C (Pdx + Qdy) = -\iint_S \left(\frac{\partial P}{\partial y} - \frac{\partial Q}{\partial x}\right) dS,$$

where the right-hand side is a double integral of a function of x and y over a plane region S

An immediate consequence of this theorem is If P and Q are functions satisfying the preceding conditions, and if $\frac{\partial P}{\partial y} = \frac{\partial Q}{\partial x}$, then $\int_C (Pdx + Qdy) = 0$, and conversely, if $\int_C (Pdx + Qdy) = 0$, then $\frac{\partial P}{\partial y} = \frac{\partial Q}{\partial x}$ (L L S)

GREEN'S THEOREM IN SPACE. This is one of several mathematical results discovered by Green, it is of very great importance in all parts of mathematical physics It gives a transformation of a surface integral in space into a triple (volume) integral, or vice versa

Let $P(x,y,z)$, $Q(x,y,z)$, $R(x,y,z)$ be **continuous** together with their first **partial derivatives**, within and on the closed boundary **surface** S of a region V of space Then

$$\iint_S \{P(x,y,z)dydz + Q(x,y,z)dzdx + R(x,y,z)dxdy\} = \iiint_V \left(\frac{\partial P}{\partial x} + \frac{\partial Q}{\partial y} + \frac{\partial R}{\partial z}\right) dxdydz$$

If dS denotes a surface element, and if α, β, γ are the **direction angles** of the outer normal to the surface, the **surface integral** above may be written

$$\iint_S (P\cos\alpha + Q\cos\beta + R\cos\gamma)dS$$

This theorem is sometimes called Green's theorem in space, sometimes the **divergence** theorem, sometimes Gauss' theorem

In **vector** language and vector notation, this theorem may be stated thus The volume integral of the divergence of a vector function **F** of position taken over any region V of space is equal to the surface integral of **F** taken over the closed surface S bounding the region V

$$\iiint_V \nabla \cdot \mathbf{F} dV = \iint_S \mathbf{F} \cdot \hat{\mathbf{n}} dS$$

Other important formulas derived from the preceding, and which are often referred to as Green's theorems also, are the following

I. $$\iiint_V u\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) dV + \iiint_V \left(\frac{\partial u}{\partial x}\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\frac{\partial v}{\partial y} + \frac{\partial u}{\partial z}\frac{\partial v}{\partial z}\right) dV = -\iint_S u\frac{\partial v}{\partial n} dS,$$

where u and v are functions of x, y, z, and where $\frac{\partial v}{\partial n}$ is the directional derivative of v along the inner normal to S; in **vector** form, this becomes

$$\iiint_V u\nabla^2 v dV + \iiint_V \nabla u \cdot \nabla v dV = \iint_S u\nabla v \cdot \hat{\mathbf{n}} dS.$$

II $$\iiint_V (u\nabla^2 v - v\nabla^2 u)dV = -\iint_S \left(u\frac{\partial v}{\partial n} - v\frac{\partial u}{\partial n}\right)dS.$$

III $$\iiint_V \nabla^2 u dV = -\iint_S \frac{\partial u}{\partial n} dS$$

IV. $$\iint_S \frac{\partial u}{\partial n} dS = 0 \quad \text{if } \nabla^2 u = 0,$$

i e , if u is a solution of **Laplace's equation.**

V $$\iiint_V \left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial z}\right)^2\right] dV = -\iint_S u\frac{\partial u}{\partial n} dS,$$

if u is a solution of Laplace's equation $\nabla^2 u = 0$ (L L S)

GREENSTONE. Greenstone is an old field term for more or less altered **basalts** and **dolerites**, which because of the development of **chlorite** or perhaps **hornblende** or **epidote** develops a characteristic green color. Many **diabases** and **epidiorites** have been called greenstones (R M F)

GREGARINIDA. An order of one-celled animals, parasitic in various invertebrates (See **Sporozoa**) (A W L)

GREGARIOUSNESS. An association of animals of the same species which may be of benefit to the individual but is not essential The incidental grouping of animals, as in the swarms of maggots in a dead body, is not an association of this type, but the grouping of caterpillars of certain moths, even though the group originates in a like manner by the deposition of eggs in a mass, must be regarded as a gregarious association because the maintenance of the group is due to the behavior of the individuals They are free to scatter but do not

Herds of grazing animals cooperate for the common defense and such animals as the killer whale and the wolves are able to attack large animals by hunting in groups, but in all such cases the individual is able to subsist without the assistance of his fellows (A W L)

GREISEN. An old German **petrological** term originally proposed by Werner for an **igneous** rock of **granitic** or **aplitic** texture composed principally of **quartz, alkali feldspar**, the **fluorine**-rich micas, and sometimes containing **topaz** Greisens are pneumatolytically altered granites which are closely associated with the development of the tin ore mineral, **cassiterite** (R M F)

GREYHEN Aves, Galliformes The female of the Eurasian black **grouse** (A W L)

GRIBBLE. Crustacea, Isopoda A small marine **crustacean**, *Limnoria lignorum*, which bores into submerged timbers. A source of serious damage to docks and piling. (A W L)

GRID. The grid is one of the elements of the three-element **vacuum tube**, being interposed between the **filament** and the **plate.** It is made in the form of a mesh and controls the number of **electrons** passing from filament to plate, for when the grid is positively charged, it increases the flow of electrons, and when negatively charged, repels When the grid is attached to some feeble source of alternating current, such as the impulse coming in on an antenna, it causes a flow of electrons from the filament to the plate, which is in proportion, though amplified, to the impulses received. (F T M)

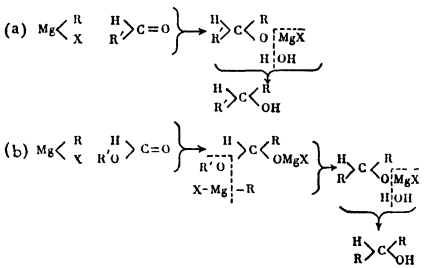
GRIGNARD REACTION. Magnesium metal plus haloid (See **Chlorine, Bromine, Iodine**) hydrocarbon ($Mg\langle^{R}_{X}$) in anhydrous **ether**, introduced by Grignard, is used as reagent for the preparation of

1. Secondary alcohols by treatment with **aldehydes** or **formic acid** esters
2. Tertiary alcohols by treatment with **ketones** or **esters** (not formic acid esters)
3. Primary **alcohols** by treatment with **formaldehyde**
4. Alcohols by treatment with **oxygen** gas or **hydrogen peroxide**
5. **Hydrocarbons** by treatment with water, alcohols, **phenols, amines** With R X as ethyl bromide (C_2H_5Br) the volume of ethane gas (C_2H_6) evolved may be utilized as a measure of hydroxyl (OH—) or amino (NH_2—) radical One mol of ethane for each equivalent of either
6. **Carboxylic acids** (group —COOH) by treatment with **carbon dioxide**
7. Sulfinic acids (group —SOOH) by treatment with **sulfur dioxide**
8. Organic **phosphines, arsines, mercury** di-, **tin** tetra-, **lead** tetra- compounds

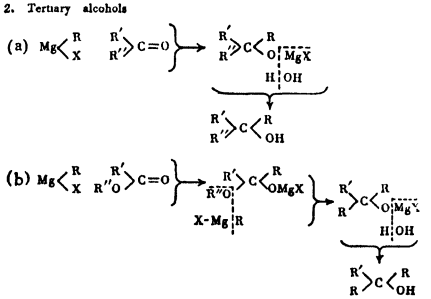
An intermediate compound, identified in numerous cases, but generally not isolated, is formed, and this is decomposed subsequently by addition of water or acid with the formation of magnesium hydroxyhalide (magnesium halide solution when acid is used) plus the main product The main product is usually extracted with ether followed by recovery upon evaporation of the ether "Within recent years no single group of compounds has proved of such value in synthetic chemistry as these (Grignard) reagents" (Bernthsen-Sudborough, 1930)

Illustrative examples follow:

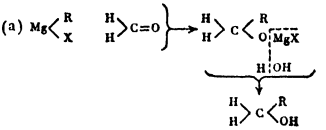
1. Secondary alcohols



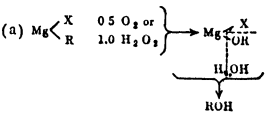
2. Tertiary alcohols



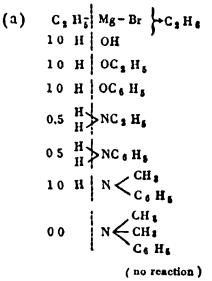
3. Primary alcohols

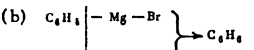


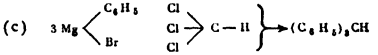
4 Alcohols

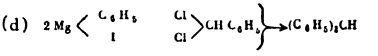


5. Hydrocarbons

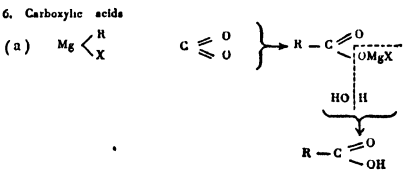




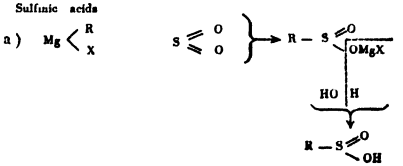




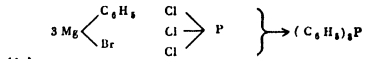
6. Carboxylic acids



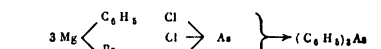
7 Sulfinic acids



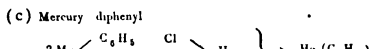
8 (a) Triphenylphosphine



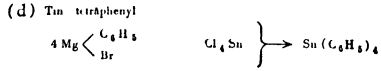
(b) Triphenylarsine



(c) Mercury diphenyl

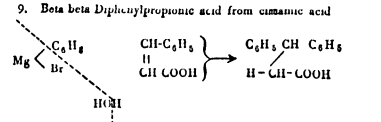


(d) Tin tetraphenyl



(e) Lead tetraphenyl

9. Beta beta Diphenylpropionic acid from cinnamic acid



The choice of haloid hydrocarbon is in some cases important in determining the yield of the desired substance

GRILLAGE. A grillage is a system of timber or steel beams which is used under **columns** to spread the **loads** over a comparatively large area Timber grillages, consisting of layers of wooden beams, laid at right angles to each other, are generally used for temporary construction, although there are instances in which they have been inclosed in concrete for permanent construction If this grillage is used for permanent foundation it should be either entirely submerged or creosoted to withstand deterioration

The steel grillage consists of one or more layers or tiers of beams which are encased in concrete If there are two or more tiers the beams in one tier are laid at right angles to those in the next tier The individual beams in each tier are held in place by rods and pipe separators, cast-iron separators or steel diaphragms Since the concrete encased steel grillage has more resistance to bending than the ordinary reinforced concrete spread **footing** it can be used to distribute heavy column loads over large areas (C W C)

GRISON Mammalia, Carnivora *Galictis* A small South American animal with long slender body and tail and short legs Related to the weasels (A W L)

GRIT An old term for coarse-grained sandstones whose components are angular or "gritty" There is a tendency to use it for any coarse-grained sandstone without regard to the angularity of the fragments (R M F)

GRIVET. Guenon.

GROSBEAK. Finch.

GROSSULARITE. Garnet.

GROUND. In electrical terminology, a ground is a conductor connected to earth, or a large conductor whose **potential** is taken as zero (e g, the steel frame of a car) A ground may be an undesirable, inadvertent, or accidental path taken by an electrical current in its effort to reach ground potential, or it may be the deliberate provision of **conductors** well connected to the ground by means of plates buried therein, or similar device

There is always the possibility that, during the life of an insulated conductor, the insulation may be punctured or broken down and a ground occur Usually, a ground develops rapidly into a low-resistance path through which currents of damaging magnitude may flow **Insulation** may be damaged in many ways—by the effect of moisture, or chemical vapors, by age, heat, abrasion, breaking, or crushing Two-wire direct-current systems are permanently grounded on one side of the line, three-wire direct-current systems permanently grounded on the neutral wire The same applies to two- or three-wire single-phase alternating-current systems The common grounding point of station three-phase lines is the generator neutral

The grounding system of the alternating-current generating station fulfills two distinct functions The first is the grounding of non-current carrying parts, the second is the furnishing of a ground connection for generator or transformer neutral to provide for the operation of a ground protection system A common ground **bus** is employed, to which are connected the frames of all electric machines, the cases of instruments, transformers, circuit breakers, the secondaries of current and potential transformers, the switchboard ground bus, conduits, insulator bases, building structural steel, etc Thus, if the grounding system is effective, a zero, or earth, potential will be established on all metal parts which might otherwise be dangerous in case a ground developed To the common ground bus is also connected the fault bus, when used

Grounds should be detected as soon as possible after they occur and the defective section immediately taken out of service If the ground persists, in a short time an otherwise small repair job may become a large one Lamp type ground detectors are used to a considerable extent on low-voltage circuits because they are reliable and cheap It is important that the low-voltage control circuits be kept as free of grounds as the main circuits They may be applied to high-voltage lines through the interposition, between lamps and line, of potential transformers Also the vacuum tube type and the electrostatic type of ground detector are available for direct connection to the high-voltage lines

In the terminology of building construction, a ground is a strip of wood about 2 inches wide and as thick as the plaster, which is applied to the framing when nailing room is needed Grounds are used around windows and doors, at baseboards, cornice, etc (F T M)

GROUNDHOG. Woodchuck.

GROUND ICE Ice will occasionally form in stream beds, especially in the lee of rocks or other obstructions which tend to reduce the velocity of the water and allow freezing to take place Such ice formations are known as ground ice or anchor ice (R M F)

GROUND MORAINE. When a valley glacier melts completely away the debris carried on or within it is dropped upon the valley floor forming a deposit called ground moraine The ground moraine from the melting of the great **Pleistocene** ice sheets is usually spoken of as till (R M F)

GROUND PEARL Insecta, Homoptera The iridescent covering secreted by some of the scale insects which live on the roots of plants Used as ornaments. (A W I)

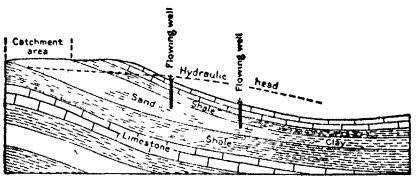
GROUND WATER. At varying depths below the surface of the earth, depending upon wet or dry seasons, underground structures, and other natural and unnatural factors, is a zone which is saturated with water most of

which comes from rain which has penetrated the ground The upper surface of this saturated zone is called the water table, and the water itself, the ground water or the sub-surface water The region above the upper surface of the water table is called the zone of aeration or vadose zone

There is a lower limit to the saturated zone as well as an upper limit Little ground water exists at depths below two or three thousand feet Deep down in the earth's crust the pressure must be so great that all pores in the rocks are completely closed, thus at depths of several miles below the surface there could exist no zone of saturation

The ground water moves through the rocks and unconsolidated materials of the earth near the surface, constantly seeping into streams and lakes to maintain these bodies of water between rains If this seepage is sufficiently strong on hillsides or elsewhere springs may result A well is simply an opening dug deep enough to encounter the zone of saturation

In certain cases the ground water will flow through porous tilted beds called aquifers from higher to lower localities, establishing a "head" which is sometimes sufficiently great to cause the water to flow out under pressure and rise above the surface of the ground, when the aquifer is penetrated by a drill Such a source of water is called an artesian well from Artois, France, a classic locality for such waters Artesian conditions exist along much of the Atlantic Coastal Plain of the United States and in North and South Dakota, Nebraska, Kansas, Illinois, Indiana, Missouri and Arkansas Since the supply of underground water is largely dependent upon structure, the geology of water supply is one of the most important economic phases of the earth sciences From the point of view of their origin, groundwaters are classified as juvenile, connate and meteoric Juvenile waters are of volcanic or magmatic origin, hence original Connate waters are those in which the sediments were originally deposited Meteoric waters are those of atmospheric origin



Structure section illustrating flowing artesian wells in a monocline (After U S Geological Survey)

All pure water, and most of all of the underground waters are of meteoric or surface water origin (R M F)

GROUP. For the significance of this term in Geology, see **Era**

GROUPER Pisces, Teleostei A marine game fish (**Pisces**) of the West Indies and the Atlantic Coast Related to the sea bass (A W L)

GROUPS. A set of elements G is said to form a group when they satisfy the following conditions

(1) There is an operation by which to each ordered pair of elements A and B of G there is associated an element C of G, denoted by $C = AB$

(2) For this operation the associative law holds $(AB)C = A(BC) = ABC$ for any three elements A, B, C of G

(3) There exists (a) a unit-element E in G such that $EA = A$ for each element A of G, and (b) to each element A of G there exists a reciprocal (or inverse) element A^{-1} of G such that $A^{-1}A = E$

If the commutative law $AB = BA$ holds for any elements A and B of G, the group G is called an Abelian group (L L S)

GROUP VELOCITY. The velocity of propagation of an **interference** pattern between two or more wave trains traveling in the same direction with different speeds It may be quite different from the velocity of any one of the component wave trains If there are more than two components, the character (wave form) of the resultant wave changes as the "group" progresses, so that the group velocity becomes ambiguous For two components the analysis is fairly simple

To illustrate, first suppose for the moment that the wave train A of shorter wave length λ is standing still, and the other, B, of wave length $\lambda + \Delta\lambda$ is moving past it in the

Two sets of waves traveling with different velocities. Resultant maximum is at X

positive direction (see figure) For example, let $\lambda = 1$ centimeter and $\lambda + \Delta\lambda = 1.1$ centimeter, and let the velocity Δv of the train B relative to the (stationary) train A be $+3$ centimeters per second As often as B moves forward 0.1 centimeter, the coincidence or **beat** maximum X moves backward 1 centimeter, consequently X moves with respect to A with the velocity -30 centimeters per second, which is -10 times, or in general $-\frac{\lambda}{\Delta\lambda}$ times, the velocity Δv with which B moves (The analogy to a **vernier** should be quite apparent) Now suppose that an additional velocity v is imposed upon both wave trains, so that now A moves with velocity v and B with velocity $v + \Delta v$ If $v = +100$ centimeters per second, A moves with this velocity, B moves 103 centimeters per second but X moves only $100 - 30 = 70$ centimeters per second That is, the velocity of the interference maximum X is $u = v - \lambda\ \Delta v/\Delta\lambda$ This is the group velocity, usually written

$$u = v - \lambda \frac{dv}{d\lambda}$$

In the case of media in which there is **dispersion**, v is a function of λ, where there is no dispersion, $u = v$

Take the case of sodium light traveling through carbon bisulphide This light has two close components with respective wave lengths 5890 angstroms and 5896 angstroms The **refractive index** for the 5890-angstrom component being about 1.64, the velocity v of this component in CS_2 is about 1.83×10^{10} centimeters per second Now the dispersion of CS_2 in this part of the spectrum is such that $\frac{dv}{d\lambda}$ is readily computed to be 3.81×10^{13} centimeters per second per centimeter, while the wave length λ in CS_2 is 3590 angstroms or 3.59×10^{-5} centimeters Hence the group velocity u is 1.83×10^{10} centimeters per second $- 3.59 \times 10^{-5}$ centimeters $\times 3.81 \times 10^{13}$ centimeters per second per centimeter $= 1.69 \times 10^{10}$ centimeters per second

Michelson, using the same revolving mirror method as for the **electromagnetic constant**, actually obtained this velocity in carbon bisulphide, showing that it is the group velocity which this method really measures (L D W)

GROUSE. Aves, Galliformes Game birds with compact rounded bodies and legs feathered to the feet The closely related ptarmigans have both legs and feet feathered

Grouse are birds of the northern hemisphere The ptarmigans, including the red grouse of the British Isles and the willow grouse, are found at high altitudes and in the north Most of these birds have white plumage

in the winter. Grouse vary in habits, some frequenting woodlands and others open ground

Among the best known North American species are the ruffed grouse, *Bonasa umbellus*, the prairie chicken, *Tympanuchus*, and the sage grouse, *Centrocercus urophasianus* The heath hen, *Tympanuchus cupido*, an eastern species resembling the prairie chicken, has recently become extinct Two western species, the Franklin grouse, *Canachites franklini*, and dusky grouse, *Dendagapus obscurus*, are locally called the fool hen (A W L.)

GROUSE LOCUST. Grasshopper.

GROUT. Grout is a mixture composed of **cement** and sand with just enough water added to make it flow readily It may be used to reinforce the bearing value of soils underneath **foundations.** This is done by forcing grout, under pressure, into the voids (openings) between the soil particles Grout is also excellent for use in connection with **column footings** and machine foundations which require level bearing surfaces Since a column footing can never be poured to an exact elevation it is usually built up to within about an inch of its final elevation Steel shims (fillers) are placed on the top of the footing so as to provide the correct elevation for the bottom of the base plate of the column. The column base which is an integral part of the column is then set on the shims After the anchor bolts, which are used to fasten the column to the footing, have been tightened, the space between the top of the footing and the bottom of the base plate is filled with grout (C W C)

GROWTH Increase in size Growth of living structures depends upon increase in the number of cells or in the bulk of cells and intercellular material It is based on the process of intussusception through which materials received as food become an integral part of the structures already present Accretional growth is of very limited occurrence in living things and is not independent of intussusception

Most animals exhibit determinate growth, that is, they increase in size until they approximate a limit characteristic of their kind A few mature within rather wide limits according to the amount of food available In the adult body the capacity of various tissues to continue their growth varies, but in all cases tissues which are worn away in the course of normal life have the power of renewal and some, such as the bone producing cells of vertebrates, are capable of becoming active for the restoration of damaged structures These aspects of growth are closely associated with **regeneration.**

The rate of growth in different parts of the body also varies, as also does the rate of total growth at different periods of life Most mammals increase in size rapidly during early life and gradually slow down as maturity is approached, while man grows rapidly during infancy, slowly during childhood, rapidly again during youth, and more slowly toward the completion of his size In his body the nervous system most rapidly approaches its maximum size and the reproductive system lags until the onset of maturity Some of the glandular tissues increase rapidly before maturity and then decrease in bulk The balance of all of these processes when normal food is available results in the gradual process of general growth, and the attainment of stability in adult life is a result of their correlation with external factors Although no one factor is wholly responsible for growth, **hormones** of the pituitary and thyroid glands are of great importance in its regulation in vertebrates Deficiency of either gland may result in dwarfing and pituitary excess sometimes causes human beings to attain unusual height Persons taller than seven feet are probably due in all cases to such abnormality. (A W.L.)

GROWTH SUBSTANCE. Auxin.

GRUB. The soft white larvae of certain beetles. They have few legs, limited to the anterior part of the body Other animals of similar appearance are also called grubs (A W L)

GRUIFORMES. The **rails, coots, cranes** and related species An order of wading and swimming birds (**Aves**) of varied form with lobed toes or with neither lobes nor webs. Feet never fully webbed. (A W L)

GRUNERITE. Cummingtonite.

GRUNT Pisces, Teleostei A term applied to food fishes (**Pisces**) of several marine species on the Atlantic Coast. (A W L)

GUACHARO. A native name for the **oil bird.** (A W L)

GUAN. Aves, Galliformes Game birds (**Aves**) of Central and South America, related to the curassows. One species, the chachalaca, *Ortalis vetula*, enters southern Texas (A W L)

GUANACO, HUANACA. Mammalia, Artiodactyla. A wild representative, *Lama huanacus*, of the group commonly called **llamas,** the New World representatives of the camel family The guanaco ranges from high altitudes in Ecuador to Tierra del Fuego and is larger than the vicuna, the one other wild species (A W L)

GUANIDINES Amines and Amides.

GUANINE. Alkaloids

GUARD CELLS. Stoma.

GUAVA. *Psidium guajava*, and other species Myrtaceae Guava, a shrub or small tree indigenous to tropical America, has oblong, short-petioled leaves and white flowers The fruits have a curious penetrating odor and vary greatly in appearance Their slightly acid, seedy pulp is principally used in making guava jelly The plant has been widely introduced into tropical countries throughout the world, in the United States it is grown in Florida and southern California (R M W)

GUAYULE. Rubber.

GUDGEON. Pisces, Teleostei *Gobio* Small freshwater fishes (**Pisces**) of Europe (A W L)

GUEMAL. Deer.

GUENON. Mammalia, Primates. A group of African **monkeys** of the genus *Cercopithecus* All species are slender and of moderate or small size The genus includes the vervet, grivet, mona monkeys, patas, nisnas, ludio, hocheur, and several other species named as monkeys. (A W L)

GUEREZA. Mammalia, Primates An African thumbless **monkey** of the genus *Colobus* (A W L)

GUILLEMOT. Aves, Charadriiformes *Uria* Birds (**Aves**) with short legs, webbed feet, and upright posture, related to the auks The several species are found chiefly about the northern oceans. (A W L)

GUINEA FOWL. Aves, Galliformes. African birds (**Aves**) of several species, related to the pheasants All have some dark plumage with light spots, and brightly colored bare skin about the head and neck The common Guinea fowl, *Numida meleagris*, is among the common domesticated species (A W L)

GUINEA PIG. Cavy. These little rodents are widely kept as pets and are useful to medical science as laboratory animals Because of their high rate of reproduction they have also been bred for the study of heredity. (A W L)

GUINEA WORM Nemathelminthes, Nematoda A large roundworm, *Filaria medinensis*, parasitic in man. It sometimes reaches a length of more than a yard The

worm lives in the superficial tissues, forming an abscess open to the surface, and can be removed by gradual traction on the end of the body exposed in this opening. The eggs are dropped in the water and the young develop in the bodies of water fleas The species occurs in tropical Asia and Africa. (A W L)

GULL. Aves, Charadriiformes Water birds (**Aves**) with webbed feet and long narrow wings Their flight is powerful and easy, and they are more often seen in the air than on the water They are common along the seashore and on larger bodies of fresh water, but Franklin gulls are often seen far from water, even following the plow to pick up insects With the exception of the sabine gull they may be distinguished from the closely related terns by the square end of the tail The kittiwake is a related species of the North Pacific and Bering Sea (A W L)

GUMBO. Till.

GUMMA. A soft spongy **tumor** that occurs in late untreated **syphilis.** (R S M)

GUMS. These are **carbohydrates** of complex structures which are formed as decomposition products in many plants They are particularly common in plants growing in very dry regions They have neither taste nor odor and are insoluble in alcohol and ether Many gums are soluble in water, while others unite readily with water to form a mucilaginous product, or swell greatly in water

Gums are employed in making adhesives, in calico-printing, in sizing fabrics, both silk and cotton, and in confectionery Medicinally they are widely used because of their soothing properties, and as a vehicle for insoluble substances

While a great many plants form gums, only a few of these are of any importance to man One of these, gum arabic, is a product of an **acacia** tree of tropical Africa This tree, *Acacia Senegal,* grows in very dry regions It has bipinnately compound leaves which have a gray color, and small yellow flowers borne in axillary racemes The gum exudes from cracks which are formed in the bark of the stem and branches at the beginning of the dry season when very rapid drying of the plant occurs Gum arabic is entirely soluble in water Another gum is obtained from a small shrub growing in desert regions of southwestern Asia This shrub, *Astragalus gummifera,* a **legume,** has pinnate (See **Pinna**) leaves The leaflets fall off, leaving the leaf axis as a stiff thorn The plant has small yellow flowers and small one-seeded pods The gum, known as gum tragacanth, is only partially soluble in water In America several small shrubs of the dry plains yield a gum called mesquite One of these shrubs is *Prosopis glandulosa* Many species of *Prunus,* including the common cherries and plum trees, yield a dark-colored gum which is entirely insoluble in water (R M W)

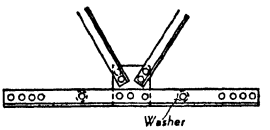
GUN COTTON. Explosives.

GUNDI Mammalia, Rodentia A nocturnal burrowing animal living in rocky country near the Sahara desert (A W L)

GUPPY. Pisces, Teleostei *Lebistes* A small species of the **killifish** family, popular for tropical aquaria The males are brightly colored and variable, the females larger and duller They bear living young and are easily reared if protected from the cannibalistic parents. (A W L)

GURNARD. Pisces, Teleostei *Trigla* Marine fishes (**Pisces**) with high angular heads and finger like appendages on the pectoral fins These processes are tactile and also aid in supporting the fish on the bottom Some are called the sea robins and one British species is known as the piper The flying gurnards and beaked gurnards belong to a related family They are widely distributed marine fishes whose bodies are strangely formed and armored with bony plates. (A W L)

GUSSET PLATE. A gusset plate is a flat plate connecting two or more structural members where they meet at a **joint. Stress** is transferred between the members through the gusset plate by riveted, bolted, or welded connections A gusset plate should be of a shape giving a minimum waste of material, which can



be fabricated in the shop with minimum amount of labor For this reason it should be cut with straight edges The thickness of a gusset plate should be sufficient to give *bearing* value, so that the material or the rivet will not be crushed The area between rivet holes should be great enough to transmit the stress from one member to another Examples of gusset plates are to be found in all types of welded and riveted steel structures, and in gussets which strengthen and make the joints in the rib structure of an airplane wing (F T M)

GUTTA PERCHA. *Palaquium Gutta,* and related species , Sapotaceae Gutta percha is prepared from the **latex** found in the stem and leaves of certain trees native in Malaysia and various South Sea Islands To obtain the latex, which does not flow readily from living trees, the tree may be felled and a series of rings cut in the bark From these the latex oozes and may be gathered Such a method is naturally very destructive to continued production A more desirable method is practiced in plantations of today Fresh leaves are gathered and chopped up and crushed The crushed mass is then boiled in water and the gum removed and pressed into blocks

In South America a related tree, *Mimusops Balata* (Sapotaceae) yields a similar gum of somewhat inferior quality This tree is usually tapped by cutting a row of zigzag gashes which connect one with another Down these the latex flows, to be gathered in a cup at the bottom, and later coagulated in trays

Gutta percha is a yellowish or brownish somewhat leathery solid containing up to 90% of a **hydrocarbon,** gutta On heating, it becomes plastic and is very resistant to water It is therefore much used as insulation for marine cable and electrical equipment, as well as in the manufacture of golf balls and in dentistry The cheaper balata is also used in the manufacture of beltings (R M W)

GUTTATION. Transpiration.

GWYNIAD Pisces, Teleostei *Coregonus* A whitefish (**Pisces**) of the English lakes (A W L)

GYMNOLAEMATA. Bryozoa.

GYMNOPHIONA. A class of **amphibians** made up of legless burrowing species which resemble worms or small snakes They live in the tropics of South America and the Old World About forty species are known (A W L)

GYMNOSPERMS. The Gymnosperms form one of the two main divisions of the seed plants or **Spermatophytes.** The characteristic feature of the Gymnosperms is the occurrence of the **ovule** on the surface of the scale which bears it, and not surrounded by the **ovary** wall In most Gymnosperms the reproductive bodies

are borne in cones The overlapping scales of the ovulate cones protect the developing **embryo** and cover the seed until it is mature

The Gymnosperms are the most primitive of seed plants Arising early in geological time, these plants became abundant and widespread in the **Carboniferous** period From that period to the present gymnosperms have decreased in numbers, many groups becoming entirely extinct Today there are about 500 species of Gymnosperms, occurring in nearly all sections of the world, but attaining their greatest development in the temperate zones There they often form a dominant forest tree, with a comparatively small number of species, but many individuals Other species occur in small isolated groups of few individuals occupying a very limited area

Gymnosperms are woody plants The majority of them are trees, which often attain immense size, being among the largest known plants A few are low shrubby plants, and a very small number of vine-like species exist Nearly all Gymnosperms are plants of xerophytic habit, that is, fitted to survive in regions in which water is not abundant Some, like *Welwitschia* of the arid deserts of southwestern Africa, live in regions where the annual rainfall is but a fraction of an inch

The living orders of Gymnosperms are the Cycads, Ginkgo, the Conifers, and the Gnetales The last order, composed of three genera of widely different habit, has no single distinguishing feature, except the presence of vessels in the secondary wood The three genera are (1) *Gnetum*, a genus of tropical Africa, most of whose species are lianas, growing over other plants A few are trees or shrubs (2) *Welwitschia mirabilis*, a most striking odd plant growing in deserts of southwestern Africa The plant has a large turnip-shaped stem which tapers into a long slender taproot which goes deep into the ground to reach the water table It has two thick leathery leaves which last throughout the life of the plant, growing at the base as they wear away at the tip (3) *Ephedra*, comprising low much-branched shrubs found in desert regions of Africa and America *Ephedra* yields the drug ephedrine, a crystalline alkaloid which is used to give relief to sufferers from asthma and hay fever (See also **Paleobotany.**) (R M W)

GYMNOSPORE Asexual reproductive cells which are capable of active locomotion by amoeboid movement or by cilia or **flagella.** (A W L)

GYMNURA Mammalia, Insectivora Small animals of Burma, the Malay Peninsula, and adjacent islands They resemble the shrews in appearance, with a sharp nose, long tail like that of a rat, and short legs The name is that of a genus but is also used as a common name (A W L)

GYNANDROMORPH. An abnormal individual whose body shows the characteristics of the two sexes in different parts Not synonymous with **hermaphrodite** although this term is sometimes applied to these abnormalities

Gynandromorphs are fairly common among the insects, where they are often of the bilateral type Such individuals have one side of the body male and the other female, with a sharp boundary in the median line Mosaic gynandromorphs present an irregular distribution of the sexual characters (A W L)

GYNECOLOGY. That branch of medicine and surgery which covers diseases of women related to the genital organs and associated structures (R S M)

GYPSUM The mineral gypsum is hydrous **calcium** sulfate, $CaSO_4 \cdot 2H_2O$ It occurs as flattened **monoclinic** crystals, often twinned, transparent cleavable masses, called selenite, or silky and fibrous, called satin spar, it may also be granular or quite compact It is a soft mineral, hardness 1 5–2, has two good cleavages which yield rhombic plates whose angles are 66° and 114° Its specific gravity is 2 31–2 33, luster vitreous to silky or pearly, color, colorless to white and gray, may be tinted red, yellow, blue, brown, etc, by impurities, transparent to opaque A very fine grained white or lightly tinted variety of gypsum is called alabaster, and prized for ornamental work of various sorts Gypsum is a very common mineral, thick and extensive beds of which are associated with **sedimentary rocks.** The largest deposits known occur in strata of **Permian** age Besides being a result of deposition in sea and lake waters, gypsum has been deposited by hot springs, from volcanic vapors, and by sulfate solutions in veins Notable foreign localities for gypsum are in Greece, Czechoslovakia, Austria, Saxony, Bavaria, Italy, France, Spain, England and Mexico In the United States well known localities are at Lockport, New York, the Mammoth Cave, Kentucky, Ellsworth, Ohio, Grand Rapids, Michigan, Hermosa, South Dakota, Wayne County, Utah, and San Bernardino County, California In Canada the Provinces of New Brunswick and Nova Scotia have large gypsum deposits The word gypsum is derived from the Greek meaning to cook, in reference to the burnt or calcined mineral Because the gypsum from the quarries of the Montmartre district of Paris has long furnished burnt gypsum used for various purposes this material has been called plaster of Paris (E S C S)

GYPSY MOTH. Insecta, Lepidoptera A **moth,** *Porthetria dispar*, introduced from Europe and now a serious pest in the northeastern United States The caterpillars are able to defoliate shade and forest trees and also attack apple and sometimes the conifers The damage and control are the same as in the case of the **brown-tail moth** (A W L)

GYRO-COMPASS The first successful application of the gyro-compass was made in 1911 During the years immediately following, the device was rapidly perfected and during the world war was universally adopted by naval vessels Since the war the gyro-compass has become standard equipment both for naval and merchant vessels

The detailed theory of the **gyroscope** is too complex for inclusion here The essential part of the instrument is a heavy wheel which is driven by electric power at a relatively high speed The frame of the wheel is mounted in gimbals and has attached to it a "ballistic tube" This tube forces the wheel to set itself so that the axis of rotation is in the plane of the axis of rotation of the earth, and hence will always lie in the true **meridian. A compass card** is then attached so that the north-south line is parallel to the axis of rotation of the instrument and the instrument may then be placed in the ship's binnacle in place of the magnetic **compass.** Such an instrument is independent of all of the **compass corrections** of the ordinary magnetic type compass, but has certain peculiar corrections of its own which depend upon the speed and course of the ship and also the latitude These corrections are all taken care of automatically in modern gyro-compasses

In modern installations one "master gyro" is located in a protected part of the ship and cared for by the engineering department An electric circuit carries the course of the ship as indicated by the master compass to "repeaters" located at various places in the ship where they will be valuable to the navigating department This same circuit may be used for a variety of other purposes such as keeping a constant record of the course of the ship and also for operating the steering mechanism in such a manner as to hold the ship automatically on any predetermined course The application of this automatic steering, known commonly as "metal Mike," does not eliminate the necessity for keeping a helmsman continually on duty In case of emergency, such as the

appearance of some floating obstruction, the metal mike must be immediately disconnected and "old fashioned" hand steering used. (W.K.G.)

GYROCOTYLIDEA. Cestoda.

GYROSCOPE. A gyroscope is a heavy wheel or disk which may be set into rapid rotation and, because of the conservation of its angular **momentum**, serves to illustrate in various ways the tendency of rotating bodies to maintain a fixed axis of rotation or to exhibit **precession.** In its usual form the "gyro," or rotating disk, is mounted in a ring so that it can be handled while spinning; and this is frequently hung in a second ring or frame to form gimbals. In this case the outer ring or frame may be moved or turned in any manner, without bringing to bear a torque tending to change the direction of the axis of rotation.

The complete theory of the gyroscope is far too complex to be included in a work of this character and reference must be made to advanced texts on mechanics Within recent years the gyroscope has been successfully applied in the **gyro-compass,** in stabilizers for ships, etc. (L D W , W K G)

GYROSTAT. Gyroscope.

H

HABIT. As used by the mineralogist, this term denotes the sum of the external characteristics of a mineral. It is also, but more rarely, applied to rocks. (R M.F.)

HADDOCK. Pisces, Teleostei. An important marine food fish, *Gadus aeglefinus*, taken on both sides of the Atlantic. It is closely related to the cod. Usually dried and smoked for the market. (A.W L)

HADE. Fault.

HAEMATOXYLIN or **LOGWOOD.** *Haematoxylon campechianum.* Leguminosae Logwood is obtained from a small tree which is native in Central America, but has been extensively planted in the West Indies and South America The tree, seldom more than 25 feet tall, has **pinnately** compound leaves with smooth obovate leaflets, and fragrant yellow flowers in terminal **racemes.** The fruit is a dry two-seeded pod

The wood is very hard and yellow, on exposure to air it turns red It has a rather pleasant odor. To obtain the dye the sapwood is cut away and the heart wood cut up into chips From these chips the dyestuff is extracted Logwood dye is used to color cottons, woolens, silks and leathers To make the dye **mordants** must be added, in this case the salt of some metal, usually iron. Haematoxylin is also used in the making of **inks,** and as a histological stain in the preparation of organic tissues for microscopic examination. Small quantities are used medicinally, in the form of extracts or decoctions, in cases of chronic diarrhoea. It is also a mild astringent (R M W)

HAEMOCOELE. A cavity in which blood or haemolymph circulates Well developed in the **arthropods,** and **mollusks** where it superficially resembles a true body cavity It is associated with some tubular blood vessels whose contractions propel the blood in it, and these movements are supplemented by the shifting of its contents as a result of body movements (A W L.)

HAEMOCYANIN. A **protein** containing copper which combines readily but unstably with oxygen and serves as a respiratory medium It occurs in the blood of **arthropods** and **mollusks.** When oxidized it is bluish in color (A W L)

HAEMOLYMPH. The **blood** of higher **invertebrates,** consisting of a clear plasma and white cells but without red cells Respiratory pigments are dissolved in the plasma. It contains a lower percentage of water than the blood of more primitive forms. (A.W.L.)

HAEMOSPORIDIA Sporozoa.

HAFNIUM. Symbol: Hf. Atomic number: 72. Atomic weight 178 6. Melting point: 1700° C.

Hafnium is similar in chemical properties to zirconium, but separable from the latter by repeated fractional crystallization of the double **potassium** fluoride (K_2HfF_6), which collects in the mother liquor, from potassium zirconium fluoride which collects in the crystals Discovered by Coster and Hevesy in 1922 in the mineral **zircon** of Norway by the Moseley **X-ray** spectrographic method of analysis, and later found to be present in almost all **zirconium** minerals and chemicals (most of these containing about 5% Hf in the zirconium).

The use of hafnium metal in lamp filaments and radio tubes has been proposed.

Oxide: Hafnium oxide (HfO_2), white. (R.K.S.)

HAGFISH. Cyclostomata.

HAIL. A precipitation is often called hail if it is in the form of lumps or pellets of ice. Strictly, the term should be applied only to the globose or sometimes irregular masses which fall at the beginning of a thunderstorm in hot weather. The most typical hailstones are somewhat oblately spheroidal and of the size of a hazelnut, though very rarely they attain a diameter of two or three inches or larger. When broken, they reveal a structure of concentric alternate layers of clear and opaque white ice.

The fact that true hail never occurs except during a violent thunderstorm indicates that wind plays an essential rôle in its formation. It seems probable that hailstones have their origin in those vortices or whirlwinds in whose interior masses of cloud-laden air rush upward with great speed and then circle downward outside, only to be drawn inward and upward again; like a gigantic smoke-ring The lower part of such a thundercloud may be composed of raindrops and the upper part of snow crystals. A raindrop, blown upward into the colder region, freezes and collects a layer of snow, then descends to have more water frozen upon it, then upward for more snow, and so on, until it finally becomes too heavy to circulate further, and falls. Often several hailstones freeze together into a shapeless, nodular mass. Large hailstones, naturally, are somewhat dangerous and often very destructive. (L D W)

HAIRSTREAK. Insecta, Lepidoptera Small **butterflies,** those of the temperate zone dull colored and those of the tropics often brilliant. The hind wings of most species bear hairlike tails. With the coppers and blues they make up the family Lycaenidae. (A W L.)

HAIR-TAIL. Pisces, Teleostei. Predacious fishes, (**Pisces**), chiefly tropical, whose bodies taper at the posterior end to a slender point They are long, slender, scaleless, and have the fins reduced excepting a long dorsal and the pectorals. (A.W L.)

HAIRWORM. Nemathelminthes, Nematoda. Long slender roundworms of small size which live as parasites in the bodies of **invertebrates,** chiefly insects. (A.W.L.)

HAKE. Pisces, Teleostei. Inferior marine food fishes (**Pisces**) related to the cod Both sides of the Atlantic and colder waters of southern hemisphere The squirrel hake and white hake are also called codling and the silver hake, *Merluccius bilinearis,* is known as the whiting or stockfish. (A W.L.)

HALF-VALUE PERIOD. Decay Coefficient.

HALIBUT. Pisces, Teleostei. A large **flatfish,** *Hippoglossus,* reaching a length of six feet and a weight of four hundred pounds. Found in all of the northern seas.

The flesh of the halibut is inferior to that of some of the smaller flatfishes but the species is valuable as a source of vitamins. Halibut liver oil is reported to be about ten to thirty times as rich in vitamin D and eighty to two hundred times as rich in vitamin A as cod liver oil. (A.W.L.)

HALITE. Rock Salt. The mineral halite is naturally occurring **sodium** chloride, NaCl, common salt. It is isometric with cubic habit and cleavage. It is brittle; hardness, 2.5; specific gravity, 2.4–2.6; luster, vitreous; colorless when pure, but usually white, yellow, red or

blue It is soluble Halite occurs interbedded with sedimentary rocks in all parts of the world and in all but the very oldest rocks It frequently occurs in association with **anhydrite** and **gypsum.** In the United States this type of "salt beds" have been exploited in Michigan, New York, Ohio and Pennsylvania Louisiana produces salt from great sub-surface dome shaped masses often from two to four thousand feet thick The salt domes of the Gulf Coastal Plain are particularly important as sub-surface structures on the flanks of which are apt to occur large and important pools of **petroleum.** Poland, Saxony, Austria and France possess well known deposits of salt as well as Russia, England, Algeria, India and China Salt is chiefly used in cooking and as a preservative, in the manufacture of soda ash for the glass industry, and as a source of many **sodium** compounds It derives its name from the halogen group of elements to which **chlorine** belongs (R M F)

HALL EFFECT. In 1879 Hall, at Johns Hopkins University, discovered that if a strip of gold leaf, carrying an **electric current** longitudinally was placed in a **magnetic field** with the plane of the strip perpendicular to the direction of the field, points directly opposite each other on the edges of the strip acquired a difference of electric potential, and that if such points were joined through a sensitive galvanometer a feeble current would be indicated In other words the equipotential lines, ordinarily running across at right angles to the edges, were skewed into an oblique position, and the electric lines of flow in the plate were deflected to one side

If one looks along the strip in the direction of the current, with the magnetic field directed downward, then with strips of antimony, cobalt, zinc, or iron the electric potential drop is toward the right and the effect is said to be positive, while with gold, silver, platinum, nickel, bismuth, copper, and aluminum, it is toward the left and the effect is called negative The transverse electric potential gradient per unit magnetic field intensity per unit current density is called the "Hall coefficient" for the metal in question A special case known as the "Corbino effect" occurs when a circular disk carrying a current radially is placed at right angles to a magnetic field, the result being a current component around the disk

The Hall effect as first observed, in gold, agrees in direction with the lateral thrust on current-carrying armature conductors in a motor, and suggests the identity of these phenomena But this explanation is upset by the reverse action in other metals, and is further complicated by many other experimental facts At present the Hall effect cannot be said to be fully understood See **Ettingshausen, Nernst,** and **Righi-Leduc Effects.** (L D W)

HÄLLEFLINTA. A Swedish term for hard, dense **metamorphic** rocks composed chiefly of microscopic crystals of quartz and feldspar with occasional **phenocrysts.** Accessory minerals may be **hornblende, chlorite, hematite** or **magnetite.** The texture and composition of halleflinta suggests that it is the metamorphosed equivalent of **acid** lava flows or **tuffs.** (R.M F)

HALLER'S ORGAN. Sense organs of uncertain function borne on the anterior legs of some **ticks.** (A.W L.)

HALLEY'S COMET. This is probably the most famous of all the **comets** and is deserving of special mention The general subject of comets is discussed elsewhere, and this article, therefore, will confine itself to Halley's comet alone

Halley's comet is of special interest because of the fact that it was the first comet whose return was predicted When Halley computed the **orbit** of the great comet observed in 1682, he found the elements to be almost identical with those of prominent comets observed and studied by Kepler in 1607 and by Apian in 1531 He noticed that the interval between 1531 and 1607 was not exactly equal to the interval between 1607 and 1682, but suspected that the difference might be due to attractions by other planets He was unable to predict just what effects the attractions of Jupiter might produce on the next return, but suspected that they would retard it and predicted the return for the early part of 1759 In the meantime, mathematical astronomy had developed to such a point that April, 1759, was predicted by Clairaut The comet actually came to **perihelion** on March 13th of that year At the next return in 1835, the predicted date of perihelion differed from the observed date by only two days, and for the return in 1910 the agreement was practically perfect

Extensive calculations made by Crommelin and Cowell after the observations in 1910 carried the dates of perihelion pasages back through the centuries Examination of ancient records prove that the comet was observed and recorded at every perihelion passage back to 87 B C In some cases, the descriptions are complete enough to prove, both that the comet has always been a striking object and also that the ancient records were surprisingly accurate as to position of the comet

Due to **perturbations** of the planets the periods between successive perihelion passages have varied considerably The average is about 77 years Historians have, at times, attempted to use observations of comets as a means for fixing dates, employing the hypothesis that any bright comet appearing at about the correct date was Halley's This is a very dangerous practice for there have been many others of as equally striking appearance as Halley's and their appearances were always noted

At the return in 1910 the comet was first picked up by Wolf at Heidelburg on September 11, 1909, when it was 310,000,000 miles from the sun, and it was followed photographically until July 1, 1911, when it was 520,000,000 miles from the sun When close to perihelion it was a magnificent object, particularly during the early part of May, when it was observed in the morning sky On May 19th, about a month after perihelion passage, the comet passed directly between the earth and the sun, but no change in the brightness of the sun could be observed even with the most delicate instruments At one time the tail of the comet extended across the sky for a distance of nearly 120°, appearing as a broad bright band much like the milky way On May 21st the earth certainly grazed the tail of the comet and may have passed directly through it

In 1949 the comet will reach its greatest distance from the sun, being at that time more distant than the planet **Neptune.** It will return to perihelion on April 29, 1986 (W K G)

HALLUCINATION. A mental state in which sensory impressions are not based on reality The sensory impressions may be of sight, hearing or smell Hallucinations are most frequently seen in some forms of acute **alcoholism, opium,** and **cocaine** habituation, delirium from high fever and in certain forms of insanity

An hallucination should not be confused with (1) a delusion, which differs in being a false belief, not correctable by reasoning or evidence of the senses, or (2), an illusion—a false interpretation of a sensory image. (R S M)

HALO. This term applies to a class of phenomena observed in the sky in connection with the **sun** (or sometimes the **moon**) and due to particles of frost suspended in the air. The minute spicules of ice, in falling, take some definite attitude determined by their shape. Some are needlelike and assume a horizontal

position, some are flat disks or stars and fall with their planes horizontal, while others, made up of both disks and rods, behave like a parachute The sunlight is refracted by each type in a characteristic manner and dispersed into colors, it is also reflected from their external surfaces without dispersion The most commonly observed effects are the colored parhelia (commonly called "sun dogs") on a level with the sun and 22° each side of it, a 22° halo passing through the parhelia, a 46° halo, usually faint, and certain other appended arcs or partial halos due to refraction and reflection by the variously oriented crystals

In addition to these phenomena may be mentioned the colored rings, called coronae, often surrounding the sun or moon These are due to **diffraction** by particles of fog or mist The diameter of the **corona** is greater, the smaller the fog particles. (L D W)

HALYS. Reptilia, Sauria Asiatic vipers of several species, related to the copperhead and water moccasin of North America One small species of Ceylon and India is called the carawila (A W L)

HAMADRYAD. Cobra.

HAMMERHEAD Pisces, Plagiostomi *Sphyrna* Large **sharks** of the tropical seas The head is greatly widened to form lateral projections bearing the eyes (A W L)

HAMSTER. Mammalia, Rodentia Burrowing animals of Europe and Asia The common hamster, *Cricetus*, attains a length of one foot It is sometimes extremely numerous and is then a serious pest to the farmer It damages crops of all kinds The flesh is eaten and the fur is useful, although not of high quality (A W L)

HAND The terminal portion of the pectoral appendage of **mammals,** developed for grasping and in some species largely freed from locomotor uses True hands appear only in the **primates.**

The skeletal structure of the hand includes the series of five bones, the metacarpals, which attach it to the wrist, and the five divergent series of phalanges located in the digits Of the digits one, the thumb, is placed and articulated so that it can be opposed to the other four, which are fingers As a result the appendage can be used for grasping like a forceps and also as a prehensile organ by folding the fingers back against the palm In some of the monkeys the prehensile method of grasping is more important in moving through the trees and the thumb has shifted and become smaller so that it can no longer be opposed

The human hand is the most versatile grasping organ in the animal kingdom and has been of primary importance in the manufacture of tools and machines, which distinguishes man from all other living things (A W L)

HANGING VALLEY. Under normal conditions a tributary stream enters the main stream at grade, that is, at the same level Under certain circumstances the tributary valley may be at a greater elevation than the main valley into which the tributary stream will plunge, forming a waterfall In such cases the tributary valley is called a hanging valley, and the stream in it is said to be out of adjustment with the main stream

Hanging valleys originate in the following ways: by glacial action, the main glacier cutting down its valley faster than a tributary glacier, by river action, the main stream eroding its bed faster than the tributary stream, by **faulting,** the tributary stream flowing off the upthrown block A fourth type of hanging valley, much less common, may result from a stream plunging over wave cut cliffs or other escarpments into a lake or ocean basin (R M F)

HANGING WALL. The use of this term in geology is discussed in the article on **Fault.** (R M F)

HANGNEST. Aves, Passeriformes A group of birds (**Aves**) whose nests are woven of vegetable fiber, grass, and hair, and are suspended from small branches The Baltimore **oriole** is a common North American species. Others occur from the southwestern states to Brazil. (A W L)

HANUMAN. Langur.

HAPALOPS Miocene

HAPLOSPORIDIA. Sporozoa.

HARD COAL. Coal.

HARDENING OF THE ARTERIES. Arteriosclerosis.

HARDNESS. The significance of this term as applied to solids has various interpretations Commonly it refers to the resistance of the substance to surface **abrasion,** so that of two solids, the one that will scratch the other, as diamond scratches glass, is the harder Again, it may denote rigidity, or lack of plasticity, or even strength, in some cases a combination of several such properties A number of arbitrary tests have been devised, and used especially in industrial laboratories, for such types of hardness as may be deemed important In the Brinell test, for example, a steel ball a few millimeters in diameter is pressed against the surface of the specimen with a force of several hundred kilograms, and the hardness is indicated by the smallness of the resulting indentation The Mohs Scale of Hardness, used by mineralogists is as follows 1 **Talc** (softest), 2 **Gypsum,** 3 **Calcite,** 4 **Fluorite,** 5 **Apatite,** 6 **Orthoclase,** 7 **Quartz,** 8 **Topaz,** 9 **Sapphire,** 10 **Diamond** (hardest) Example if a mineral can be scratched by orthoclase and will not scratch apatite its hardness is between 5 and 6 Other techniques employ in a similar manner an obtusely conical or a flat-ended cylindrical steel punch, while still another utilizes the resistance to the rolling friction of a steel ball Any apparatus used for the measurement of hardness is called a sclerometer, there are several types, depending upon different principles (L D W, R M F)

HARD-PAN. The term which prospectors and miners give to the sub-surface or basal layers of placer deposits in which the gold-bearing gravels have been cemented and hardened The same term is also used to designate till or boulder clay which has been cemented by **limonite.** (R M F)

HARE. Mammalia, Rodentia Rodents (**Rodentia**) with long ears, large hind legs and small front legs, and a very short tail Adapted for speed and for jumping The Old World species burrow and those of the New World often occupy holes in the ground although they do not burrow The rabbits and hares belong to the same genus and the two names are not sharply distinct The North American species are more commonly called rabbits but the white or snowshoe rabbit of the north is also called the varying hare, and the white-tailed jack rabbit is known as the prairie hare Hares are indigenous to all continents except Australia

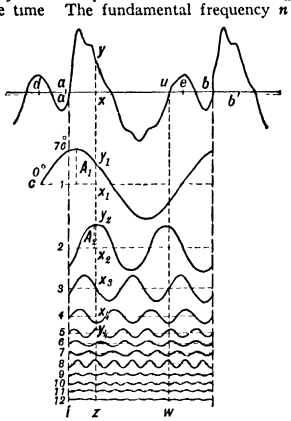
Among the domesticated species of hares and rabbits many breeds have been developed These animals are kept for pets and as a source of meat They are also valuable laboratory animals in medical science and have been used in the study of heredity The fur is fine and soft but the pelts are relatively weak They are valuable for linings and when sheared and dyed are used in inexpensive garments Rabbit fur is also used in making felt (A W L)

HARELIP. A congenital deformity in which there is a cleft in the upper or lower lip It is more common in the upper lip and may be associated with a cleft palate It may be double, where there is a division on either side of the mid line of the lip, or it may be on one side only The treatment is surgical (R S M)

HARMONIC ANALYSIS. Not only is it possible to combine two or more simple **harmonic motions** of different period, amplitude, and phase to form a complex motion, but there are also means of analyzing the resultant motion, when the latter is given, to find its component harmonics For example, if the wave form of such a complex tone as that produced by a bell or a saxophone is accurately graphed by means of a phonodeik (See **Vibrations and Waves,** and **Musical Sounds**), the equation of the vibratory motion can be deduced in such form as to show the separate components Fourier showed that the same analysis is possible for any periodic motion, however complicated The equation, called **Fourier's series,** may be written

$$y = a \sin 2\pi nt + b \cos 2\pi nt + c \sin 4\pi nt + d \cos 4\pi nt + e \sin 6\pi nt + f \cos 6\pi nt + \cdots,$$

in which y is the displacement of the vibrating particle and t the time The fundamental frequency n and the



Records of a complex sound and twelve of its components (Courtesy of D C Miller)

constants a, b, c, d, etc must be calculated from the given wave form or the data from which it is plotted There is a type of instrument, called a "harmonic analyzer," which automatically computes the coefficients, or it may be done mathematically, though the process is very laborious The accompanying figure shows the wave form and the twelve components of a complex tone, analyzed by Professor D. C Miller (L D W)

HARMONIC CURVE. By a harmonic curve is usually meant a curve whose equation is of the form $y = a \sin nx$ or $y = a \cos nx$ (L L S)

HARMONIC DIVISION OF A LINE-SEGMENT. A line-segment is said to be divided harmonically by two points if these two points divide the segment internally and externally in the same ratio The two points of division are called harmonic conjugates (L L S)

HARMONIC FUNCTIONS A harmonic function is any real **function** u which satisfies **Laplace's equation** $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = 0$, and which, together with its first and second **partial derivatives,** is **continuous** and single-valued throughout a certain region (See also **Laplace's Equation**) (L L S)

HARMONIC LAW. **Keplerian Laws.**

HARMONIC MOTION. A distinct type of periodic motion, or vibration, characteristic of elastic bodies, illustrated by a bird-cage bobbing up and down at the end of a spiral spring, or (approximately) by the piston of a steam engine It may be either simple, with only one **frequency** and amplitude, or made up of two or more simple components and consequently of more complex character The essential feature of simple harmonic motion is that, with its range extending to equal distances on both sides of an equilibrium position or origin, the **acceleration** is always toward the origin and directly proportional to the distance from it With elastic vibrations this is easily seen to follow from Hooke's law, since the force tending to restore the deformed body to equilibrium is proportional to the deformation (See **Elasticity**) The motion is called "harmonic" undoubtedly because the vibrations of bodies emitting musical sounds are of this character Any simple harmonic motion may be represented by the equation $y = a \cos 2\pi nt$, in which y is the distance at time t, a is the amplitude, and n is the frequency or number of vibrations per unit time

It is interesting to note the relationship between harmonic and circular motion If a peg is inserted in the face of a circular disk or wheel and the latter uniformly rotated, the motion of the peg, as viewed with the wheel seen edgewise, is simple harmonic In fact, uniform circular motion is made up of two simple harmonic components of the same period and amplitude at right angles, one being a quarter-period ahead of the other in phase If the two harmonic components have a phase difference other than a quarter-period, the resultant in general is motion in an ellipse, while if they have unequal periods, the path is one of a class of more or less complicated loci called "Lissajous' curves" (L D W)

HARMONIC PROGRESSION A harmonic progression is a succession of numbers whose **reciprocals** form an **arithmetic progression.**

The harmonic mean between two numbers is the middle term of an harmonic progression whose first and last terms are the given numbers The harmonic mean between a and b is given by

$$H = \frac{2ab}{a+b}.$$

If A, G and H are respectively the arithmetic, geometric and harmonic mean of two numbers, then $G^2 = A\,H$ (L L S)

HARMONIC SERIES. The **infinite series** $\sum_1^\infty \frac{1}{n}$ is called the harmonic series. It is **divergent.** (L L S)

HARMOTOME. The mineral harmotome is a **zeolite,** composition approximately $(K_2Ba)Al_2Si_5O_{14}\cdot 5H_2O$, it is monoclinic but often forms double twins giving the effect of a square prism It is a brittle mineral, hardness 4 5, specific gravity 2 44 – 2 50, luster vitreous, color white to gray or perhaps yellow, red or brown, white streak, translucent Harmotome like other zeolites is found in cavities in basalts and similar rocks, sometimes in **trachytes** or in **gneisses,** occasionally as a gangue mineral in veins of metallic minerals Some well known localities are in Bavaria, in the Harz Mts, Norway and Scotland Harmotome occurs in the United States with stilbite, near Port Arthur, Lake Superior The name harmotome comes from the Greek meaning joint and to cut, referring to the division of the pyramid formed by the prismatic faces of the mineral when in the twinned position (E S C S)

HARPY. Aves, Falconiformes. *Thrasaëtus.* Large crested **eagles** related to the true buzzards. The several species range from Mexico to Patagonia. (A.W.L.)

HARRIER. Aves, Falconiformes. Moderately large **eagles** of several species, and a group of **hawks.** The harrier eagles are mostly limited to Africa but one species extends to Asia and Europe. The hawks are found in all continents. They are slender birds **with** long wings, and in general are useful as destroyers of reptiles and rodents. The marsh hawk, *Circus hudsonius,* is a North American harrier. (A.W.L.)

HARTEBEEST. Mammalia, Artiodactyla. *Bubalis.* An African **antelope** with large ringed horns, irregularly spiraled with the tips pointing back. There are several species. (A.W.L.)

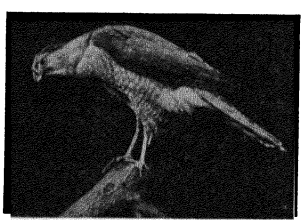
HARVESTMAN. Arachnida, Phalangida. Spider-like animals, most species with small oval bodies and extremely long slender legs. Those with shorter legs are more easily confused with the true spiders but all may be recognized by the segmented abdomen. Daddy longlegs. (A.W.L.)

HASHISH. Hemp.

HAUSEN. Pisces, Chondrostei. The giant **sturgeon,** *Acipenser nuso,* of the Mediterranean and the large rivers and inland seas of Europe and western Asia, also found on both sides of the Atlantic. Specimens weighing over 3000 pounds are said to have been taken in the Volga River, although half that weight is large for the species. (A.W.L.)

HAÜY'S LAW. Crystallography.

HAWK. Aves, Falconiformes. Birds (**Aves**) of prey with hooked beaks and large curved claws, closely



Cooper's Hawk. (Courtesy of American Museum of Natural History.)

related to the eagles, falcons, harriers, and others and not sharply distinguished as a group. Hawks are found on all continents. North America has many species, including **buzzards, harriers, goshawks** and other forms. Most of them are beneficial as destroyers of vermin but the sharp-shinned (*Accipiter velox*), and Cooper (*A. cooperi*) hawks destroy too many birds, including poultry, to be regarded as friends. (A.W.L.)

HAWK MOTH. Insecta, Lepidoptera. Large **moths** composing the family Sphingidae, one of the largest of the order. These moths have a long rather stout body projecting beyond the narrow wings. The front wings are much longer than the hinder pair, and because of their limited surface they are vibrated rapidly in flight. The moths have long tongues and visit deep-throated flowers. From their habit of hovering as they probe the flower for nectar they are also called hummingbird moths. Another common name is sphinx moth. (A.W.L.)

HAWKSBILL. Turtle.

HAWTHORN. Rose Family.

HAY. Grass Family.

HAY FEVER. (Allergic Coryza.) This condition is one manifestation of an **allergic** reaction that is seen in those subjects who are hypersensitive to **pollens,** other air-borne substances, and certain **foods.** It is characterized by an intense irritation of the membranes of the upper respiratory tract and the eyes. It is seen in two forms (1) the seasonal type which is due to pollens (2) the non-seasonal type which occurs in attacks throughout the year and is due to animal emanations, vegetable or seed powders, or ingested substances.

A common form of hay fever is seasonal hay fever which is sometimes known as Rose Cold. Any pollen may cause this kind of hay fever in a sensitive individual. The spring type of hay fever lasts from March to the beginning of June and is due usually to pollens of trees—elm, birch, maple, oak, and hickory. The summer type occurring through June and part of July is due to pollen of **grasses** such as red-top, timothy, June and orchard grass, sweet vernal, and plantain. The fall type begins in August and lasts until frost and is usually due to the pollen of the ragweeds.

The symptoms of hay fever are local and are characterized by attacks of severe itching, congestion, and weeping of the eyes. Sneezing is apt to be violent due to the irritative reaction within the nose. Swelling of the nose may cause obstruction to nasal breathing. An irritating discharge from the nose is usually present. The entire attack closely resembles a severe head cold.

Over fifty per cent of hay fever subjects are sensitive to more than one pollen. Those that are sensitive to only one pollen are relieved of the hay fever as soon as pollenization of the particular plant stops. During the following years attacks begin at the same time of year.

The most frequent complication of hay fever is **sinusitis** and this occurs in a large percentage of cases. **Asthma** is present in fifteen to twenty per cent of hay fever cases.

There is also a non-seasonal hay fever (perennial hay fever, Vasomotor Rhinitis). This form of hay fever may be continuous or occur in paroxysmal attacks throughout the year. The substances causing this form may be inhaled or ingested. They are animal dust and vegetable or seed powders. House dust is one of the most common exciting agents. The specific substance in house dust has not been identified. The dust of hay and straw causing hay fever is not related to the pollens of these substances that cause the seasonal type.

The finding of the specific offending substances is done by means of skin tests done by the scratch or injection of dilutions of various test substances. A positive test is said to occur when a wheal of irregular outline, surrounded by a zone of irritation, is produced. The wheal may vary from one-fourth to several inches in diameter. Marked itching may be present at the site of the wheal. The individual is frequently sensitive to more than one substance. Sensitivity tests may also be carried out by instilling dilutions of test substances into the conjunctival sac of the eye.

Prophylactic treatment against hay fever attacks is successful in many cases, especially those of the seasonal type. Subcutaneous injections of a solution of the offending substance are begun ten weeks in advance of the expected attack. The dose injected is very dilute at first—the strength being gradually increased. The effects of the treatment is not permanent and they have to be repeated each year. Results are quite satisfactory even in those cases where **asthma** also complicates the picture.

Some forms of hay fever, especially of the non-seasonal type, can only be prevented by avoidance of the exciting agent. (R.S.M.)

HEAD. Head, as used in the science of **hydraulics,** is the height, actual or imaginary, of a column of fluid

which creates a pressure at its base Viewed in this way, head is a measurement of pressure It is convertible to the pressure (force per unit area) by multiplying by the density of the fluid Not only is the static pressure designated in terms of head measured as a linear dimension, but velocity as well, this being distinguished from static head by being called velocity head. This pressure, measured as a head necessary to give a fluid, originally at rest, a velocity V, is $\frac{V^2}{2g}$, wherein g is the **acceleration** of gravity.

In zoology, the head is the region of a bilaterally symmetrical animal body lying at the front end in relation to the ordinary direction of locomotion, or in bipedal vertebrates like man and some of the birds at the highest level

The development of a head is indicated in animals which are without sharply separated body regions, such as the flatworms This process of cephalization is closely correlated with bilateral symmetry The portion of a bilateral animal which goes first inevitably is the first to encounter new sources of stimuli, and shows some concentration of sense organs Usually the chief nerve center, a cerebral ganglion or brain, also develops here The concentration of sense organs and nervous control in the head remains characteristic of the region throughout the animal kingdom and in most groups is accompanied by the location of the mouth in the head, together with associated structures for securing food (FTM, AWL)

HEADACHE. Headache is not a disease but one of the most common symptoms met in medical practice It may be the first symptom of existence of grave organic disease Before treating persistent headache lightly, the cause should be determined The explanation of the mechanism of headache is difficult The pain is often a pressure phenomenon within the skull This may be due to increased or decreased pressure within the blood vessels of the brain or in the brain substance itself The causes of these pressure disturbances are exceedingly numerous

Headache varies in location, character, and severity of pain and time of occurrence Often pain in the face and outside the skull is indistinguishable from headache as the pain accompanies toothache, **sinusitis**, eyestrain, and neuralgia of facial nerves

The causes of headache fall into three classifications (1) *Organic causes* These include injury to the brain, either from simple compression or fracture of the skull, **syphilis, abscess** and **tumor** formation of the brain or its coverings, cerebral accidents (stroke, hemorrhage, or **embolism**) **meningitis, arteriosclerosis**, middle ear disease, diseases and disorders of the eye, high or low blood pressure, etc (2) *Toxic causes* (a) Toxic substances from without the body such as poor air, poisonous gases, especially **carbon monoxide**, and overindulgence in alcohol, tobacco, etc (b) Toxic substances from within the body which includes headache accompanying any severe infection or illness, kidney disease (**nephritis**), **constipation, digestive** disorders, **allergic** diseases, and **menstrual** disorders (3) *Functional causes* These include mental strain, eye strain, epilepsy, sun stroke, seasickness, excessive emotion, anger or strain of any kind, fatigue, etc **Migraine** is discussed separately (RSM)

HEADER. Any **pipe, conduit, duct,** or **channel,** which acts as a central point of distribution of a fluid flow to several branch lines, is a header Examples of headers are the steam header, which is usually a large steam pipe well anchored, to which several **boilers** supply steam through boiler lead pipes, and from which steam is taken for such uses as the individual case presents Header ducts are used where a fan is to supply air to several sources. Cases often arise, also, where a liquid, such as water, oil, etc, is to be distributed from a header for several uses (FTM)

HEART. Circulatory system.

HEARTBURN. A burning sensation in the **esophagus** and stomach caused either by some irritating substance that has been eaten or by increased acid production in the stomach It is frequently complained of in ulcer of the stomach as hyperacidity of the gastric juice, usually accompanies ulcer formation (RSM)

HEARTWOOD. Wood.

HEAT. That heat is a form of **kinetic energy** has been known only since the work of Rumford and Davy in the first decade of the nineteenth century They succeeded in boiling water and melting ice by heat generated mechanically Prior to their work, heat had been believed to be a substance, a sort of gas called "caloric" This was no doubt suggested by the shimmering appearance of the air surrounding a hot object. No one appears to have tested the question as to whether a heated body weighs more than a cold one, or to have attempted the isolation and analysis of the supposed caloric as it escaped from the body on cooling This well illustrates the very imperfect state of scientific thought a century ago

The chaotic agitation of **molecules** which we now know to constitute heat, and the violence of which determines the temperature, is strikingly exhibited, though on a much altered scale, by the **Brownian movement.** When a substance is heated, its molecules receive impulses which result in the acceleration of their motions of translation, of rotation, and sometimes of internal vibration With a gas composed of diatomic molecules, a simple calculation based upon the known **specific heat** and upon the **kinetic theory** shows that 60% of the energy, at ordinary temperatures, goes into the translational molecular motion and the other 40% to rotational motion, the internal vibrations apparently do not begin until higher temperatures are reached This apportionment is in accord with the principle of **equipartition of energy** and the **quantum theory.**

Although we now recognize that heat is energy, it is still customary to express quantity of heat in the old water-temperature measure, by means of **British thermal units** or of **calories;** and whenever heat quantities so expressed are used in thermodynamic calculations, it is necessary to use the **mechanical equivalent of heat** as a conversion factor between these and the ordinary dynamic units of energy (foot-pounds or **ergs**). See **Temperature, Calorimetry, Thermal Convection, Thermal Conduction, Thermal Radiation, Thermodynamics,** etc (LDW)

HEAT BALANCE. A **heat** balance is a method of accounting for all heat units in a process or change during which heat is transferred Examples of cases where heat balances might be undertaken are (1) determining the nature and the magnitude of the various losses which occur when coal is burned in a steam boiler **furnace;** (2) accounting for all heat units during the operation of a prime mover such as a **Diesel** engine or a **steam turbine;** (3) determining the distribution of heat in a static heating device such as a water heater supplied with steam

Heat balance work is based upon the first law of **thermodynamics,** a statement of which is Energy may not be created or destroyed, but may be converted from one form to another The significance of this law applied to the heat balance is that the total energy may be accounted for by straight addition, hence striking a heat balance resembles bookkeeping, with heat supplied on the credit side of the ledger, and various heats usefully employed on the debit side One way of showing a heat balance is a tabular form, another shows the heat as a stream, properly branched and subdivided

to indicate the distribution of heat Briefly, a heat balance might be said to be the bookkeeping by which heat supplied is shown to be equal to the sum of heat utilized and lost (F T M)

HEAT CONTENT. Heat may be absorbed by a substance in several ways It may be absorbed in the form of external work done when the heated substance expands against a pressure It may be absorbed by increasing internal energy associated with the motion of the molecules commonly measured by temperature Again, heat may be absorbed by change of state of the substance (See **Heat of Fusion,** and **Heat of Vaporization**), examples of which are the vaporizing of a liquid, the melting of a solid, etc The total thermal energy possessed by a substance includes that present in these various forms Heat content at the absolute zero temperature (minus 460° Fahrenheit, or minus 273° Centigrade) is zero However, an arbitrarily taken datum for heat content often proves more valuable than with the absolute heat content, thus, for example, steam tables which display the heat content of steam do so upon the assumed basis of zero heat content at 32° Fahrenheit See **Enthalpy.** (F T M)

HEATH FAMILY Ericaceae This is a small family composed mainly of woody plants Nearly all plants of this family grow in acid peaty soil, often covering extensive areas Most of the heaths have a pronounced **xerophytic** habit The leaves are usually entire, leathery and have a thick cutinized upper surface Many are evergreen The flowers may be solitary, but are more frequently in **racemes** Usually they are regular There are generally four or five **sepals** and four or five **petals,** more or less united, eight or ten **stamens** and a single **ovary** composed of four or five **carpels.** The **pollen** grains, formed in fours, are discharged from the **anthers** through apical pores The fruit may be a **capsule,** a **drupe** or a **berry.** Pollination is mainly by bees

Many plants of this family are used by man Rhododendrons and Azaleas are frequently cultivated because of their beautiful bright-colored flowers, and many hybrids have been formed There are over 200 species Eastern Asia is especially rich in plants of this genus *Epigaea repens,* the trailing arbutus or mayflower of eastern North America, is another plant much sought for its delicately fragrant flowers It is not easily grown in cultivation Species of *Gaultheria,* including the red-berried *G repens,* called checkerberry, or wintergreen, contain an oil which is sometimes distilled from the plant The fruits of blueberries, huckleberries and cranberries, members of this family, are widely used In recent years considerable attention has been given to the blueberries and several new varieties having very large berries have been developed Species of *Erica* cover vast areas of moor in England One species, *Erica arborea,* grows in southern Europe and northern Africa It is a stout bush several feet high, with a yellow hard close-grained wood From the rootstocks of this plant briarwood is obtained This is used in making briarwood pipes (R M W)

HEATH HEN Aves, Galliformes A **grouse** of the eastern United States, resembling the prairie chicken of the central states The last of these birds were rigidly protected on Martha's Vineyard and increased to a large number by 1016 Later, disease introduced with domestic turkeys affected the birds and other destructive agents further reduced their numbers until the last individual disappeared in 1931 (A W L)

HEATING Electric heating results from the flow of an **electric current.** As an electric current flows through a **conductor,** a certain amount of energy is consumed in overcoming the **resistance,** and is transformed into heat energy This heat effect is sometimes detrimental, sometimes useful When the primary purpose of a conductor is to transfer electrical energy from one point to another, any loss by heat is undesirable However, in the case of the incandescent light, the electric range, the electric welder, electric furnace, etc, the heating effect is put to a useful purpose The heat generated when a current of I amperes flows through a resistance of R ohms, for t seconds, is expressed as follows:

$$\text{Heat} = \frac{I^2Rt}{1055} \text{ B t u}$$

The instances where electric heating is of use are almost numberless in this day, since one may add to the large assortment of domestic electric devices, such as irons, corn poppers, percolators, etc, an equally great variety of commercial devices, like annealing furnaces, bakers' ovens, glue pots, vulcanizers, etc However, the use of electricity for building heating, though apparently successful in some experimental installations, is at a great disadvantage because of the high cost of electric heat compared to that obtained directly from the fuel

Portions of buildings where persons work or live are heated when the outside temperature falls below that considered necessary for health and comfort The heat that must be supplied equals the heat which is dissipated from the building The amount needed varies with the difference in temperature between that maintained on the inside and that determined by the state of the weather But other things also have a determining influence upon building heating, namely, the area and type of the exposed walls, the roof, the windows, and the leakage through cracks, ventilators, etc Heat is lost from a building by **conduction** through walls, and by **convection** and **radiation** from outside surfaces such as windows, walls, roof Heat is also dissipated by air leaking from a building, or by air intentionally discharged by a ventilating system Research and accumulated statistics have provided the data from which the amount of heat lost through walls, windows, roof, etc, can be determined, given the composition of the walls

The heat transfer coefficient is stated as the number of **British Thermal Units** lost per square foot of surface area per hour per degree difference of temperature By multiplying the coefficient by the exposed surface and the difference between outside and inside temperature, part of the heat loss is determined This, however, does not take care of heat loss by leakage or filtration To allow for that a certain number of air changes per hour are included in the needed heating For the ordinary room having windows, it is assumed that to allow for leakage, the heating system must supply heat to take care of a complete change of air each hour (Halls, stores, factories, may need two or three times this allowance) By computing the heat needed for each heated room, and summing these for the building, the required heat output of a heating system may be determined

A person gives off some 400 to 600 B T U per hour It will be necessary to reckon with this source of heat in any heating analysis of a public building, where large numbers of people may gather in one room The building heating system and ventilation are jointly considered in a large building, especially a public one With any attempt to ensure adequate heating, the modern building owner usually will find it economical to spend money for heat insulation, since by proper coordination of investment in heat insulation, heating system, and fuel, a minimum annual heating cost can be secured

Heat insulation is available commercially in a number of forms The air space between studding, if blocked at the top floor levels, becomes a dead air space, and is effective in insulating against heat loss Plaster and brick are fairly good conductors, wood, building paper, fiber wall board, are heat insulators Rock wool, either granular, fluffed, or in bats, is widely used where the maximum of heat insulation is attempted.

Central heating means the supply of heating service to a group of surrounding buildings from a central heating plant The heat carrying medium is sometimes steam, sometimes hot water District heating is similar to central heating, but a distinction can be drawn as follows A central system can be thought of as that which supplies a group of buildings which are under common building superintendence, or having common aim, as, for example, buildings of an educational institution, or a manufacturing plant District heating, on the other hand, is a public utility service and applies to the heating of buildings in densely occupied city sections, from a public utility heating plant which sells heating service

While the words heating system generally convey the idea of one of the indirect systems employed at the present time, to heat homes or buildings, direct radiation is, itself, a system of heating A stove located in the room which it is heating proves to be a very efficient means of getting heat from a fuel into the air of the room As a system, it suffers from the following disadvantages

1 Unsightliness
2 Multiplicity of heating units required for a building containing a number of rooms
3 Unequal distribution of heating
4 Fire hazard

While most of the heat supplied by a stove is black body radiation, there is some considerable amount of convection resulting from air currents sweeping up over the heated portions

A fireplace delivers no heat by convection, rather, it withdraws heat from a room by leakage up the flue The heating effect of a fireplace comes entirely from radiation As a heating system, a fireplace is inefficient and wasteful of fuel The adequate heating of buildings seems to be obtained best by the use of indirect heating, that is generation of the heat at a central point, as a **furnace**, then loading that heat onto the medium which conveys it to the various rooms in the required amount The different heating systems in use today can be classified on the basis of the heat conveying medium, i e , warm air, hot water, steam Each of these systems is briefly described below

In a warm air heating system the furnace is enclosed by a casing, leaving an air space between casing and furnace From the casing ducts lead out to the different rooms Air is supplied to the casing, either directly from the furnace room, from outside the building, or from return ducts which withdraw the air from the rooms The air in the casing being in contact with the heated furnace, expands, becomes lighter than normal, and rises in the ducts until it is discharged in heated condition into the rooms through registers located in the floor or side wall The older warm air systems had a circulation that was maintained entirely by the levity of the heated air leaving the furnace, but had certain disadvantages For example, the effect of wind blowing against one side of the building caused infiltration which opposed duct air pressure in the windward rooms, an action which tended to give unequal distribution of heat, leaving the rooms on the windward side unheated, and those on the leeward side, overheated Also, the furnace had to be centrally located, the basement was encumbered with large numbers of ducts, and homes which were not roughly cubical in shape were not well adapted to this style of heating

Recent developments in the field of warm air heating have led to the employment of forced circulation of the hot air by a motor driven fan Having the fan, it is not necessary to be so careful about friction losses, and smaller ducts, trunk line systems, and filters are possible Since the available pressure is of much higher order than that obtained from gravity alone, there is no difficulty about forcing air equally into all rooms This system of heating, furthermore, is admirably adapted to **air conditioning** requirements The operation of a forced circulation warm air heating system is controlled by a thermostat located in a representative room The **thermostat** is connected electrically to a small draft-controlling motor, and in effect becomes a switch for that motor A certain differential of a few degrees is allowed in a room When the temperature sinks to a predetermined point, the thermostat operates the draft-controlling motor, which in turn closes the check damper and opens the draft so that the rate of combustion is increased With the fan not running, and the only means of dissipating heat in the casing being the natural levity of the heated air, the temperature of the air in the bonnet of the casing rises until a thermostatically operated switch located there starts the fan The warm air is then circulated in the rooms until the temperature rises to a predetermined limit, upon which the room thermostat closes the draft and stops the fan

Hot water heating systems have been very popular in recent years When the reason for this is sought, it will be found that hot water, as compared to steam or gravity circulated warm air, offers a more uniform and steady heat It is free from the unequal heat distribution and bulky duct work of the warm air system, and from the condensate troubles of the steam or vapor system Like the steam system, it has no summertime usefulness, and offers no possibility of air conditioning The radiators and piping, furthermore, are larger than those for an equivalent steam system In a hot water system the water is heated in a heater similar to a boiler except that it is completely filled with water, and no boiling takes place Most hot water systems operate at atmospheric pressure, which limits the temperature to which the water may be raised to slightly over 200° F However, for heating homes, this temperature is entirely adequate for the coldest weather Over much of the heating system, temperatures of 140 to 180° F are sufficient From the heater the water passes to the radiators located in the rooms, where the heat is transferred to the air Delivery of heat to the air cools the water which, as a result, becomes more dense than that in the supply mains, and it sinks to the heater, thus circulation is maintained by gravity and is due to the difference in density between the columns of hot and cool water between the radiator and the heater Central hot water heating systems, and occasionally domestic systems, work on forced circulation created by a pump mounted at the heater outlet This gives more flexibility to the system and permits the use of smaller pipes The control of a hot water heating system is vested in a thermostat which operates the check damper and draft The expansion elements of the thermostat are immersed in, or are subjected to the temperature of, the hot water in the heater (The thermostat tends to maintain uniform water temperature by adjusting the rate of combustion) The temperature of the rooms is controlled by altering the temperature of the water leaving the heater through opposing the action of the thermostat with adjustable weights or springs provided for that purpose.

Steam heating, although lacking flexibility, and sometimes having difficulties of clearing condensate from the system, is, nevertheless, a convenient medium for indirect heating because a considerable heating effect is obtained from a relatively small volume of the circulating fluid Because the heat is released by condensing, the latent heat is made available, whereas in hot water systems, only a portion of the heat of the liquid is available Since latent heat is several times the amount of heat of the liquid, the size of a steam heating system compares favorably with any other of equivalent heating capacity It is widely employed for large buildings, and to a more limited extent, for residences As the circulation depends on the difference in density between steam and water instead of between hot water and cool

water, it is quite positive In laying out a steam heating system, it is very important to pitch the return pipes so that condensate will drain properly In some cases the return and supply pipes are the same, that is, the condensate flows against the steam, but this is suitable only for small inexpensive installations Two-pipe heating systems are found in many different arrangements involving differences of points of admission of steam to radiators, methods of expelling air, and returning of condensate to the boiler (F T M)

HEATING VALUE. The heating, or calorific, value of a fuel is the quantity of heat produced by the combustion, under specified conditions, of unit weight or volume of the fuel The heating value of a fuel may be calculated by formula which may be derived for any fuel by multiplying the percentage of each chemical element present by its heating value per unit weight, and summing the products for all combustible elements in the fuel Thus for coal, whose combustible elements consist of carbon, hydrogen, and sulfur, the heating value is

$14{,}540\,C + 62{,}000\,H + 4{,}000\,S$ (B T U per pound of coal).

The numbers in the above formula are the heating values per pound respectively, of carbon, hydrogen, and sulfur In the use of this formula, it is essential that only that portion of the element that is actually free to burn be employed For example, all coal contains some moisture Now the hydrogen present in this water is not free to burn (i e it is already combined with oxygen) Therefore the figure used for H in the foregoing formula should not include the hydrogen present as water

Heating value by formula will not necessarily be the same as that obtained experimentally with the fuel calorimeter The difference lies not in the accuracy of the experiment, nor of the calculation, but in the possible endothermic or exothermic reactions which take place when a compound fuel, such as a hydrocarbon, is burned The volatile matter of coal must be broken down into the elements of carbon and hydrogen by heat absorbing action before they may reunite with the oxygen during combustion For this reason, experimentally determined heating values are less than those which are computed by formula, which make no reference to endothermic or exothermic reactions Approximate heating values of some of the common fuels are coal, 13,000 B T U per pound, natural gas, 1,000 B T U per cubic foot, artificial gas, 300 B T U per cubic foot, gasoline, 19,000 B T U per pound, wood, 5,000 B T U per pound (F T M)

HEAT INSULATION. Bare surfaces at temperatures considerably above atmospheric lose much heat to the atmosphere The B T U. per hour loss from bare pipe may not, on first thought, seem to amount to much, but if it be remembered that this loss is nearly steady 8760 hours per year (unless the pipe is out of service part of the time), and that, in the case of the boiler leads at least, the B T U so lost are high potential heat and therefore more valuable than the average B T U in a pound of steam, it will be understood why practically every hot pipe in the modern plant or factory is covered Cold pipes are also insulated to keep heat out, and insulation for this service is common in refrigeration plants By keeping heat in hot lines not only is there a conservation of B T U which have, at considerable expense and trouble been transferred to the fluid, but also there is the avoidance of an uncomfortably overheated atmosphere in the vicinity of the pipe Besides the pipe itself, fittings, valves, ducts, boiler drums, tanks and heaters are insulated

Flow of heat through a brick wall is analogous to flow of electric current in a series circuit composed of a number of conductors of different lengths and different resistances per unit length. A square foot cross-section of the furnace wall is analogous to the conductor cross-section B T U per hour flow through the square foot section is analogous to amperes If the amperage represented loss, as for instance a leak to ground, we would interpose a high resistance to limit it to as low values as practicable So, in the heat conductor the insulating layer is added in the nature of a high resistance In order to prevent great heat loss, a furnace wall must have an insulating layer, or else be built so thick that, in addition to being costly, it is inelastic and has large thermal storage capacity In most cases the temperature of the inside furnace wall is near enough to that of furnace gases to be taken the same The outside wall temperature will be enough higher than the surrounding atmosphere to discharge to it a heat flow sufficient to cause the temperature drop between the furnace and outside wall The reader will readily note the analogy to Ohm's law of the electric circuit Heat is discharged from the outside wall to the atmosphere by convection and radiation It has been found that the total heat so transferred to still air is about 50% higher than the radiation component The radiation formula is

$$Q = CA(T_1^4 - T_2^4)$$

(See **Stefan-Boltzmann Law.**)

A = surface area in square feet, usually taken as unity

T_1, T_2 = hot and cold radiant surface temperature, in degrees absolute

C = a coefficient of radiation as follows

Bare brick work	16.3×10^{-10}
Unfinished iron surface	16.3×10^{-10}
Asbestos	16.0×10^{-10}
Aluminum paint	11.0×10^{-10}
Flat black paint	16.4×10^{-10}
Glossy black paint	14.0×10^{-10}

A good pipe covering should, of course, be non-conducting A perfect non-conductor is not yet available Those materials whose conductivities are the lowest are best Insulation should be able permanently to withstand the temperature to which it will be subjected, that is, it should be stable and resist deterioration over the working life of the pipe It should be easily molded and applied and have the requisite mechanical strength No insulation commercially procurable will overload the pipe by its dead weight, for density is not one of the attributes of a good insulator In fact, the non-conducting properties seem chiefly to be derived from the presence of large numbers of air cells The materials most commonly used are asbestos, "magnesia" (magnesium carbonate), cork, hair felt, wool felt, rock wool, and diatomaceous earths Most commercial insulations are either built up from corrugated asbestos paper, or laminated asbestos paper artificially roughened to produce air spaces, or are molded, or felted with asbestos, etc A very common and effective insulation for temperatures up to 600° F is the molded "85% magnesia," so called because it is 85% carbonate of magnesium and 15% binder Pipe insulation for higher temperatures should have an inner layer of some special high-temperature insulation, since 85% magnesia alone will deteriorate. Painting with aluminum or bronze paint will greatly decrease the radiation losses

As in the case of furnace wall design, calculations of heat transfer through pipe covering take the form of an addition of resistances of a series circuit

Manufacturers publish insulation efficiency tables for the various standard thicknesses of their different grades of insulation The "efficiency" of an insulating material is expressed as the per cent heat saved by using the insulation, compared to what would have been lost had the surface been left bare Like many other design problems, the amount of insulation to apply is, basically, an economic problem The cost of the covering must be weighed against the saving of heat. See **Thermal Conduction.** (F.T.M)

HEAT OF COMBUSTION. Fuels, and Thermochemistry, and Fuel Calorimeter.

HEAT OF FORMATION. Thermochemistry.

HEAT OF FUSION. Very simple experiments show that the **fusion** of a given mass of any crystalline substance requires a definite quantity of **heat.** The quantity required per unit mass, without any change of temperature, is called the heat of fusion of the substance It may be measured by means of a **calorimeter** The fused substance is introduced into the calorimeter at a temperature somewhat above its melting point and allowed to cool, the heat evolved being measured At the melting point it ceases to cool for a time, but continues to give out heat as it solidifies; and when all congealed, it begins to cool again At this stage the process is terminated, and the total heat evolved, with corrections for the cooling before and after solidification calculated from the known specific heats, gives the heat of fusion For ice the value is about 79 25 calories per gram

The freezing of 10 pounds of water gives out 1440 British thermal units of heat, which is equivalent to the burning of 0 1 pound of coal or about 2 cubic inches of kerosene, or which would raise the temperature of 1 gallon of water 171° F This fact is sometimes utilized to prevent vegetables from freezing in unheated basements, by setting tubs of water near them, or likewise to protect the battery and radiator of a car on very cold nights (L D W)

HEAT OF REACTION. Thermochemistry.

HEAT OF VAPORIZATION. The **evaporation** of a given mass of any liquid requires a definite quantity of **heat,** dependent upon the liquid and upon the temperature at which it evaporates The quantity required per unit mass at a fixed temperature is called the heat of vaporization of the substance at that temperature It may be measured by allowing the vapor to condense in a suitable **calorimeter,** the heat thus evolved, corrected for fall of temperature before and after condensation, being observed (The heat evolved in condensing is equal to that absorbed when the liquid evaporates) The result is often surprising For example, the evaporation of water at the boiling point requires about 540 calories per gram, or more than five times the heat required to raise its temperature from freezing to boiling The explanation is the large amount of energy necessary to separate the molecules against their cohesion, and the much smaller amount (about 7 4% of the whole) which is used in expanding the vapor against atmospheric pressure At lower temperatures the value is still greater, because the cohesion is then more effective, with water, for each degree below the normal boiling point about 0 6 calorie per gram must be added to the heat of vaporization Trouton found that the heat of vaporization per mole for different liquids bears a constant ratio to the absolute temperature of the boiling point (L D W)

HEAT TRANSFER The three ways by which heat can be transferred from one body to another are **convection, radiation,** and **conduction.** Convection implies a carrying medium The heat absorbed by the medium is

$$Wc(t_1 - t_m),$$

and the heat delivered by the medium is

$$Wc(t_m - t_2),$$

in which t_m is the temperature of W pounds of a carrying medium whose specific heat is c The medium is usually a gas or liquid receiving its heat either through conduction or radiation The fundamental equation of radiation is the Stefan-Boltzmann relation,

$$Q = CS(T_1^4 - T_2^4)$$

The fundamental equation for conduction is

$$Q = \frac{SK\theta}{d}$$

This is frequently written $Q = SK\theta$, wherein K includes the thickness element.

In the above equations

Q = heat transferred
C, K = coefficients of radiation and conduction
S = surface area in radiation or conduction
T_1, T_2 = temperature of radiating and receiving surfaces
θ = temperature difference of fluids on opposite sides of conducting partition
d = thickness of the conducting partition

Quanta of radiant energy travel about at great speed—the speed of light—but conduction is a process of intermolecular excitation that takes place more slowly

The laws of heat transfer and their applications have received thorough study from scientists and engineers Examples of heat-transfer calculations are.

1 Radiation from fuel bed and luminous gases to boiler and other surfaces
2 Convection of heat from the **combustion** region to the more remote heater surfaces
3 Conduction of heat through pressure vessel surfaces
4 Conduction of heat through **condenser** or heater tubes
5 Conduction and radiation in so-called "heat **insulators,**" such as **refractories** and pipe coverings

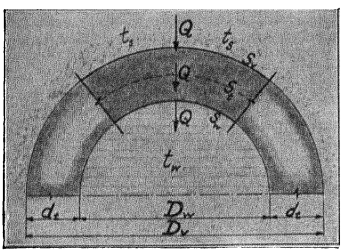
The first three of these are met in boiler design Energy quanta are emitted at a high thermal potential by the combining molecules of fuel and oxygen, then partially absorbed as direct radiation by various water-cooled surfaces bounding the furnace The portion unabsorbed by the envelope is conveyed to the gas, via absorption by carbon dioxide, water vapor, and thermal diffusion, raising its temperature to that with which it enters the convection zone During its passage through the boiler and its auxiliaries, the gas gradually loses its thermal potential until it reaches the stack potential A characteristic of modern boilers is that a large portion of this heat is given to surfaces which "see" the incandescent region The thermal potentials of the absorbing surfaces vary, for instance, that of the boiler is all at the saturation temperature, that of the superheater is variable from saturation to superheat temperature, while those of the economizer and air preheater offer further instance of variable temperatures on both sides of the conducting surfaces

Actually, the heat transmission by convection to many surfaces and by conduction through them, does not warrant laborious and exact calculation because of the continually varying operating conditions and their very great influence on rate of heat transfer They are

1 Varying accumulation of scale on the water side
2 Varying accumulation of soot on the gas side
3 Varying mass flows at different boiler loads and at different percentages of excess air supplied

In spite of this, improved designs must always rest on better, more rational and accurate methods of predicting performance, and design of equipment. This has been especially true in the field of heat transfer While certain basic relationships are well known now, there is considerable difference in the constants which different investigators have found necessary for their interpretation Most practical cases of heat transfer involve the combination of two, sometimes three, of the possible methods of transferring heat Thus, for example, the transfer of heat from one fluid medium to another is generally accomplished, not by direct mixture, but by a transfer of the heat across a separating surface First

the heat must be delivered from the hot medium to the surface, then conducted through its thickness and delivered to the receiving fluid. The overall coefficient of heat transfer naturally depends on the character of the two fluids, their velocity and viscosity, as well as the temperatures involved, and the nature of the separating surface.



Half-section of condenser or heater tube.

Consider the case of a straight tube carrying a fluid under turbulent flow condition and surrounded by a condensing vapor. The condensing vapor is at t_v. If a quantity of heat Q is to flow through the element shown in the accompanying figure, a temperature difference θ must exist between t_v and t_w, the temperature of the fluid in the tube. If the tube is clean, θ is the sum of θ_v, the temperature drop to the tube, θ_t, the temperature drop across the tube, and θ_w, the temperature drop from tube to fluid. Since $Q = SK\theta$,

$$\frac{Q}{SK} = \theta = \theta_v + \theta_t + \theta_w.$$

Calling the coefficients of heat transfer k_v, k_t, k_w, we have

$$Q = k_v\theta_v S_v = k_t\theta_t S_t = k_w\theta_w S_w,$$

whence

$$\theta = \frac{Q}{S_v k_v} + \frac{Q}{S_t k_t} + \frac{Q}{S_w k_w}.$$

(F.T.M.)

HEAVE. Fault.

HECTOCOTYLUS ARM. One of the arms or tentacles of the male of certain species of **cephalopod** mollusks, specialized for the insemination of the female. It may serve as an intromittent organ, introducing **spermatophores** into the mantle cavity of the female, and in the paper nautilus (*Argonauta*) it breaks away from the body and enters the mantle cavity of the female, remaining inside for some time. (A.W.L.)

HEDGEHOG. Mammalia, Insectivora. Small compact animals with short legs and tail and a sharp nose. The entire upper surface is covered with sharp spines which protect the entire body when it is curled up. The numerous species live in Africa, Europe, India, and the remainder of Asia north of the Himalayas. They are nocturnal animals. The European hedgehog, *Erinaceus europaeus*, is also called the urchin. (A.W.L.)

HEEL. The prominence at the posterior end of the foot. It is based on the projection of one bone, the calcaneum, behind the articulation of the bones of the lower leg. In the long-footed mammals, both the hoofed species and the clawed forms which walk on the toes, the heel is well above the ground at the apex of the angular joint known as the hock or hough. In plantigrade species it rests on the ground. (A.W.L.)

HELIANTHIN. Dyes.

HELICAL GEAR. Spur Gear.

HELICOPTER. An **aircraft**, the sustaining forces of which are obtained from the thrusts of propellers which rotate in a horizontal plane, and which are engine-driven, is known as a helicopter. Although helicopters have been experimented with for many years, commercially successful ones have not yet been produced. Their design has attracted many gifted inventors, due to the attractive aspects of hovering flight, of which a true helicopter is capable. Mechanical complexity, cumbersomeness, inefficiency, and poor stability have been reasons for failures of many helicopters which have been built. (F.T.M.)

HELICOSPORIDIA. Sporozoa.

HELIOTHERAPY. The treatment of disease by exposure of the body to the rays of the sun or to **ultraviolet** rays from an artificial source. The method of procedure consists either of general exposure of the body as a tonic measure or a stronger local exposure for use in various skin diseases and in indolent ulcers or slow-healing infected wounds. In **tuberculosis,** heliotherapy has proved of little value in the pulmonary form, but in other forms, such as tuberculosis of bone, lymph-glands, spine, larynx, abdomen, genito-urinary tract, and mucous membranes, it has proven to be of considerable value. (R.S.M.)

HELIOZOA. Sarcodina.

HELIUM. Symbol: He. Atomic number: 2. Atomic weight: 4.003. Density: 0.1785 gram per liter, 0° C., 760 mm., or 0.138 when air equals 1.000. Melting point: —272.2° C. Boiling point: —269.0° C. No isotope but of single atomic form: 4.

Helium is a colorless, odorless gas, of negative chemical properties, with ordinary materials, except under the influence of electric glow discharge or **electron** bombardment, helium forms compounds with **tungsten, iodine, sulfur, phosphorus.** In a **vacuum** electric discharge **tube** shows green to canary yellow glow. Discovered first in the vapors surrounding the sun by Lockyer in 1868, through the yellow spectral line near the two yellow lines of sodium, then by Ramsay in 1895 in the mineral **clevite.**

Helium occurs (1) in minerals of **uranium** and **thorium,** such as **clevites, pitchblende, carnotite, monazite,** and also in **beryl,** (2) in mineral waters (1 part He per thousand of water, in some Iceland waters), (3) in volcanic gases, (4) especially in certain natural gases of the United States. The first discovery of this kind was made in Kansas. The richest helium wells are in Utah. In Northeastern Texas, four wells have produced fifty-five million cubic feet of helium. The fields in which are located the wells having the greatest percentage (1.3–8.0%) of helium are now held as government reserves. The primary use for helium is in inflating airships. Helium is a very light gas. Its lifting power is 92.64% that of hydrogen (of course, the comparative net buoyancy in **airships** is much less than this), and it is non-inflammable, (5) in ordinary air, about 1 part in 200,000.

The most striking properties of helium are its **radioactivity,** when emitted as the positively charged (+2) alpha particles in **radioactive changes,** its formation in radioactive change by uranium-**radium** and thorium containing substances, emitting alpha particles, later losing the charge to become helium, and recently, its production artificially by bombardment of **lithium** or **boron** with high velocity **protons** or alpha rays.

The liquefaction of helium was accomplished by Onnes in 1908 in Leiden, and Keosom in 1926 succeeded in solidifying helium in the same laboratory. Helium is the most difficult of all the gases to liquefy. An astonishing property of certain metals is that at the temperature of liquid helium they possess electrical **super-conductivity,** e.g., mercury, lead, and tin.

Helium-oxygen atmospheres are utilized in high pressure breathing work, such as diving suits, caisson work, because helium is inert, less soluble in the blood stream than nitrogen, and diffuses 2 5 times more rapidly than nitrogen The time for de-gassing is materially reduced, as also the hazard resulting from the gas collecting in the joints (R K S, R M F)

HELIX. A helix is a **skew curve** or twisted curve in space which is defined as the **locus of a point** which moves on a right circular **cylinder** in such a way that the distance it moves parallel to the axis of the cylinder varies directly as the angle it turns through around the axis

Parametric equations of the helix are

$$x = a \cos \theta,\ y = a \sin \theta,\ z = b\theta,$$

where θ is a parameter (L L S)

HELLBENDER Amphibia, Urodela A large aquatic **salamander,** *Cryptobranchus alleghenensis,* of the Mississippi river system It reaches a length of eighteen inches and has a flattened head and body, short legs, and a compressed tail The **gills** are concealed, but otherwise it resembles the mudpuppy (A W L)

HELLGRAMMITE Insecta, Neuroptera The large aquatic larva of the dobson fly, *Corydalus* It lives in running water and is an excellent bait for bass (A W I)

HELMINTHOLOGY A biological science dealing with the **worms** Since many worms are parasitic, the term parasitology is more commonly used The study of roundworms is important in agriculture and has resulted in the science of nematology (See **Nematoda**) which is properly a subsidiary of helminthology (A W L)

HEMATITE. The mineral hematite, ferric oxide, Fe_2O_3, occurs as thick or thin tabular **rhombohedral** forms, sometimes in pyramids but rarely in **hexagonal** prisms It also assumes **botryoidal,** columnar and lamellar shapes, and may be granular or compact Its hardness is 5 5–6 5, specific gravity varies from as low as 4 2 to as high as 5 25, luster, metallic to earthy or dull, color, dark gray to black, earthy forms may be different shades of red, streak, red to red brown, translucent (in very thin flakes) to opaque Hematite with a metallic luster is called specular iron It is a widely distributed and common mineral, found in **igneous, sedimentary** and **metamorphic** rocks as beds and veins, having probably been formed in many different ways under very different conditions Beautifully crystallized hematite has been found in the Urals of Russia, Rumania, Switzerland, the Island of Elba, Alsace, France, Cumberland, England, and Brazil Perhaps the greatest hematite region in the world lies along the southern and northwestern sides of Lake Superior in Michigan, Wisconsin and Minnesota where this mineral has long been mined Extensive beds of hematite are found throughout the Appalachian region from New York to Alabama, being principally mined near Birmingham in the latter state Hematite occurs in quantity in Nova Scotia and Newfoundland It is the most important ore of iron, and has other industrial uses in paint manufacture, polishing compounds, etc The name hematite is derived from the Greek word meaning *blood* (E C E S)

HEMATOLOGIST. A specialist in the disorders of the **blood.** (R S M)

HEMATOLOGY. That branch of medicine that has to do with the study of the **blood,** the blood-forming tissues and the diseases of the blood (R S M)

HEMATOMA. An accumulation of free blood in the body tissues This usually follows an injury where rupture of blood vessels takes place (R S M)

HEMATURIA. The presence of **blood** in the **urine.** This condition is found in certain forms of **nephritis** and with injury, tumors, stones, or calculi in the urinary tract It is also seen in **scurvy** and in some cases of severe **sepsis.** (R S M)

HEMICHORDATA. A subphylum of the phylum Chordata containing only a few primitive marine animals without common names The genus *Balanoglossus* has lent its name to the forms most commonly seen, although some belong to other genera They are wormlike animals which live in mud and sand at the bottom of the ocean The central nervous system is dorsal in this group but it remains partly or wholly at the surface The **notochord** is limited to the anterior part of the body and is sometimes connected with the alimentary tract Gill slits vary from one to many pairs The group is also commonly named Enteropneusta and rarely Adelochorda

There are two orders

Order Balanoglossida Wormlike animals with many gill slits and with a fleshy proboscis before the mouth *Balanoglossus* and related forms

Order Pterobranchia (Cephalodisca) Sessile animals, some solitary and some colonial One pair of gill slits A proboscis and branching tentacles lie before the mouth and the intestine is U-shaped *Cephalodiscus* and *Rhabdopleura* (A W L)

HEMIGALE. Civet.

HEMIMETABOLA A division of the **insects** characterized by incomplete metamorphosis The immature insect differs conspicuously from the adult in form and is adapted to an entirely different mode of life, in this the group resembles the **Holometabola** The young have compound eyes, however, and the wings develop externally as in the **Paurometabola** The group includes the three orders, **Plecoptera, Ephemerida,** and **Odonata,** all with aquatic larvae which are called naiads (A W L)

HEMIMORPHITE. Calamine

HEMIPODE Aves, Galliformes *Turnix* The **bustard-quails** of the Australian, Oriental, and Ethiopian regions They are unusual in the larger size and brighter colors of the female and in the fact that the male incubates the eggs and cares for the young (A W L)

HEMIPTERA. The true **bugs,** an order of insects containing about 21,000 species, many of economic importance They have a piercing and sucking mouth and live on the blood or juices of animals or the sap of plants The wings, when present, are usually distinctive The basal half is thicker than the terminal, and the tips overlap partially so that the margins of the wings form an X on the back The chinch bug and bed bug are species of economic importance

Bugs of several families are aquatic and some forms live on the surface of the water, supported by the surface film The swimming forms are the **water boatmen, back swimmers,** and giant water bugs and the **water striders** skate on the surface One of the last, *Halobates,* is the only marine insect known Shore forms include the **toad bugs** On dry land the order is represented in almost every possible habitat (A W L)

HEMOGLOBIN A chemical compound which is the coloring matter of red **blood** cells Its composition is complex One portion of the molecule is a protein known as globin, the other portion is hematin, and contains iron (See **Aminoacids, Polypeptides, and Proteins**)

Hemoglobin, having a power of combining with oxygen is the means of supplying the body cells with oxygen When oxidized, it is oxy-hemoglobin In the circulation when the oxygen is liberated, the hemoglobin is known as reduced hemoglobin

The amount of hemoglobin may easily be estimated from a fresh specimen of the blood Normally it varies from 80 to 100 per cent In **anemia** the percentage is reduced (R S M)

HEMOLYTIC JAUNDICE (Congenital jaundice, familial jaundice, acquired jaundice) A chronic disease due primarily to increased fragility of the red **blood** cells accompanied by destruction of these red blood cells, with resultant **anemia** and **jaundice.** The acquired form is seen as a secondary development of various acute infections but may appear without apparent cause The congenital or familial form is thought to be hereditary In the acquired form treatment consists of removal of the cause if discoverable If the cause cannot be discovered or removed surgical removal of the **spleen** gives a cure in most cases (R S M)

HEMOPHILIA. An hereditary disease marked by a tendency toward prolonged and repeated bleeding following any injury throughout life The disease occurs in the male but is only transmitted by the female Bleeding usually follows an injury although it may occur after an exceedingly trivial one

The cause of this disease is unknown It is largely confined to the Teutonic race The incidence of the disease follows the laws of Mendelian inheritance (See **Heredity**) A female capable of transmitting the disease does so to about two-thirds of her male children while two-thirds of her female offspring are conductors of the disease

Treatment during **hemorrhage** is similar to that of ordinary hemorrhage requiring quiet, **morphine,** and often transfusion **Protein** sensitization works particularly well in some cases

Since the disease cannot be cured the hemophiliac must lead a guarded life with hygienic surroundings and should always have access to a suitable **blood** donor for emergency use (R S M)

HEMORRHAGE. Marked bleeding, from or, in any part of the body The common sites of hemorrhage, excluding hemorrhage following accident and injury or occurring operatively or post-operatively are (1) Pulmonary hemorrhage which varies markedly in degree The blood is usually bright red and frothy due to a mixture of air, and usually occurs in tuberculosis of the lung, (2) Gastric hemorrhage occurring in ulceration of the stomach when a blood vessel is eroded in the ulcer bed The blood is vomited and is usually a dark red or brown due to admixture with the gastric juices, (3) Uterine hemorrhage due to premature separation of the **placenta** or occurring after delivery It may also be due to malignant or benign tumors of the **uterus,** various glandular disorders causing excessive bleeding with the menses or periods, and abortion, (4) Rectal bleeding usually due to ulcer formation or malignant growths in the intestinal tract In this type of hemorrhage the expelled blood may be black or tarry in color Occasionally bleeding from **hemorrhoids** is severe although this is not usually copious in amount, (5) Nasal hemorrhage, common ordinary nose bleed which is not usually serious, (6) Cerebral hemorrhage, hemorrhage from an artery in the **brain,** the so-called stroke (R S M)

HEMORRHOIDS. Popularly called piles. Hemorrhoids are small **tumors,** made up of dilated varicose veins, occurring at or near the rectal outlet They are divided into three groups, external, internal and a combination of the two External hemorrhoids occur at the external margin of the rectum beneath the skin. Internal hemorrhoids are situated just inside the rectum and are covered by mucous membrane which lines the rectum Long standing internal hemorrhoids, however, may protrude through the anal opening In cases of long duration, both internal and external hemorrhoids may be present.

The chief factor in the development of hemorrhoids is **infection** of the veins in this region The main predisposing factors are chronic **constipation** or the frequent taking of cathartics—particularly those which produce thin, watery stools

The chief symptoms of hemorrhoids are, bleeding, pain, spasm of the anal muscles—often causing reflex abdominal symptoms

The treatment of choice of all varieties of hemorrhoids is surgical excision, which when expertly done is a simple procedure causing little or no postoperative pain If internal hemorrhoids alone are present, and there is no acute infection at the site, they can be treated by the multiple injection method This can be done in the home or office and when done by experts in the technique and with suitable selection of cases, fairly satisfactory results can be obtained If the causative factors are not corrected, hemorrhoids will usually recur no matter what treatment is used

Cancer seldom if ever develops from hemorrhoids (R S M)

HEMP. *Cannabis sativa* Cannabinaceae Hemp is obtained from a tall hollow-stemmed annual which is a native of central and western Asia In cultivation the slight branching which characterizes the plant is considerably reduced by planting thickly The plants grow from five to sixteen feet in height They have digitately compound dark green leaves and small inconspicuous flowers which are of two kinds, occurring on different plants The staminate (See **Stamen**) flowers appear in small axillary (See **Axil**) clusters on male plants, and the pistillate (See **Pistil**) flowers are borne in leafy spikes on female plants The fruit, an **achene,** is a hard ovoid structure, often called hemp seed Cultivation of hemp has been carried on in China for many centuries From that country its culture has spread to many countries, Europe taking it up long before the Christian era dawned It is widely grown in the United States, although extensively in only a few states, such as Wisconsin and Kentucky Hemp grows best in regions having a warm humid growing season of about five months, the plants grow rapidly, soon shading the ground so effectively as to suppress all other plants present, for which reason its culture is sometimes recommended as a way to eradicate obnoxious weeds When the staminate flowers are mature, the plants are ready for harvest, to delay after that is not desirable, since the male plants die soon after flowering, furthermore, after flowering the fibers become coarser Harvesting and the treatment of the plants after harvesting are very similar to those of **flax** plants The hemp plants are cut off or pulled up, denuded of leaves, roots and tops, and tied in bunches and left to dry for about two weeks They are then immersed in water to ret In retting the intercellular substance of the stems is acted upon by **bacteria** and softened so that the fibers are readily cleaned of surrounding tissues Scutching removes the woody tissue, after which the rough hemp fibers are hackled, or drawn over coarse combs which pull out the fibers

Hemp fibers are coarse and rather harsh, and much less pliable than flax fibers Furthermore, they are dark colored and not easily breached without injury So the principal use made of them is in the making of rope and coarse twine, sail cloth, the warp of carpet and belt and upholstery webbing, all products where strength and durability are the principal aim, and appearance of little consequence Short fibers of hemp, called tow, are used in packing joints in iron pipes, and as pump packing, also as a stuffing for upholstery The woody waste from hemp fiber production has been used in paper making

From hemp seeds, a valuable oil is pressed out, it is used in the making of soft soaps, and also in mixing paints and varnishes. The seeds themselves are used as bird food

From the hemp plant also a drug is obtained This substance is located in the glandular hairs of the leaves and stem From the pistillate flowers and fruits is obtained a resinous substance, which is smoked in the Orient under the name of hashish or bhang. As a medicine the drug may have a quieting effect on the nervous system, but large doses are dangerous The Mexican preparation, marihuana, is very similar to hashish in its properties (R M W)

HENNA. *Lawsonia inermis* Lythraceae This plant, a native shrub of Africa and Asia, is widely cultivated in tropical countries The small flowers are inconspicuous, but very fragrant The leaves are powdered and made into a paste which applied to the hair or beard gives it a bright red color It stains the skin yellow and is used by some Oriental people to color the hands and feet From the fragrant flowers, a rich perfume is obtained, which is used in oils and ointments (R M W)

HENRY. Inductance; Electric and Magnetic Units.

HEPATICS. Bryophytes.

HEPATOPANCREAS. A digestive gland of the mollusks (**Mollusca**) and **arthropods** which discharges into the stomach (A W L)

HERCULES. (Map, page 306) A large and important **constellation** between **Lyra** and Corona Borealis The constellation contains no strikingly bright stars and hence is somewhat difficult to locate Once found, however, it is a fertile field for a small **telescope.** In 1934 Hercules received considerable notice because of the brilliant **Nova** that appeared in it just before Christmas Perhaps the most interesting object in the constellation is the remarkable star **cluster** which was first noted by Halley in 1714 While the cluster can be distinguished as such in a telescope of only 2-inch aperture, it requires a telescope of larger than 6-inch to really appreciate the magnificence of the object In addition to the star cluster there are several **double stars** to be observed with small telescopes, many of them having components of different colors (W K G)

HERCYNIAN REVOLUTION. Permian.

HEREDITY The transmission of developmental potentialities from one generation of living things to the next through the process of **reproduction** The materials of the parent bodies from which a new individual develops are its actual heritage During its own embryonic (**embryology**) development the potentialities of this heritage are expressed in the structural characteristics of the new body, normally like those of the parents or those of a more remote generation of ancestors This fact leads to the common statement that the organism inherits certain characters, while not precisely true, the interpretation is permissible for all ordinary purposes of description

The fact of inheritance is obvious It has been expressed for ages in unscientific observations Attempts to determine the scientific foundations of inheritance are relatively recent, however, and the establishment of a sufficient body of facts relating to heredity to constitute a science has occurred only during the twentieth century This science is called genetics

The first steps in genetics were taken by plant hybridizers of the 18th and 19th centuries, chiefly in Europe, and culminated in the experiments of Gregor Johann Mendel, a monk at Brno, Czechoslovakia, then Brunn in Austria Mendel's results were published in 1866 and lay almost unnoticed until 1900, when they were corroborated by three scientists in the birth of modern genetics The published report of Mendel's work repeated the significant observations of his predecessors and added a simple mathematical analysis that had not previously been expressed As a result of the far-reaching importance of this work the term Mendelian heredity is now commonly applied to the established fundamentals with which all subsequent discoveries have been correlated

Mendelian heredity depends on three fundamental concepts (1) The organism is a mosaic of **unit characters** capable of separate hereditary transmission (2) A unit character may mask a related unit character completely when the potentialities for the development of both are present in the same individual This principle is called **dominance,** and the masked character is said to be recessive. (3) Unit characters may be **segregated** during reproduction, regardless of the combinations in which they have been associated

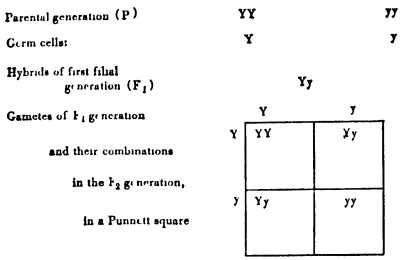
To these concepts modern genetics has added that the association of different related unit characters in one individual may result in the development of both in different parts of the body, in a mosaic inheritance, or in an intermediate condition through blending inheritance

Some characters, particularly of a quantitative nature, are not amenable to these rules unless through a very complex association of underlying hereditary unit characters Such characters must be studied by statistical methods They were the foundation of another attempt to formulate laws of inheritance made by Sir Francis Galton, from which we retain the law of ancestral inheritance and the law of filial regression The former indicates that each parent contributes one quarter of the total heritage of the individual, each grandparent one sixteenth, and so on in a rapidly diminishing percentage The law indicates the great reduction of the possibility of a hereditary character reappearing after a lapse of generations Filial regression is the tendency of extreme parents to produce offspring less extreme than themselves Thus tall parents beget tall children, but usually shorter than themselves Galton studied human inheritance and in addition to his mathematical analyses, so necessary in this field, took the initial steps in proposing deliberate control, which led to the modern science of **eugenics.**

Modern science has also added to early discoveries the definite recognition that hereditary potentialities are resident in the **chromosomes** of body cells and that definitely located **genes** within these chromosomes are the determiners through which specific unit characters are brought to expression The behavior of chromosomes is strictly in harmony with the transmission of characters by Mendelian heredity (**Meiosis; Fertilization**) Since nothing was known of chromosomes during Mendel's life, this correlation had to await further advances in cytology

Mendel's chief contributions were derived from the study of garden peas, in which he observed seven pairs of unit characters, all similar in behavior He noted, for example, that seed colors included two unit characters, yellow and green When he crossed parent plants of the two strains the resulting hybrid seeds were entirely yellow, indicating the dominance of this color over green He then inbred the hybrids, and in their offspring both yellow and green seeds appeared in the ratio of three yellow to one green Related unit characters of this kind are said to be alleles or allelomorphs It is now known that their genes occupy the same position in the paired chromosomes of the cell, while only one can be represented in the single chromosome of a **germ cell.** Since each parent contributes one chromosome to each pair in its offspring, it may also contribute one gene of an allelic pair The one parent plant contributed a gene for yellow, the other for green, and through dominance the offspring were yellow Segregation, however, enabled these hybrids to transmit either yellow or green during their reproducton, and through random fertilization all possible combinations of these determiners were established The characters are commonly represented by symbols, using a capital letter for the dominant and a small letter for the related recessive, as Y and y for yellow and green respectively For the

pair of characters mentioned, the following diagram is representative



The YY and yy individuals in this diagram are homozygous, while the Yy individuals are heterozygous Since all YY and Yy individuals look alike, due to the dominance of Y, they belong to the same phenotype, but since their hereditary potentialities are different they belong to different genotypes The yy individuals from hybrid parents are known as extracted recessives There are twice as many heterozygotes as homozygotes of either kind in this 3 1 ratio because similar individuals in this category result from reciprocal combinations of genes, half of the individuals receiving the dominant from one parent and half from the other Examples of this kind, involving only one pair of allelic characters, are known as monohybrids

Additional complexity arises in dihybrids, trihybrids, and polyhybrids of still more characters through the free reassortment of the unrelated pairs of alleles Thus peas from smooth yellow seeds crossed with others from wrinkled green seeds, a dihybrid combination, produce only yellow smooth seeds in the F_1 generation, but when inbred these plants give rise in the F_2 generation to the four possible combinations smooth yellow, smooth green, wrinkled yellow, and wrinkled green, in the ratio 9 3 3 1 The reason is evident in the following diagram

	SY	Sy	sY	sy
SY	SY SY	Sy SY	sY SY	sy SY
Sy	SY Sy	Sy Sy	sY Sy	sy Sy
sY	SY sY	Sy sY	sY sY	sy sY
sy	SY sy	Sy sy	sY sy	sy sy

In this diagram each pair of symbols above and at the left side represents the contribution of one parent in one of its germ cells, and in the small squares the possible combinations from the two parents are shown Dominance prevails as in the monohybrid

In a trihybrid free reassortment results in an F_2 ratio of 27 9 9 9 3 3 3 1 The number of phenotypes is always a power of two indicated by the number of pairs of alleles under consideration

The study of heredity in animals has shown that these principles are applicable in that kingdom as well as in plants, but relatively few animals are sufficiently prolific to demonstrate complex ratios The fruit fly, *Drosophila melanogaster*, has been the most productive of all genetic subjects, while man and the domestic animals yield very limited Mendelian data

Modern genetics, largely from studies of the fruit fly, has disclosed many principles as corollaries of simple Mendelian heredity The more important are as follows:

Multiple alleles More than two unit characters may be related to each other as alleles In such cases only two of the series may be present in any one individual, and dominance is in a graded series, as may be determined by experimental results

Multiple factors More than one gene may be necessary for the production of a single unit character If two genes are essential for its appearance and either alone is incapable of expression, they are said to be **complementary** If one expresses itself alone, a gene that modifies this expression is **supplementary** If two are capable of producing the same effect whether present singly or in combination, so that the resulting character is absent only from homozygous recessives, they are said to be **duplicate** genes In all cases recombination of the genes during reproduction follows the same course as in simple Mendelian heredity but the resulting phenotypic ratios differ because less unit characters are involved

Lethal genes Some genes completely inhibit development or modify it in such a way that the individual dies They also modify the usual ratios of associated characters

Linkage Some characters, although not allelic, are inherited in definite groups, they are said to be linked Modern genetics shows that linkage is due to the presence of genes for the linked characters in the same chromosomes

Crossing over Linkage relations are sometimes interrupted in a limited number of individuals, permitting some reassortment of normally grouped characters This change is due to the breaking of paired chromosomes in **synapsis** and the reunion of their fragments in new combinations to form similar chromosomes, sometimes with new combinations of genes

Translocation This change is a shifting of the relations of genes in the chromosomes, due to looping, fusion, and rupture, or to the attachment of fragments to other chromosomes It may result in the duplication of genes within a chromosome or in a change in the serial arrangement of the included genes

The inheritance of sex has also been shown in many cases to depend on a simple chromosomal mechanism Males of many species have an *x* chromosome without a synaptic mate or with a *y* chromosome mate that is evidently abortive The females of such species have two *x* chromosomes In the formation of germ cells all eggs receive an *x* chromosome while half of the sperm cells receive an *x* chromosome and half a *y* or none Random combination of these cells restores the *xx* combination in one-half and *x* or *xy* in the other, thus producing half females and half males Other investigations have shown that the quantitative balance between the sex and other chromosomes is the active factor in conditioning the differentiation of the sexes

This disclosure also explains the phenomenon of sex linkage Genes lying in the sex chromosomes, mostly in the *x* chromosomes but a few in the *y*, are inevitably transmitted and expressed in some definite relation with sex, hence they are said to be sex linked Such characters need have no active sexual role

The findings of genetics have been of great practical value in plant and animal breeding Although the improvement of cultivated plants and domestic animals by **selection** preceded by many years the formulation of scientific principles of heredity, the discovery of these principles has made possible much more precise and efficient procedure in the establishment of useful strains. **Hybridization** and selection together are the chief means of improvement Applied by scientists they have brought about many modifications of living things and have disclosed many facts concerning heredity Corn has been studied in detail and subjected to many experiments, both practical and purely scientific Tomatoes, radishes, various cereals, and flowers of many species have also commanded attention More has been done with plants

than with animals because the domestic animals are less amenable to experiment From the practical point of view plants are more satisfactory subjects because desirable hybrid strains may often be propagated by cuttings, grafting, and other asexual methods which avoid the segregation that is inevitable in sexual processes Only rigid selection can establish desired hybrid combinations in plants or animals that must be produced sexually

The study of human heredity depends entirely on observation of the family, since controlled mating is impossible Genealogical records have furnished a large amount of valuable material and the records of public institutions such as prisons and asylums have been equally useful to the geneticist Such records are not to be compared with scientifically assembled experimental data, but they leave no doubt that the principles of heredity worked out in the study of other organisms are also applicable to man In a few cases they have also disclosed adequate evidence of a specific type of Mendelian inheritance of human characters

The clearest evidences of human heredity are found in the behavior of simple structural defects, such as the appearance of extra digits (polydactylism), the fusion of bones in the digits (symphalangism), and shortness of the fingers (brachydactylism) These defects are transmitted as Mendelian unit characters allelic to normal structure Red-green color-blindness (**vision**) is one of the most striking examples of inheritance in man It is a sex-linked recessive allele of normal vision Both x chromosomes of the female must carry the gene for the defect if she is to be color-blind, whereas the male may be color-blind if he receives such a gene in his one x chromosome Females may be heterozygous carriers of the defect, with normal vision, males are either strictly normal or defective In this type of inheritance the male always receives the genes for his characters from his mother, therefore a carrier mother may have some color-blind sons A color-blind man and a genotypically normal woman cannot produce color-blind children, but all of their daughters are carriers On the other hand, a color-blind woman and a normal man will produce carrier daughters and color-blind sons **Hemophilia** is inherited in a like manner

Since man is concerned chiefly with his behavior, in the broad sense of the term, the inheritance of ability is much more important It is, however, extremely complex, depending upon many simpler heritable unit characters that are only slightly understood Nevertheless the inheritance of specific types of ability, and particularly of various degrees of ability, are well established by our records Deficient families usually produce deficient children, and superior families normally maintain their superiority There are occasional exceptions in both cases but in the long run superiority, mediocrity, and mental and social inadequacy tend to persist generation after generation in family lines These general terms are not to be taken to indicate hereditary traits in the strict sense of scientific genetics, but the heritage of individual organization whose expression in the behavior of the individual is quite evidently amenable to the principles so readily appreciated in the study of simpler structural unit characters. The possibility of practical application of this knowledge is the field of **eugenics**

The study of all aspects of heredity is now pursued extensively and is the foundation of a voluminous and constantly increasing literature. (A W.L)

HERMAPHRODITE. An animal with functional reproductive organs of both sexes. The condition is common among the flatworms and segmented **worms** and occurs in a few species of **echinoderms** and mollusks (**Mollusca**) Among the vertebrates the occurrence of both sexes in one individual is rare and the sexes appear at different periods. Animals in which such a transition is possible are sometimes influenced by external conditions and during the transformation may be functionally hermaphrodite This is true of some fishes and **amphibians** (A W L)

HERMAPHRODITE DUCT. The duct of the ovotestis (**gonad**) of certain **snails** (A W.L.)

HERMAPHRODITISM. Only about twelve cases of supposedly true hermaphroditism in the human race have been reported The term signifies the presence of all of the functioning genital organs of both sexes in one individual The cases mentioned above were supposed to have both a testicle and ovary present The ability to impregnate as well as to conceive has never been reported in the one individual

Many cases of pseudo-hermaphroditism have been seen In this condition the genital organs, internal or external, do not conform either totally or in part with the sexual glands (testicles or ovaries) present In the male testicles are present but may be abdominal in position The penis is small and more nearly resembles a large **clitoris** in the female, the **scrotum** is divided by a cleft resembling the female labia with a small short **vagina** **Uterus** and tubes are not present

The female hermaphrodite has a large clitoris more like a small penis, rudimentary vagina, a uterus and ovaries Various in-between stages may be present, giving a very bizarre picture where the sex can only be determined by operation or in some instances by determination of the amount of sex **hormone** in the blood and urine While this is seen in both sexes, in the female the amount of hormone exhibits a regular monthly cyclic curve corresponding to menstruation

In general an hermaphrodite is best raised as a female Other bodily characteristics may not be sharply differentiated in regard to sex (R S M)

HERNIA (Rupture). The protrusion of a portion of tissue or organ through a weakness or abnormal opening in any part of the body Thus it is possible to have a herniation of the brain through an opening in the skull, or herniation of muscle if an opening occurs in the covering membranes of the muscle

Common types of hernia such as femoral, inguinal, umbilical (navel) occur as protrusions of a sac-like process of the lining membrane of the abdominal cavity—the **peritoneum**—through a weakness at certain sites in the abdomen These sites are usually where some structure such as a blood vessel or other structure passes out from the abdominal cavity or formerly did during uterine life These sites are frequently congenitally weak, so that if any strain causing increased abdominal pressure occurs, this weakness is accentuated and a hernia results Chronic cough, constipation, heavy lifting, violent games, etc , are all predisposing causes of hernia, as they increase the pressure within the abdomen As continued pressure increases the size of the sac-like process, there may be forced into it a loop or small portion of intestine or some easily movable organ in the abdomen Sometimes, when the opening through which the rupture occurs is small, the intestinal organ forced into the sac cannot be pushed back into the abdomen Such a condition is known as a strangulated hernia This produces acute symptoms with local pain, often vomiting, and an emergency operation is necessary If this is not performed, **gangrene** may develop in that portion which is strangulated, since circulation to the part is shut off by the constriction of the abdominal wall opening around the sac

Common types of hernia are (1) *Inguinal Hernia*, developing along the course of or through the wall of the inguinal canal, where, in the male, the ducts leading from the testicle pass upward along the lower portion of the abdomen above the groin into the abdominal cavity In the female the corresponding structure, the round ligament of the **uterus**, runs through the inguinal canal Inguinal herniae are of several varieties and are more common in men than in women. Some

herniae of long standing will push their way downward into the scrotum; (2) *Femoral Hernia* occurs in the upper anterior portion of the thigh just below the groin. The weakness here results from imperfect closure around the large femoral blood vessels that pass from the abdomen into the thigh. Femoral herniae are more common in women; (3) *Umbilical Hernia.* This type of hernia occurs at the navel, where, during fetal life, the blood vessels connecting the fetal and maternal circulations passed. Imperfect closure after birth produces a weak navel through which a hernia may develop; (4) *Ventral Hernia* may occur in any portion of the abdominal wall where a weakness develops or occurs around an operative wound. Post-operative herniae are apt to occur in fat or weak abdominal walls where there has been an infected or drained wound or some post-operative complication that has increased the abdominal pressure such as prolonged coughing, vomiting or distention of the abdomen, before complete healing has occurred.

Other sites for hernia are less common, such as hernia through the diaphragm, where the hernial sac protrudes through the diaphragm into the chest. (R.S.M.)

HEROIN (Di-acetyl morphine). This drug is rarely used at present in medicine because it is more toxic than **morphine**, is more markedly habit forming, and its powers to allay pain and promote sleep are decidedly less than those of morphine or **codeine**. It is much used by drug addicts, especially those in the younger ages. More than any other narcotic, it destroys the emotional values of a subject, obliterates all traces of remorse or responsibility, and makes the user anti-social, criminal, and immoral. In the early stages of its use by an addict, it gives a sense of exhilaration and inflation of the ego. It is taken as snuff, as pills, or hypodermically. (R.S.M.)

HERON. Aves, Ciconiiformes. Long-legged wading birds (**Aves**) with a sharp slender beak and when adult with plumes or a crest. They live chiefly on fish.

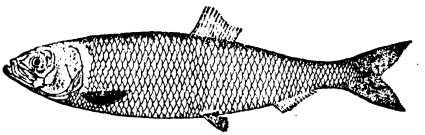
Herons are found throughout the world. The most widely known North American species are the great blue heron, *Ardea herodias*, the green heron, *Butorides virescens*, and the egret, *Egretta*. The last is a white bird which bears beautiful plumes known as aigrettes during the breeding season. It was once threatened with extinction through the use of these plumes as ornaments for hats, but the remaining birds are adequately protected. (A.W.L.)

HEROTA. Mammalia, Artiodactyla. An African **antelope**, also known as Hunter's hartebeest. (A.W.L.)

HEROULT FURNACE. Electric Furnace.

HERPES ZOSTER OR SHINGLES. A disease due to inflammation of sensory nerves caused by an unknown organism, probably a **virus**, that appears to be closely allied to chicken-pox. In some instances it occurs in epidemics. The unusual symptom of this disease is severe pain over the course of a nerve and the usual diagnosis is neuralgia. Constitutional symptoms characteristic of an acute infection may appear, that is, malaise, fever, chills, etc. Within a few days a rash breaks out in that portion supplied by the irritated nerve. Small blisters appear which may ulcerate, healing in three to six weeks. Scarring often results. The disease is self-limited, although injections of **pituitary** extract or **sodium** iodide may shorten the course of illness and lessen the pain. In older people the neuralgic pains are often particularly severe and may persist for months or years after the acute disease has disappeared. There are also other forms of herpes that are caused by **syphilis**, arsenical poisoning, and occurring with the common infectious diseases. (R.S.M.)

HERRING. Pisces, Teleostei. Food fishes (**Pisces**) of numerous species, found in both fresh and salt water. The common herring, *Clupea harengus*, is among the most important of the smaller food fishes on the New



Herring.

England coast and northward, and several fresh water species of the genus *Leucichthys* are equally important in the fisheries of the Great Lakes. The smaller sizes are canned as "sardines," especially in the United States and Norway. (A.W.L.)

HERTZIAN RADIATION. Electric Oscillations and Electric Waves; Electromagnetic Radiation.

HESPERIDIUM. Fruit.

HESSIAN FLY. Insecta, Diptera. One of the worst pests of wheat. It is a small two-winged **fly**, *Phytophaga destructor*, a member of the **gall-gnat** family, which was introduced into the United States in the Revolutionary period. The larva lives between the base of a leaf and the stem of the wheat plant and either kills or weakens the plant so that no grain develops. Other cereals are attacked to some extent.

Fall plowing and burning stubble aid in destroying many insects. The most effective means of avoiding damage to winter wheat is to sow late enough to avoid the attack of most of the adults. They live no more than ten days and the date of emergence is known for various regions, hence late planting subjects the crop only to the light infestation due to the eggs deposited by the relatively few flies which emerge late. (A.W.L.)

HESSONITE. Garnet.

HETEROCYCLIC COMPOUNDS. This is a class of organic compounds containing one or more rings in which there are elements other than carbon present. Examples are **furane, pyrrol,** and **pyridine.** (See **Carbon** for index to articles on heterocyclic compounds.) (R.K.S.)

HETEROGAMY. Gamete. In addition to the widely accepted application of the word to the occurrence of male and female gametes of different form, it has been applied in one work to the peculiar life cycle of the plant lice, in which generations with different characteristics succeed each other. The latter use is not to be recommended. (A.W.L.)

HETEROMORPHOSIS. Deviation from normal form. Malformation or deformity and also less extreme departures incidental to slightly different conditions in the animal or its environment. (A.W.L.)

HETERONEMERTEA. Nemertea.

HETEROTHALLISM. Phycomycetes.

HETEROTRICHIDA. Ciliata.

HEULANDITE. The mineral heulandite is a **monoclinic zeolite** whose crystals are often quite suggestive of **orthorhombic** forms. Its chemical composition is probably $(Ca,Na_2)O \cdot Al_2O_3 \cdot 6SiO_2 \cdot 5H_2O$; strontium may be present. Heulandite has one good cleavage, is brittle with a conchoidal fracture, hardness 3.5–4., specific gravity 2.18–2.22, luster vitreous to pearly, color white to gray, red or brown, streak white, transparent to translucent. Occurs chiefly in cavities in **basaltic** rocks with other **zeolites**, but may be found in **granites, pegmatites, gneisses,** and **schists.** Famous localities are in Iceland, India, the Harz Mountains, Italy, Switzerland, Scotland, Nova Scotia; and in the United States at Bergen Hill and West Paterson, New Jersey. This min-

eral was named for the English mineralogist Heuland (E C E S)

HEUSLER'S ALLOYS. In the earlier stages of knowledge concerning **magnetism, iron** and materials containing iron were supposed to be the only substances possessing appreciable magnetic properties It is now known that a large number of metals are magnetic, most of them, however, very feebly so About 1903 Heusler and others found that certain metals, not of themselves notably magnetic, when mixed in suitable proportions, produce alloys exhibiting ferromagnetic properties in a surprising degree Such, for example, is a mixture of copper, manganese, and aluminum in the proportion of 65 21 14, this alloy has a magnetic permeability comparable to that of cast iron Considerable study has been devoted to these magnetic alloys. (L D W)

HEXACTINELLIDA. The glass **sponges**, constituting a class of the phylum Porifera The spicules of the skeleton are silicious (See **Silicon**) and of six-rayed form Many of the species have a large central cavity, resulting in a tubular or vaselike form, and when freed of organic matter appear to be made of spun glass These sponges are found in deep water in the ocean Venus' flower basket (*Euplectella*) and the glass-rope sponge (*Hyalonema*) are the most common examples (A W L)

HEXAGONAL SYSTEM. Crystallography.

HEXAGONITE Tremolite.

HEXAMETHYLENE TETRAMINE. A compound of formaldehyde and ammonia (See **Formaldehyde.**) (R K S)

HEXAPODA Synonymous with **Insecta.**

HIBERNATION. The passing of the winter in a state of torpor The condition is unavoidable to the cold-blooded animals when the surrounding temperature falls low enough to slow the chemical processes of their **metabolism** below the level necessary for normal activity Under such conditions they live through the winter if the body is able to endure the lowest temperatures to which it is subjected Even in such forms preparation may be made for the winter by entering a more resistant form Some **rotifiers** and plant lice, for example, produce specially formed winter eggs and many insects pass the winter in the inert pupal stage

Hibernation is more striking in warm-blooded animals, since their bodily processes are not necessarily slowed by low surrounding temperatures The species that hibernate, like some of the bears, store up reserve energy through the warm season and hide away for the winter During this period their activity is reduced to the very slow respiration and reduced circulation By spring they have used up the fat stored during the previous year

Many animals hide away in nests or burrows for the winter without hibernating in the strict sense Their activities are, of course, lessened, but they seek food or live on stores accumulated previously, like the squirrels and beavers The honey-bee is an exceptional example of this kind among cold-blooded animals The colony maintains its warmth by the activity of some of the bees, and all individuals are intermittently active throughout the winter (A W L)

HICCOUGH OR HICCUP. An intermittent sudden contraction of the **diaphragm** The condition is due to a great variety of causes which may irritate either the nervous pathways leading to the motor centers controlling the diaphragm, the motor centers themselves, or the pathways from the centers to the diaphragm The condition occurs at any age

Hiccough commonly and ordinarily follows swallowing very hot or irritating substances, or occurs with disorders of the esophagus or stomach, such as **gastritis** or dilation of the stomach Hiccough may occasionally occur after operations and at times may prove very severe It occurs quite often in **peritonitis** or in any severe infection such as **typhoid** In severe toxic conditions, especially **uremia** and alcoholism, hiccough may be severe and exhausting An inflammation or tumor formation about the centers controlling the diaphragm will cause hiccough An epidemic variety of hiccough has been described, the disease lasting about a week Many cases of prolonged hiccough are of psychogenic origin Attacks in such people may last for weeks, but the disorder is not present while eating Many of these attacks may be aborted by sudden emotion such as fear, anger, etc (R S M)

HIDDENITE Spodumene.

HIGHER DERIVATIVES. The **derivative** of the derivative of a **function** $y = f(x)$ is called the second derivative of $f(x)$, and is denoted by $D_x^2 y$ or $\frac{d^2y}{dx^2}$ or $f''(x)$ or y'' Similarly, the derivative of the second derivative is called the third derivative, and is denoted by $D_x^3 y$ or $\frac{d^3y}{dx^3}$ or $f'''(x)$ or y''' In general, the n^{th} derivative is the derivative of the $(n-1)^{st}$ derivative, and is denoted by $D_x^{(n)} y$ or $\frac{d^n y}{dx^n}$ or $f^{(n)}(x)$ or $y^{(n)}$

The curves $y = f'(x)$, $y = f''(x)$, . . . are called the first, second, , derived curves corresponding to the curve $y = f(x)$

The relations between the derived curves are best brought out by drawing the curves one below the other The **ordinate** of the first derived curve is the **slope** of the original curve at corresponding points Corresponding to points on the original curve which are **maxima and minima,** the first derived curve crosses the X-axis, corresponding to **points of inflection** of the original curve, the first derived curve has maxima and minima Corresponding to points of inflection of the original curve, the second derived curve crosses the X-axis, corresponding to a maximum point on the original curve, the second derived curve has a negative ordinate, and for a minimum point, a positive ordinate (L L S)

HIGHER PLANE CURVES. By the term "higher plane curve" is usually meant any plane **curve** which is not a **straight line** or a **conic section**

Among the most important and most interesting higher plane curves are the following **bipartite cubic, cardioid, Cartesian oval, catenary, cissoid, conchoid, cubical parabola, cycloid, epicycloid, folium of Descartes, hyperbolic spiral, hypocycloid, lemniscate, limacon, lituus, logarithmic spiral, ovals of Cassini, parabolic spiral, rose curves, semi-cubical parabola, serpentine, spiral of Archimedes, strophoid, trisectrix of Maclaurin, trochoid, witch of Agnesi** (L L S)

HIGHEST COMMON FACTOR. The highest common factor of several **polynomials** is the polynomial of highest degree that is a factor of each of them It is usually found by factoring the given polynomials separately, and picking out the highest common factor by inspection

In cases where the polynomials are not readily factored, the following method, known as Euclid's algorithm, may be used

Let P and P' denote two polynomials and suppose that the degree of P is greater than or equal to the degree of P' Divide P by P' until a remainder R_1 is obtained whose degree is less than the degree of P' Divide P' by R_1 and obtain a remainder R_2 whose degree is less than that of R_1 Continue this process until the remainder $R_k = 0$, then R_{k-1} (the preceding remainder) is the highest common factor of P and P' (L L S)

HIGH-HOLE. Flicker.

HIGH-PRESSURE PHENOMENA. The earlier researches in this field were associated with the study of

the liquefaction and the **critical states of gases**, for example, the work of Andrews (1801) The critical pressure of water, for example, is something over 2000 kilograms per square centimeter The hydrostatic pressure at the greatest ocean depths must be about 1000 kilograms per square centimeter But these would now hardly be considered "high" pressures, since with modern technique it is possible to attain pressures as great as 30,000 kilograms per square centimeter The usual means of attaining high pressures is the "intensifier," which is merely a double free piston, that is, a straight rod with a large piston on one end and a small one on the other, each in its own cylinder Any pressure applied to the larger piston is multiplied in the smaller cylinder by the ratio of the two areas The chief problem is that of packing to prevent leaks, and this has been met by special devices perfected by Bridgman, Poultir, and others (See **Pressure Gages**)

Substances often exhibit unfamiliar properties at high pressure For example, the minimum volume of water, at 4° C under normal pressure, occurs at lower and lower temperatures as the pressure is increased, and finally, at about 2500 kilograms per square centimeter, a minimum no longer exists Solid bismuth kept at 250° C melts at a pressure of 5600 kilograms per square centimeter, but liquid sodium at 150° C solidifies at 7200 kilograms per square centimeter Some oils behave like sodium, so that they cannot be used as the media in high-pressure apparatus The thermal expansion of liquids under great pressure decreases with temperature instead of increasing as it normally does When liquids are subjected to 12,000 kilograms per square centimeter, the work of compression causes them to become almost boiling hot Many other properties have been studied in detail, such as density, electrical resistance, thermal conductivity, viscosity, dielectric constant, and polymorphic transitions

It is interesting, but at present futile, to speculate as to the state of matter subjected to such pressures as must exist in the far interior of the earth or of the sun—millions of times greater than anything artificially attainable—and especially at the inconceivable temperatures also prevailing there It is not improbable that states of aggregation quite unknown to us are produced under these conditions (L D W)

HIGHWAYS. Of the historical importance of highways as aids in the progress of civilization, and the closer association of peoples of the earth, little can be said in this article The highly interesting way in which development in road building is interwoven with the affairs of man as he stumbled forward from a barbaric state has, however, been adequately treated in literature Suffice it to say here that the modern highway reaches a degree of perfection attained only through many years of attempts to suit the road type to the vehicular traffic carried by it Usually perfection of types lags behind progress in the invention and building of vehicles which travel over them It seems necessary for vehicular improvement to precede roads satisfactory for the operation of the vehicle

A road system plays a very important part in the economic affairs of a country such as the United States, particularly in these days of widespread automobile ownership Nowhere else in the world are there to be found such conditions of congested, high-speed, or long-distance traffic The large sums collectible through automotive taxation have made possible a network of hard-surfaced highways, the main arteries of which are representative of great progress in the accommodation of large amounts of high-speed traffic The special intersections where it is unnecessary for any cross traffic to exist, but in which the full choice of direction of travel of an ordinary cross-roads is still available to the driver, aerial highways, in which the roadway is carried over congested districts, and entirely removed from local traffic, highway tunnels driven under rivers, and many other gigantic engineering enterprises, are part of the highway picture of the present time Roads and highways are comparatively expensive, seldom costing less than $2000 per mile for the most elementary form of earth road, ranging from that upward to $30,000 per mile for an ordinary two-lane concrete road, and into the hundreds of thousands of dollars per mile for super highways These gigantic sums are raised through taxation which reaches nearly every person in the United States The rates, however, direct and indirect, are not exceptionally high in that there are few persons indeed who do not make considerable use of highways

The simplest form of road is that which is constructed by leveling a right-of-way about 10 feet wide by excavating, filling, blasting, felling trees, grubbing roots, and providing ditches for drainage Such roads are satisfactory only for the lightest form of horse-drawn traffic If the type of road just described is adequately drained by deepening the ditches on the side and lowering the water table, then provided with an earth surface which is more of a road material than the original soil, a road is produced which is serviceable for light traffic the year round

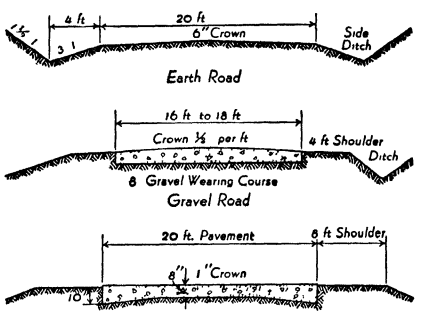
The most important element of a highway is its foundation This should be firmly compacted, and have sufficient bearing power to keep a tire or rim of a vehicle from cutting through, and it should also be sufficiently porous so that water will readily drain from it Deep side ditches are provided to drain the water from this foundation, keep it firm and hard, and reduce frost heavage Earth as a road foundation is not altogether satisfactory unless it happens to exist in proportions of sand and binder which are suitable The sand is necessary for bearing power, while clay or silt is necessary for binding the particles of sand together

A sand-clay road is made by forming the sub-grade, properly drained, and spreading on top of that from 8 to 12 inches of sand-clay mixture in proportions of about 20% clay and silt to 80% sand If the natural soil is to be used, and is deficient in either clay or sand, the deficiency may be made up by spreading the other material in proper amounts, after which it is mixed with harrows or plows The sand-clay road must be crowned so as to shed water directly and at low velocity to the ditches, otherwise it will wash badly under heavy rains Maintenance consists of scraping from ditches into the road and crowning up the surface, also adding more top-soil as needed

The gravel road is suitable for heavier traffic than the sand-clay or earth, and is more expensive to construct A comparatively wide roadway is built up in which a trench 6 to 10 inches deep and of the desired width is left to be filled with a mixture of gravel and sand-clay This type of road tends to deteriorate to a washboard-like surface under the wear of high-speed automotive traffic, particularly in the hollows, and must be scraped when damp

The macadam road is one of the oldest types, and one of the first really improved roads to be invented A macadam road is one whose foundation is built of crushed stone in graded sizes, the larger stones being placed at the bottom, the smaller at the top A water-bound macadam surface has stone screenings or other suitable fillers spread on the top surface, watered and rolled This type of surface has not been able to withstand modern traffic conditions, due to the unraveling of the surface layer, so road engineers have turned to different fillers **Asphalt**, **tar**, and heavy oil are materials that have been used for filler binders on modern macadam surfaces. Hard-surfaced roads may be constructed of some bituminous substance in conjunction with crushed stone, or of concrete with or without a bituminous surface Practically all hard-surface mileage is of this type, and surfaces like brick, cobble stone, or blocks, are but little used except for special traffic conditions in and around cities

Bituminous hard-surfaced roads will be briefly de-



Road sections.

scribed Bituminous macadam roads have a sub-base of gravel or stone An old macadam road can readily be converted, for the bitumin in the surface is usually put on in more than one layer For example, a course of crushed rock bound together with stone screenings, dampened and thoroughly rolled, is then covered with fine crushed rock to which is applied a penetrating binding and sealing compound of asphalt, either hot or cold, depending on the particular grade used A bituminous concrete road is built upon a well-compacted base of stone or gravel, or upon a **concrete** slab It is essentially a premixed, bituminous concrete, consisting of asphalt, sand, and finely crushed rock It is laid hot, and immediately rolled to about a two-inch wearing course Most bituminous concrete mixtures are patented

The concrete road is made up of Portland cement concrete from 6 to 10 inches thick, poured in slabs Unless the foundation is exceptionally well compacted, the concrete slab should have metal reinforcement Adjacent slabs should be separated by a small space to allow for expansion The spaces should be filled with asphalt to keep moisture from the sub-grade A typical concrete section is shown in the accompanying figure After the slab is poured it must be kept moist for several days in order properly to cure the concrete and develop its full value as a road surface While the concrete mixture employed is not standardized, a 1 2 3 mixture is about what is ordinarily used The coarse aggregate may be either gravel or crushed rock, and the fine aggregate washed sand

A standard two-lane highway should have a pavement surface from 18 to 20 feet wide, with 4- to 6-foot earth shoulders on the side of that Where traffic conditions are exceptionally severe, it has been necessary to increase this width and add more lanes for traffic The three-lane highway should not be used, if at all avoidable, since it does not increase the traffic capacity of the road in proportion to the added expense, and statistics show such roads to be extremely productive of traffic accidents The four-lane highway is far superior in that cars going the same direction may pass without invading an area set aside for traffic moving in the opposite direction In spite of this fact, however, many head-on collisions have occurred on four-lane highways, and are particularly disastrous because of the high average speed of traffic on these highways It appears that it may eventually be necessary to separate traffic moving in opposite directions by a central strip which is unpaved, creating, in effect, two parallel roadways (F T M)

HILL MYNA. Aves, Passeriformes The **grackles** of India and adjacent regions They are glossy black birds with brightly colored wattles and in some species other bright marks When kept in captivity they learn to talk readily and imitate the inflections of the human voice much more faithfully than the parrots (A W L)

HIND. The female **deer**, especially of the European red deer

HINGE LIGAMENT. A tough elastic connection between the dorsal margins of the two valves of the shell of **bivalve** mollusks (A W L)

HINNY. The hybrid offspring of a stallion and a jennet, reciprocal of the cross of jack and mare by which mules are produced The difference between mules and hinnys is a disputed point Some writers claim that hinnys are smaller and lacking in the qualities desired in mules, while others say that both forms fall within the range of variation to be expected in the hybrid (A W L)

HIP. The joint at the attachment of the human leg to the body Also the adjacent portion of the thigh where it merges with the buttocks and less commonly the corresponding part of the leg in other animals (A.W L)

HIPPOPOTAMUS. Mammalia, Artiodactyla A large African animal with a bulky body, short strong legs, and a very broad muzzle Hippopotami have been known to attain a length of twelve feet and a weight of four tons They are largely aquatic in habits and live entirely on vegetation, including both water plants and terrestrial species They sometimes do great damage to crops

A second species, the pigmy hippopotamus of western Africa, reaches only half the length of the larger animal and is found in the forests and swampy lands (A W L)

HIRUDINEA. The leeches, a class of segmented worms (Phylum **Annelida**), well known for their habit of sucking blood Marine and fresh water species are known, and in the moist tropical forests terrestrial species occur They often attach themselves to bathers

The members of this class are distinguished from other annelids by the following characters 1 The body is relatively short, usually with thirty-two segments 2 The external segments are annuli numbering from two to fourteen to each metamere 3 Each end of the body bears a sucker 4 The mouth is usually provided with three toothed plates or jaws 5 The alimentary tract is provided with an enormous pouched crop in which blood is stored prior to digestion 6 The anus opens dorsal to the posterior sucker 7 The **coelom** is partially obliterated by a peculiar **mesenchymal tissue** 8 At the anterior end of the ventral nerve cord several ganglia (**ganglion**) are fused to form a large mass

Leeches were once extensively used in medicine for letting blood and are still of minor importance for this purpose Otherwise they are of no importance to man save as an occasional annoyance They eat small aquatic animals as well as the blood of vertebrates and some species are entirely predacious

Two orders are recognized

Order Rhynchobdellida With a protrusible proboscis, colorless blood, and no jaws Marine and fresh water

Order Gnathobdellida With jaws and red blood No proboscis Fresh water and terrestrial The medicinal leech belongs to this order It is native to Europe but is naturalized in ponds and streams of the eastern United States (A W L)

HISTIDINE. Amino Acids, Polypeptides, and Proteins.

HISTOBLAST. A group of cells in the immature stages of **insects** from which some organ of the adult is developed The forerunners of the wings in insects with complete metamorphosis, for example, are small thickened layers of cells in the **larva** Also called imaginal disks (A W L)

HISTOLOGY. The science which deals with the minute structure of living things The study of the structure and functions of cells is the special province of **cytology,** leaving the study of special forms of **cells** and their association in **tissues** and **organs** as the field of histology, but histology necessarily includes much cytological matter

The science is made up of two subordinate fields, general and special histology In the former are considered the specialization of cells in the multicellular body and the characteristics and classification of the tissues in which they are grouped The details of minute structure of the organs and organ systems are the materials of the latter. This field of histology is necessarily extensive and detailed, even in the study of a single species

Histology recognizes five principal kinds of tissues, epithelium, nervous tissue, mesenchymal (connective and supporting) tissues, muscular tissue, and vascular tissue. All organs are made up of these components and further details of histology are included under the various organs and organ systems and under the topics **epithelium, connective tissue, nervous tissue, mesenchyme, cartilage, bone, muscular tissue, blood,** etc. (A W L)

HISTONES. Aminoacids, Polypeptides, and Proteins.

HISTORICAL GEOLOGY. The study and description of the origin and evolution of the earth and its inhabitants (animals and plants) The technical methods employed are included under the general term, **stratigraphy.** The outstanding events or important "chapters" in the history of the earth are outlined in the form of a geologic Time-Scale or Time-Table, as illustrated. The study of the extinct forms of life, from the earliest known **fossils** up to, but not including living species, is called **paleontology.** The history of the earth from its astral stage up to the oldest known rocks is included under the general term **cosmogony.** The numerous methods for determining the age of the earth, as well as the relative ages of geological events are included under the term **chronology,** which in turn may be considered as included under the more general term Stratigraphy. The fundamental data of geologic history are local sequences of formations, and the chronologic equivalences of formations in different regions Through correlation all formations are referred to a general time scale, of which the (fundamental) units are periods The formations made during a period are collectively designated a system The fundamental criteria used in delimiting geologic periods are (1) Unconformities, (2) Cycles of Sedimentation, (3) Index Fossils The ultimate aim of the historical geologist is paleogeography, or the reconstruction of the consecutive geographies of the past. (R M F)

GEOLOGICAL TIME SCALE

ERA = time GROUP = rocks	PERIOD = time SYSTEM = rocks	LIFE RECORD (FOSSILS) BOTH ANIMALS AND PLANTS
CENOZOIC Age of mammals and modern flora	QUATERNARY TERTIARY upper lower	Periodic glaciation and origin of man (Pleistocene) The transformation of the ape-like ancester into man may have begun in the Pliocene Culmination of mammals (Miocene) Rise of higher mammals (Oligocene). Vanishing of archaic mammals (Eocene)
MESOZOIC Age of reptiles	CRETACEOUS JURASSIC TRIASSIC	Rise of the archaic mammals in the interval between the Mesozoic and the Tertiary This ERA is remarkable for the great development of the ammonites which became extinct at the end of the Cretaceous The mollusks are more highly developed in this ERA than in the preceding one Culmination and extinction of most reptiles (Cretaceous) Rise of flowering plants (Comanchean), birds and flying reptiles (Jurassic); dinosaurs (Triassic).
Upper PALEOZOIC Age of amphibians and lycopods	PERMIAN CARBONIFEROUS	Periodic glaciation and extinction of many Paleozoic groups during and after the Permian Rise of modern insects, land vertebrates and ammonites (Permian); primitive reptiles and insects (Pennsylvanian); ancient sharks and echinoderms (Mississippian)
Middle PALEOZOIC Age of fishes	DEVONIAN SILURIAN	First known land floras (Devonian) not very different from those of the Carboniferous Earliest evidence of a terrestrial vertebrate in the form of a single footprint from the Devonian of Pennsylvania Rise of lungfishes and scorpions (first terrestrial air-breathers) in the Silurian
Lower PALEOZOIC Age of higher (shelly) invertebrates	ORDOVICIAN CAMBRIAN	Rise of nautiloids, armored fishes, land plants and corals Also the first evidence of colonial life (Ordovician) First known marine faunas; dominance of trilobites, rise of animals with hard shells or exo-skeletons (Cambrian).
PROTEROZOIC Primordial life	PRECAMBRIAN	Fossils almost unknown except for a few problematical forms in the Proterozoic. Fossils unknown in the Archeozoic.
ARCHEOZOIC Most ancient life		

NOTE Geological time-tables are so constructed as to show the oldest periods at the bottom and the youngest periods at the top *To get the proper order and sequence of events always read from the bottom to the top.* (Field, *Geology Manual,* Princeton University Press)

HISTORY AND EVOLUTION OF CHEMISTRY.

Pure Chemistry

1755 Black Studies on carbonic acid and carbonates
1766 Cavendish Discovered inflammable air (named hydrogen by Lavoisier in 1783) as a distinct subtance
1772 Rutherford Isolated nitrogen.
1774 Priestley Discovery of oxygen.
Scheele Discovery of oxygen
1776 Scheele Discovery of oxalic acid and uric acid
1777 Lavoisier Fundamental studies of combustion and of respiration
Wenzel Law of Mass Action
1778 Scheele Discovery of chlorine
1779 Scheele Discovery of glycerol
1780 Scheele Discovery of lactic acid
1781 Cavendish Showed hydrogen burns to form water
1782 Scheele Discovery of hydrogen cyanide
1782 Lavoisier First quantitative synthesis of water. Fermentation of sugar yields ethyl alcohol and carbon dioxide
1784 Charles Law of expansion of gases Pressure varies directly as the absolute temperature.
1785 Scheele Discovery of malic acid
1787 Lavoisier Classification of compounds
1791 Richter Law of neutralization of acids and bases.
1796 Lampadius Discovery of carbon disulfide
1799 Walter Discovery of picric acid
1800 Nicholson and Carlisle Quantitative electrolysis of water
1802–06 Proust-Berthollet controversy on constancy of chemical composition, Proust winning by proving the constancy
1805 Northmore Liquefaction of chlorine
1806 Proust Law of constant chemical composition
1807 Dalton Law of multiple combining proportions
Dalton Law of partial pressures of gases in mixtures
Dalton Atomic theory
Davy Isolated sodium and potassium.
Davy Electrochemical theory
1808 Gay-Lussac Law of simple combining volumes of gases
Gay-Lussac Law of expansion of gases Volume varies directly with absolute temperature
Davy. Isolated magnesium, calcium and barium
1810 Berzelius Isolated silicon
Davy Elementary nature of chlorine.
1811 Avogadro Molecular hypothesis
Berzelius System of chemical nomenclature
Berzelius Dualistic theory
1814 Frauenhofer Solar spectral lines
1815–22 Gay-Lussac Work on cyanogen
Prout Hypothesis that other elements are composed of hydrogen
Biot Optical activity of sugar solutions
1817 Arfvedson Discovery of lithium
Berzelius Exact ratios of atomic weights A revised table in 1826.
1819 Mitscherlich Isomorphism of crystals
Garden Isolated naphthalene
1821 DuLong and Petit Law of atomic heat
Cagniard de la Tour Critical phenomena of gases and liquids
1823 Faraday Liquefied chlorine, sulfur dioxide, hydrogen sulfide, carbon dioxide, ammonia, nitrous oxide, and cyanogen
1824–32 Gay-Lussac Methods of volumetric analysis.
Carnot Studies in thermodynamics
1825 Faraday Discovery of benzene and butylene.
1826 Unverdorben Discovery of aniline.
Balard Discovery of bromine
1827 Dumas Molecular weights by vapor density methods
Wohler Isolated aluminum.
1828 Wohler. Formation of urea from ammonium cyanate
1829 Dobereiner. Triads of elements.
1830 Roboquet Discovery of emulsion.
Liebig Modern combustion furnace and method for carbon and hydrogen in organic substances
1831 Dumas Method for nitrogen determination in organic compounds
Liebig Discovery of chloroform.
Leuchs Discovery of ptyalin
1832 Dumas and Laurent Isolated anthracene
Liebig First theory of radicals
Liebig and Wohler Studies on the radical, benzoyl, benzoin condensation
1832 Serullas Discovery of iodoform.
1833 Faraday. Laws of electrolysis, ions carry simple or multiple charge
1833 Mitscherlich Discovery of benzene sulfonic acid
Graham Studies on basicity of such acids as phosphoric
1834 Dumas Discovery of substitution in organic compounds
Mitscherlich Preparation of benzene and of nitrobenzene from benzoic acid
Payen and Persoz Discovery of diastase
1835 Thilorier Solidified carbon dioxide
Schwann Discovery of pepsin
1835 Dumas Quantitative synthesis of water by passing hydrogen over heated copper oxide
1836 E Davy Discovery of acetylene
Laurent Preparation of phthalic acid from naphthalene
1837 Bunsen Studies on the radical cacodyl
1840 Hess Law of constant heat summation
1840–70 Stas. Researches on atomic weights
1843 Laurent Definition of atomic and molecular equivalents
Pasteur Dextro and laevo tartrates
1844 Gerhardt and Laurent Classification of organic compounds.
1847 Dumas Preparation of acetamide
1849 Fehling Reduction of cupric salt to cuprous oxide as test for sugars
Frankland Ethyl iodide plus zinc at 150° C. yields butane.
Kolbe Electrolysis of acetates yielded ethane
1850 Wilhelmy. Studies on the rate of inversion of sucrose solutions
Hofmann. Prepared alkyl amines.
1851 Graham Diffusion, dialysis, and osmosis in solutions.
1852 Frankland Principle of valency
1852–62 Joule and Thomson. Observations of change of temperature by emergence of compressed gas through small orifice
1853 Hittorf. Migration of ions.
1853–1908 Thomsen Thermochemical investigations
1854 Wurtz Alkyl iodide plus sodium heated to yield paraffin hydrocarbon
Deville Thermal dissociation of substances
1857 Bunson Methods of gas analysis.
1858 Cannizzaro Rational symbols and formulas.
Gerlach Introduced biological stains.
Kekulé and Couper Quadrivalent carbon atom.
1859 Kirchhoff Black body radiation
Griess Discovered diazo compounds
1860 Bunsen and Kirchhoff Invention of the spectroscope; discovery of cesium
1861 Bunsen and Kirchhoff. Discovery of rubidium.
1862 Graham. Crystalloids and colloids.

1863 Reich and Richter. Discovery of indium
Fittig Aryl haloid plus sodium heated yields benzenoid hydrocarbon
1864 Guldberg and Waage Law of Mass Action
1867 Kekulé Formula of benzene, oscillation of double bond, 1872
1867–70 Meyer, L Molecular volumes and the periodic system
1868 Hofmann Determination of molecular weights by vapor displacement
Janssen and Lockyer Discovery of helium in the sun
1869 Andrews Variation of volume of carbon dioxide with change of pressure
Mendeléeff Periodicity of the elements
1869–85 Berthollet Thermochemical investigations
1873 Meyer, V Determination of molecular weights by vapor displacement
van der Waals Equation of state of gas and vapor
Maxwell Theory of electricity and magnetism
1874 Boisbaudran Discovery of gallium
Volhard Volumetric titration of silver as thiocyanate
Le Bel and van 't Hoff Stereoisomerism of tetrahedral carbon atom
1875 Gibbs, Willard The phase rule
Stoney The electron
1876 Kohlrausch Electrical conductivity of solutions
1877 Cailletet Liquefied methane, ethylene, acetylene, nitric oxide
Friedel and Crafts Organic reactions with anhydrous aluminum chloride
1878 van 't Hoff Stereochemistry of the nitrogen atom
Raoult Properties of solutions
1878–87 Ostwald Electrical conductivity of organic acids
1879 Crookes Suggested the nature of cathode rays
1880 Crookes Cathode rays
1881 van der Waals Gas equation
1883 Kjeldahl Estimation of nitrogen as ammonium in organic compounds
Wroblewski and Olszewski Liquefied nitrogen
1884 Dewar Vacuum walled flask for liquefied gases at low temperature
Le Chatelier and van 't Hoff Principles of shifting of chemical equilibrium
1885 Le Chatelier Thermocouple for measuring temperature perfected
Callender Resistance thermometer introduced
1886 Goldstein Discovery of anode rays
Moissan Isolation of fluorine
1887 Arrhenius Ionic theory of electrolytic dissociation
1888 Nernst Diffusion theory of electromotive force of solutions
1892 Le Chatelier Optical pyrometer invented
1893 Amagat Variation of the product of pressure and volume with change of pressure for gases
1893–1908 Landolt Conservation of matter in chemical reactions re-proved
Ramsay Work on the rare gases
Cleve Discovery of helium in minerals.
Roentgen Discovery of x-rays
Linde and Hampson Oxygen and nitrogen by fractionation of liquefied air
1894 Rayleigh and Ramsay Discovery of argon.
1895 Olszewski Liquefaction of hydrogen.
1896 Becquerel Radioactivity of uranium
1897 Thomson Nature of cathode rays as streams of electrons
1898 Wien Nature of anode rays
1899 Walden Investigation of active malic and chlorosuccinic acids
Curie, P. and Marie. Discovery of radium.
1900 Guye Atomic weights from gas densities
Grignard Magnesium—ether—organic halide as organic reagent
Sabatier Catalytic hydrogenation of unsaturated organic compounds
Gomberg Triphenylmethyl free radical (at least 2 aryl groups to each C)
1902 Rutherford and Soddy Spontaneous decomposition hypothesis of radioactive changes
Morse Optical pyrometer improved by use of glow lamp filament
1904 Barkla X-rays as (1) ether impulses, (2) characteristic rays
1905 Dewar Charcoal as gas absorbent at low temperature
1906 Miers Refractive index of crystallizing solution
1907 Willstatter Structure of chlorophyll
1908 Onnes Liquefaction of helium, approach to absolute zero
Rutherford and Geiger Detection and counting of single alpha particles
Millikan Precision measurements of the charge on an electron
1911 Rutherford Hypothesis of nuclear atom
Soddy Mesothorium isotopes
1912 Laue and W H and W L Bragg Structure of crystals by x-rays
1913 Thomson Spectrum of neon in anode-ray tube
Fajens, et al Alpha and beta particle shift in periodic table
1914 Moseley Atomic numbers by x-ray spectra of the elements
1917 Hull Structure of crystals by x-rays
Debye and Scherer Structure of crystals by x-rays
1919 Aston Mass-spectrograph for ascertaining the atomic weight of isotopes
Rutherford Artificial disintegration of elements
1921 Harkins and Hayes Fractionation of chlorine isotopes
Bronsted and Hevesy Fractionation of mercury isotopes
Bragg, W H Structure of naphthalene by x-rays
1923 Coster and Hevesy Discovery of hafnium
Debye and Huckel Strong electrolytes ionized completely Quantitative treatment of same
1925 Noddack, W and Ida Discovery of rhenium
1929 Paneth and Hofeditz Methyl free radical Half life 0.006 second $Pb(CH_3)_4$ in pure H_2 at 1–2 mm pressure, decomposition upon heating into Pb plus CH_3, combining CH_3 with metal mirrors on the walls of the tube beyond the heated zone
1930 Bothe and Becker Discovery of neutron
1932 Urey Discovery of deuterium
Anderson Discovery of positron
1934 Joliot, F, and Joliot-Curie, Mme Artificial radioactivity

Applied Chemistry

1620 Coal used for smelting iron ore
1635 Winthrop Survey of American chemical resources.
1650 Glauber Hydrochloric acid from sodium chloride and sulfuric acid
1746 Roebuck Chamber process for sulfuric acid
1747 Marggraf Discovered sugar in beet juice
1755 Nordhaussen Fuming sulfuric acid
1769 Coke manufactured
Watt Steam engine patent
1778 Baumé Hydrometer scale
1779 Achard Manufacture of beet sugar
1784 Cort Puddling process for wrought iron
1788 Le Blanc Soda process for conversion of sodium chloride into carbonate via sulfate and sulfide.

1792 Murdoch Manufacture of coal gas
1793 Harrison Manufacture of sulfuric acid in U S A
1800 Volta First electric battery
1801 duPont Company founded
1806 Coal gas used for lighting in U S A
1823 Braconnot Discovered guncotton
1827 Gay-Lussac Tower for absorbing nitrogen oxide gases from sulfuric acid chamber process at Chauncy, France
1828 Neilson Introduced use of hot air for iron blast furnace
1830 Kuhlmann Discovered platinum as catalyzer for ammonia oxidation
1831 Ure Fulminators as detonators
Phillips and Peregrine Patented essential details of contact process for sulfuric acid
1834 Runge Discovered phenol and pyrrole in coal tar
1836 Daniell Electric battery (copper-zinc)
de la Rive Introduced electroplating
1839 Goodyear Vulcanization of rubber
1841 Bunsen Electric battery (carbon-zinc)
1845 Hofmann Discovered aniline in coal tar
Petroleum discovered in Pennsylvania
1847 Maynard Collodion made in U S A
1850 First fertilizer plant in U S A
1853 Watt and Burgess Soda process (sodium hydroxide) for paper pulp from wood
1856 Perkin Discovered mauveine
Bessemer Steel process using air blast converter
1858 Hofmann Discovered aniline in coal tar
Hofmann Prepared rosaniline
1859 First petroleum refinery in Pennsylvania
Glover Tower for supplying nitrogen oxide gases to sulfuric acid chamber process
Plante Lead-lead dioxide storage battery
1861 Solvay Soda process for conversion of sodium chloride into carbonate by ammonium hydrogen carbonate forming sodium hydrogen carbonate
1862 Nobel Introduced dynamite
1867 Caro Prepared Bismarck brown
Tilghman Sulfite process (calcium hydrogen sulfite plus sulfurous acid) for paper pulp from wood
1868 Weldon Process for chlorine by hydrochloric acid and manganese dioxide with recovery of manganese
Pasteur Studies in acetic acid fermentation
Leclanché Dry cell electric battery
1869 Grabe and Liebermann Alizarin from anthracene
Hyatt Manufacture of celluloid at Albany, New York
1872 Baeyer Introduced fluorescein
Electrolytic copper refining begun in U S A
1873 Linde Ammonia compression refrigeration
1875 Winkler Contact process for sulfuric acid
1878 Fischer, O Introduced malachite green
1880 Deacon Process for chlorine by hydrogen chloride-air mixture over cupric salt catalyzer
1881 Brin Process for oxygen using barium peroxide
1882 Baeyer Synthesis of indigo
Edison Introduced incandescent carbon electric lamp
1884 De Laval and Parsons Steam turbine
First Solvay soda plant in U S A
1885 Welsbach Incandescent gas mantle
Bradley Heating of ores by electricity
Castner and Kellner Electrolytic process for sodium hydroxide from sodium chloride using mercury cathode
1886 Hall Electrolytic process for aluminum from oxide
Mond Nickel carbonyl for volatilizing and refining nickel
1888 Willson Manufacture of calcium carbide in electric furnace
1889 Introduction of cyanide in gold metallurgy
1890 Castner Electrolytic process for sodium from fused hydroxide
Acheson Manufacture of silicon carbide in electric furnace
1891 Chardonnet Manufacture of artificial silk at Besançon, France
Frasch Mining of sulfur by superheated water in Louisiana.
1892 Le Sueur Diaphragm type of electrolytic cell
1893 Moissan. Electric arc furnace
Moissan Silicon carbide
1894 Moissan Calcium carbide
Cross and Bevan Viscose for artificial fiber
Power plants started at Niagara Falls, N Y
1895 Hampson, Linde Liquefaction of air and fractional distillation of same
1896 Acheson Graphite from coal in electric furnace
1897 Large scale manufacture of indigo in Germany
1898 Sabatier Catalytic hydrogenation of unsaturated organic compounds
Goldschmidt Thermite reaction of aluminum powder and iron oxide for production of high temperature
Knietsch Contact process for sulfuric acid patented
Dow Electrolytic chlorine for bleaching powder
1900 Héroult Industrial smelting of steel in electric furnace
Edison Nickel-nickel dioxide storage battery
Ostwald Patented oxidation of ammonia by air using platinum catalyzer
Carbon disulfide manufactured in electric furnace
1901 First contact process sulfuric acid plant in U S A
1902 Readman and Parker Manufacture of phosphorus in electric furnace
1903 Birkeland and Eyde Electric fixation of atmospheric nitrogen in Norway
1904 Cottrell Electrostatic precipitation of fumes and smokes from gases
Betts Electrolytic refining of lead using fluosilicate
1905 Frank and Caro Cyanamide process from nitrogen and calcium carbide
Becket Pure ferroalloys by reduction of oxides by silicon
1906 De Forest Invention of radio tube detector
Hybinette Electrolytic process for refining of nickel
1908 Baekeland Phenol-formaldehyde resins and plastics
1909 Bradley and Lovejoy Electric fixation of atmospheric nitrogen at Niagara Falls, N Y
1911 Dreyfus Cellulose acetate for artificial fiber
1912 Brearley Stainless or corrosion resistant steels
Burton First cracking still for petroleum
1913 Haber Perfected process for synthesis of ammonia from nitrogen and hydrogen
Coolidge Filament x-ray tube
1914 Pyrex glass
1915 Langmuir. Production of tungsten filament
McAfee Introduced aluminum chloride anhydrous in petroleum refining
Weizmann Fermentation of starch to produce acetone and normal butyl alcohol
1916 Commercial production of artificial leathers
Mustard gas used in warfare
1919 Sperry Electrolytic process for white lead
1920 Phosphoric acid by electric furnace smelting
Downs Sodium metal by electrolysis of fused sodium chloride.

1922 Fink. Chromium plating
Sheppard and Eberlein Electrolytic deposition of rubber.
1923 Midgley Tetraethyl lead as anti-knock compound in motor fuel
1925 Ethylene glycol and related solvents made from petroleum still gases
Langmuir Welding by use of atomic hydrogen
Antioxidants for rubber
Steenbock and Hess Ultraviolet irradiation of sterols.
1925 Synthetic methanol imported into U S A
1926 Ethylene ripening of citrus fruits.
Quick freezing of foods
Regenerated cellulose films and tubes
1927 Vanadium pentoxide as catalyzer for sulfur trioxide from sulfur dioxide plus air
Synthetic methanol produced in U S A
1928 Cellulose acetate rayon produced
1930 Vinylite resins from acetylene
Commercial production of synthetic ethyl alcohol from ethylene.
1930 Recovery of iodine from California oil well brines.
Hydrogenation of petroleum at Bayway, New Jersey
1933 Synthetic rubber from acetylene
1934 Bromine from seawater at Cape Fear, North Carolina

AWARDS, MEMORIALS, AND LECTURES. Nobel Prize Awards, Perkin Medal Awards, Memorial Lectures, Faraday Lectures

Nobel Prize Awards The Nobel prize awards have been made annually beginning in 1901, five years after the death of the donor, Alfred Bernhard Nobel The amount of each prize varies with the income from the fund, but is usually about $40,000 The awards in chemistry and physics are made by the Swedish Academy of Science, Stockholm, and in physiology or medicine by the Caroline Medical Institute, Stockholm The following awards have been made.

Year	Chemistry (Most important discovery or improvement)	Physics (Most important discovery or improvement)	Physiology or Medicine (Most important discovery)
1901	J H van 't Hoff	W C Roentgen	E A von Behring
1902	Emil Fischer	H A Lorenz and P Zeeman	Sir Ronald Ross
1903	Svante Arrhenius	H Becquerel, P and Mme Curie	N R Finsen
1904	Sir Wm Ramsay	Lord Rayleigh	I P Pawlow
1905	A von Baeyer	Ph Lenard	R Koch
1906	H Moissan	J J Thomson	C Golgi and S Ramon
1907	E Buchner	A A Michelson	C L A Laveran
1908	E Rutherford	G Lippmann	P Ehrlich and E Metchnikoff
1909	W Ostwald	G Marconi and F Braun	Th Kocher
1910	O Wallach	J D van der Waals	A Kossel
1911	Marie Curie	W Wien	A Gullstrand
1912	V Grignard and P. Sabatier	Gustaf Dalen	A Carrel
1913	A Werner	H K Onnes	C Richet
1914	T W Richards	M von Laue	R Barany
1915	R Willstätter	W H Bragg and W L. Bragg	Not awarded
1916	Not awarded	Not awarded	Not awarded
1917	Not awarded	G Barka	Not awarded
1918	F Haber	M Planck	Not awarded
1919	Not awarded	J Stark	Jules Bordet
1920	Walther Nernst	C E Guillaume	A Krogh
1921	Frederick Soddy	Albert Einstein	Not awarded
1922	F W Aston	Niels Bohr	A V Hill and O Meyerhoff
1923	Fritz Pregl	R A Millikan	F G Banting and J J R McLeod
1924	Not awarded	K M G Siegbahn	W Einthoven
1925	Richard Zsigmondy	Jas Franck and Gust Hertz	Not awarded
1926	T Svedberg	Jean B Perrin	Johan Fibiger
1927	Henrich Wieland	A H Compton and C T R Wilson	J Wagner Jauregg
1928	Adolf Windaus	O W Richardson	Ch Nicolle
1929	A Harden and H von Euler-Chelpin	Duc de Broglie	F G Hopkins and C Eijkmann
1930	Hans Fischer	Raman	Karl Landsteiner
1931	Carl Bosch and Fred Bergius	No Award	Otto Warburg
1932	Irving Langmuir	Werner Heisenberg	Charles Sherrington and D Adrian
1933	Not awarded	P A M Dirac and Erwin Schroedinger	Thomas H Morgan
1934	H C Urey	No Award	G R Minot, W F Murphy and G H Whipple
1935	F Joliot and Mme Joliot-Curie	James Chadwick	Hans Spemann
1936	P J W Debye	Carl D Anderson and V G Hess	Sir Henry Dale and Otto Loewi,
1937	Walter N Haworth and Paul Karrer	Clinton J Davisson and George P Thomson	Albert von Szent-Gyorgyi

Perkin Medal Awards The Perkin medal awards have been made annually, beginning in 1906, fifty years after the discovery of the first synthetic dyestuff, mauveine, by William Henry Perkin The award is made by the Society of Chemical Industry, American Section, to a chemist residing in the United States of America, for the most valuable work in applied chemistry The work may have been done at any time during his career The selection is made by a committee representing the Society of Chemical Industry, American Chemical Society, Electrochemical Society, American Institute of Chemical Engineers, and Société de Chimie Industrielle.

The following awards have been made:

1906	Perkin, W H	1923	Whittaker, M. C.
1908	Herreshoff, J. B. F.	1924	Becket, F M.
1909	Behr, Arno	1925	Moore, H K
1910	Acheson, E G	1926	Moore, R B
1911	Hall, Charles M	1927	Teeple, John E
1912	Frasch, Herman	1928	Langmuir, Irving
1913	Gayley, James	1929	Sullivan, E C
1914	Hyatt, John W	1930	Dow, Herbert H
1915	Weston, Edward	1931	Little, A D
1916	Baekeland, L H	1932	Burgess, Charles F
1917	Twitchell, Ernest	1933	Onslager, George
1918	Rossi, A J	1934	Fink, Colin G
1919	Cottrell, F G	1935	Curme, G O, Jr.
1920	Chandler, Chas F	1936	Lewis, W K
1921	Whitney, W R	1937	Midgley, Thomas, Jr.
1922	Burton, W M	1938	Tone, F J

Chemical Society, London, See Memorial Lectures, Faraday Lectures

Memorial Lectures The memorial lectures are delivered since 1893 before the Chemical Society, London, following the death of an eminent foreign chemist These lectures furnish a valuable source of information concerning the life and work of these eminent non-British chemists The lectures have been delivered

Year	Memorial Lecture	Year	Memorial Lecture
1893	Stas	1909	Mendeléeff
1893	Kopp	1910	Thomsen
1895	Marignac	1911	Berthollet
1896	Hofmann	1912	Moissan
1896	Helmholtz	1912	Cannizzaro
	L Meyer	1912	Becquerel
1897	Pasteur	1913	van't Hoff
1898	Kekulé	1913	Ladenburg
1900	V Meyer	1920	E Fischer
1900	Bunsen	1923	Baeyer
1900	Friedel	1923	van der Waals
1900	Nilson	1927	Onnes
1901	Rammelsberg	1928	Arrhenius
1902	Raoult	1930	Richards
1905	Wislicenus	1932	Wallach
1906	Cleve	1933	Ostwald
1909	Wolcott Gibbs		

Faraday Lectures The Faraday lectures are delivered, since 1869, before the Chemical Society, London, upon invitation, by an eminent foreign chemist These lectures furnish a valuable source of information concerning the work of these eminent non-British chemists. The following lectures have been delivered.

Year	Faraday Lecturer	Title
1869	Dumas	Eulogy of Faraday
1872	Cannizzaro	Some Points on the Theoretical Teaching of Chemistry
1875	Hofmann	Liebig
1879	Wurtz	On the Constitution of Matter in the Gaseous State
1881	Helmholtz	Modern Development of Faraday's Theory of Electricity
1889	Mendeléeff	Periodic Law of the Chemical Elements
1895		Presentation of the Faraday Medal to J W. Strutt by Lord Rayleigh
1904	Ostwald	Elements and Compounds
1907	Emil Fischer	Synthetic Chemistry in Relation to Biology
1911	Richards	Fundamental Properties of the Elements
1914	Arrhenius	Theory of Electrolytic Dissociation
1924	Millikan	Atomism in Modern Physics
1927	Willstätter	Problems and Methods in Enzyme Research
1930	Bohr	Chemistry and the Quantum Theory of Atomic Constitution
1933	Debye	Relation Between Stereochemistry and Physics

(R K S)

HITCH. Pisces, Teleostei A fresh water fish of the **minnow** family found in the Coast Range. (A W L)

HIVES. Urticaria.

HOACTZIN. Fossil birds.

HOARHOUND. Mint Family.

HOATZIN, HOACTZIN. Aves, Galliformes. A peculiar South American bird (**Aves**) of doubtful relationship It lives along streams of the Amazon valley and eats fruit and other vegetation The young have a clawed digit on the margin of the wings which they use to grasp boughs in climbing (A W L)

HOBBY. Aves, Falconiformes A **falcon** of moderate size It ranges over Europe and Asia and migrates into Africa (A W L)

HOCHEUR. Guenon.

HOCK, HOUGH. The joint at the attachment of the foot and the leg in animals which walk on the toes (digitigrade or unguligrade), commonly applied to domestic animals It corresponds to the ankle joint of other species. Also the back of the human knee (A W L)

HODGKIN'S DISEASE. A disease of unknown origin characterized by non-painful enlargement of the **lymph glands** accompanied by fever, anemia, and in the later stages, wasting

The disease seems to be an infection with neoplastic manifestations Some observers believe that it is a kind of tuberculous infection As yet nothing specific is known either as to cause or treatment

The non-painful swellings of the lymph glands in various parts of the body—particularly the neck and within the chest—at first may not be accompanied by symptoms Soon, however, weakness, wasting, low blood pressure, and anemia become marked The disease usually results in death after two or three years either from secondary infections or through pressure on the **trachea** from enlarged glands

The disease may occur in an acute form, death developing in a few weeks

Palliative treatment is obtained by the use of **radium** or **X-ray** over the enlarged masses **Arsenic** is of some benefit but there is nothing known, to date, that will arrest or cure the disease (R S M)

HODOSCOPE. Cosmic Rays.

HOFMANN REACTION. Rearrangements.

HOGBACK Ridge-like topographic features, the result of the differential **erosion** of highly tilted hard and soft strata The steeper, or dip-slope, side is developed on the harder or less soluble formation, while the gentler slope is developed on the opposite side, on the softer rocks (R M P)

HOG SUCKER. Pisces, Teleostei A fish (**Pisces**) of moderate size found in clear streams in the northeastern quarter of the United States (A W L)

HOIST. Any device for lifting materials, weights, articles, etc, may be called a hoist Hoists often compose a part of other apparatus whose purpose may extend to movement of material other than vertically For example, the bridge **crane** incorporates within it a hoist for vertical lift The energy required for lifting is derived ultimately from a number of various sources For example, in the hoisting field one finds such varied power sources as compressed air, internal combustion engines, hydraulic power, steam and electric power The pneumatic drives may be either a direct lift supplied by air acting on a **piston** connected directly to the load, or it may be employed in compressed air engines, whose crankshaft is geared to the hoisting apparatus In the **internal combustion engine** type hoist, the gasoline engine is generally used for the light capacity hoist, and the **Diesel engine** for heavier hoists. It has the

advantage over other drives for portable service, such as locomotive cranes, power shovels, etc Hydraulic drives of hoisting machinery take the form of water pressure applied to a piston which slides in a long cylinder The hydraulic drive usually requires some other source of power for driving the pump required to force the water into the cylinder Hydraulic drives were once quite popular for elevators in buildings of moderate height, but the type has lost favor because of the speed of electrically driven hoists

The hoist which is driven by an electric motor is probably the type most used today It will be found in a variety of sizes ranging from the high speed passenger elevator of the tall office building to the small electrically driven chain hoist Steam as a drive for hoisting machinery is used principally for stationary hoists moving heavy loads such as mine lifts, and is used to a certain extent for portable hoisting An example in the latter class is the steam shovel

The essential parts of a hoist are a rope or chain which is wrapped around a drum or drive sheave A hook, grapnel, magnet, or other device for handling the load is attached to the free end The rotation of the drum winds up the rope, thus shortening the distance between the drum and the load If the drum is fixed in position over the load, naturally the load must be hoisted To drive the drum, one of the power supplies just mentioned is connected with the drum through a suitable speed-reducing, torque-increasing, mechanism A gear train is often used These component parts when supplied with a brake controlling the speed during lowering of weights, are the essential elements of all hoists except the direct acting The rope employed in hoists is either good quality manilla rope, or twisted steel rope Manilla is used principally for small or relatively unimportant hoists, multiple strand, greased flexible wire rope for others.

Various small hand-operated lifting devices may also be truly classified as hoists Among these might be mentioned the winch, the **capstan,** the screw jack, hydraulic jack, and the **chain block.** See **Elevators.** (F T M)

HOLLYHOCK. Mallow Family.

HOLMIUM Symbol Ho Atomic number 67 Atomic weight 163 5 Type of compound Ho_2O_3 Color of salts yellow Discovered by Cleve in 1879 A member of the **yttrium** sub-group of the rare earth metals (R K S)

HOLOCRYSTALLINE. The term applied by **petrologists** to **igneous** rocks composed entirely of **crystals;** in contradistinction to igneous rocks which are partly or entirely composed of natural glass, such as **obsidian.** (R M F)

HOLOGAMY. A type of **fertilization** of one-celled organisms in which interchange of material takes place between two cells indistinguishable from ordinary individuals Conjugation Also called macrogamy (A W L)

HOLOGONIA. Nematoda.

HOLOMETABOLA A division of the insects characterized by complete **metamorphosis** The insect as it hatches from the egg is a **larva** which differs conspicuously from subsequent stages and is adapted for a different mode of life in many species It has no compound eyes and the wings develop internally Caterpillars, grubs, and maggots are larvae of this type When fully grown the larva transforms into a **pupa.** This stage is relatively inert and in some species is incapable of movement It is often hidden in a subterranean cell or in a cocoon prepared by the larva before its transformation The adult or imago emerges from the pupa

The insects included here make up the orders **Coleoptera, Strepsiptera, Neuroptera, Mecoptera, Trichoptera, Lepidoptera, Hymenoptera, Suctoria,** and **Diptera.** (A W L)

HOLOSTEI. The **garpikes and bowfins,** a small order of the class **Pisces.** (A W L)

HOLOTHUROIDEA. The sea cucumbers, a class of the phylum **Echinodermata.**

These animals differ from other echinoderms in several particulars 1 The principal axis is elongated and the animal rests on its side 2 The body wall is soft because of the reduction of the calcareous ossicles 3 A branching respiratory tree extends from the alimentary tract into the body cavity

Sea cucumbers are used as food in the Oriental region They are dried for the market and in this form are called trepang or bêche-de-mer

The class includes five orders

Order Aspidochirota Tropical species with shield-shaped tentacles In shallow water

Order Elasipoda Benthonic species of deep water

Order Dendrochirota Shallow water species with branching tentacles

Order Molpadonia Burrowing species Tentacles unbranched or slightly branched

Order Apoda (Synaptida, Paractinopoda) Burrowing species without respiratory trees (A W L)

HOLOTRICHIDA Ciliata.

HOMOATROPINE Alkaloids

HOMOCLINE Group of strata which dip in one and the same direction Never a complete structure and usually representing the limb of an **anticline** or syncline (R M F)

HOMOGENEOUS COORDINATES. If the ratios of **coordinates** (one more than necessary) are used instead of the coordinates themselves, we have homogeneous coordinates Their use renders equations involving them homogeneous (L I S)

HOMOGENEOUS DIFFERENTIAL EQUATIONS Ordinary Differential Equations of First Order and First Degree, also **Linear Differential Equations.**

HOMOGENEOUS FUNCTIONS A homogeneous function is a type of mathematical expression, defined as follows

A **function** $f(x,y)$ is called homogeneous in x and y if $f(\lambda x,\lambda y) = \lambda^n f(x,y)$, the **exponent** n is then called the degree or order of the function (L L S)

HOMOGENEOUS SYSTEMS OF LINEAR ALGEBRAIC EQUATIONS. Linear Algebraic Equations, Systems of.

HOMOIOTHERMY. Warm-bloodedness The maintenance of a body temperature above that of the environment is common among animals, hence the usual terms warm- and cold-blooded are inaccurate Cold-blooded forms are those whose body temperature fluctuates with that of the surrounding air or water, so that the animal's activity is directly conditioned by external temperatures They are more accurately described as poikilothermal In contrast, homoiothermal animals tend to maintain a constant body temperature in spite of external fluctuations Fluctuations are normal, although the human body usually maintains a constant temperature

Only birds and mammals are homoiothermal Both regulate the body temperature by producing excess heat and by regulating its radiation from the surface Regulation is accomplished by nervous control of the blood vessels near the surface, by insulating vestiture, and by the evaporation of water from the body When the surrounding air is warm the blood flows more freely near the surface of the body and more heat is radiated but when the air is cold less blood reaches the surface and the heat is conserved In air too warm to permit adequate radiation the animal reduces its activity, exposes as much surface as possible, and either sweats or pants. The evaporation of water either from the mouth or from the sweat glands absorbs heat from the underlying tissues. Vestiture plays a passive role as an insulating

coat but it is capable of some regulation, especially in the birds. The erection of the feathers provides a thicker and looser covering of high insulating value and their depression results in less interference with radiation.

Homoiothermy is one of the highest adaptations of living things, since it provides for the maintenance of optimum conditions for the vital processes of the body. Through it the animal becomes virtually independent of one of the most important of the fluctuating environmental conditions. (A.W.L.)

HOMOLOGOUS SERIES. Two organic compounds are said to be homologous if their molecular formulas differ by CH_2, or a multiple of CH_2. (R.K.S.)

HOMOLOGY. Fundamental structural relationship based on similarity of embryological development and evolutionary history. The antithesis of analogy, which is superficial likeness based on adaptation for similar uses.

The anterior appendages of terrestrial vertebrates, for example, are regarded as fundamentally similar structures, derived from the **pentadactyl appendage,** yet they include the wings of birds, flippers of aquatic mammals, and a great variety of less extreme adaptations, including the legs of animals and the arms of man. In contrast, the wings of birds and of insects are broad thin structures used for flight but in structure and origin they show no resemblance beyond this point and so are analogous. (A.W.L.)

HOMOPLASY. More commonly designated as analogy. **Homology.**

HOMOPTERA. The **cicadas, leaf hoppers, plant lice, scale insects,** and numerous other forms, constituting a large order of insects. They have sucking mouths which differ from those of most bugs in that the slender proboscis arises from the hind margin of the head and extends back between the legs. The wings, when present, are membranous. The order includes about 16,000 species.

Many members of this order, particularly the plant lice, scale insects, and **phylloxerans,** are economically important. (A.W.L.)

HOMOSEXUALITY. Perverted sex practices among those of the same sex. (R.S.M.)

HOMOTHALLISM. Phycomycetes.

HONEY. A thick sweet liquid formed by **bees** from the nectar of flowers and to a limited extent from the juice of fruits and honey-dew. Honey contains a large percentage of simple sugars, **essential oils** of the flowers from which it is derived, and a minute amount of **formic acid** which acts as a preservative. Its flavor depends on the flowers from which it comes.

The honey produced by **honey-bees** is marketed in several forms and various grades. The lighter grades are more widely demanded for table use and the darker grades are sold for baking, candy making, and the compounding of medicines. In the United States Californian white sage honey ranks as the finest of the white honeys, with honey from orange blossoms and white and alsike clover next. Immense quantities of honey are produced from alfalfa in irrigated regions and from sweet clover in the Middle West. Both are very light in color but of poorer flavor. Dark honey comes chiefly from buckwheat, fall flowers such as goldenrod and asters, and from many plants in the southern states. Usually only the better grades of honey are produced in the small sections commonly called comb honey, but these grades and inferior honeys as well are removed from the comb and sold in jars or pails as extracted honey. A third form is chunk honey, consisting of pieces of comb honey in containers filled with extracted honey. (A.W.L.)

HONEY-BEE. Insecta, Hymenoptera. Insects of several species which live in colonies, build combs of wax secreted by the body, and in the cells of these combs raise their young and store honey and pollen. They make up the family Apidae.

A single species, *Apis mellifica,* is kept for the production of honey and wax in Europe and North America. This species was introduced into North America from Europe and is the chief species of economic importance in all parts of the world. It occurs in several varieties, including the dark German or black bee, the golden to leather colored Italian, and the gray Carniolan. Italian

Honey-bee.

bees predominate in the United States; the better strains are prolific, good-tempered, hardy, and otherwise desirable.

The honey-bee colony normally contains a single queen which may be active for three years. During the active summer season males or drones are produced in considerable numbers, but they are not tolerated in the winter or in times of scarcity of food. A strong colony for honey production also contains from 60,000 to 100,000 or more workers. The queen is the only normal female, although workers are also of this sex.

Owing to the economic importance of the honey-bee it has been observed in detail and an extensive literature has accumulated on the habits of bees, their structure, the organization of the colony, and all phases of the management of apiaries and the production and marketing of honey. (A.W.L.)

HONEY BUZZARD. Aves, Falconiformes. A bird (**Aves**) related to the eagles, named from its habit of robbing the nests of bees and wasps and eating the larvae. One species lives in Europe and Asia and others in the Oriental region. (A.W.L.)

HONEY CREEPER. Aves, Passeriformes. Small birds (**Aves**) of tropical South America and the West Indies. Related to the warblers. They visit flowers like the hummingbirds but are incapable of hovering flight. One species is called the banana-quit. (A.W.L.)

HONEY DEW. A sweet secretion produced by **plant lice.** When these insects are abundant on trees it sometimes spots the leaves and anything below the tree like a heavy dew. It is freely sought by ants and is sometimes gathered by bees, but it makes a very inferior honey. (A.W.L.)

HONEY EATER. Aves, Passeriformes. Birds of the Australian region. They have long tongues with which they secure nectar from flowers. The group includes the parson bird, the stitch bird, and several species called white eyes. (A.W.L.)

HONEY GUIDE. Aves, Piciformes. Birds (**Aves**) of several African and Oriental species. They lay their eggs in the nests of other birds and are named from their reputed habit of leading the way to nests of bees. (A.W.L.)

HONEY PECKER. Aves, Passeriformes. Small brilliantly colored birds (**Aves**) of the Oriental and Australian regions, related to the sun birds. One Australian species is called the diamond bird. (A.W.L.)

HOODOO. In geology, a columnar or pillar-like erosional remnant which has been carved and sculptured from relatively horizontal formations by the abrasion of wind driven grains of sand. The form and subsidiary

features of Hoodoos may be partly governed by joint plains and the differential hardness of the stratified sediments The term applies particularly to eccentric and peculiar forms which are especially noticeable because of their fancied resemblance to animals and *forms* artifacts. (R M F)

HOOKE'S LAW. Elasticity.

HOOKWORM. Nemathelminthes, Nematoda A minute worm which develops in the ground and lives as an adult in the human intestine, causing a disease which is also called hookworm (Uncinariasis, Ankylostomiasis) This **parasitic** disease is quite widespread and has existed for thousands of years The parasite causing the disease was not discovered until 1838 by Dubrin It is found throughout the world and is most prevalent near the equator In many countries of the world nearly 100% of the population is infected In the Southern United States it exists for the most part in the poorer rural districts There it is a serious problem Medical treatment for the elimination of the worms is available but to prevent reinfection in such climates is a difficult matter, even though the method is simply the protection of the hands and feet from contact with earth in which the worms are likely to occur

The disease is spread by hookworm ova in the feces Under favorable conditions **embryos** hatch out in the soil in one to three days Five days later in the larval stage the parasites are able to again infect humans When the skin—usually the feet—comes in contact with mud the parasites are able to infect an individual, penetrating with ease through the skin and are then carried throughout the body by the blood stream Six to eight weeks after an individual is infected eggs are passed in the feces capable of infecting others

Since these worms feed upon the blood it is to be expected that a severe **anemia** would develop with infection of large numbers of the parasites Practically all the symptoms of this disease result from the profound anemia Marked hunger accompanied by a craving for abnormal substances to eat, characterizes the disease Heavy infection in children results in stunted growth, apathy, lack of energy and low mental development

The diagnosis is made with ease by microscopic examination of the stools

The prognosis in this disease is excellent unless the disease has progressed too far Rapid recovery ensues if treatment with thymol (See **Phenol**), oil of chenopodium, or other similar drugs is used and all worms expelled from the gastro-intestinal tract Reinfection must be prevented (R S M, A W L)

HOOLOCK. Gibbon.

HOOPOE Aves, Piciformes Birds (**Aves**) of the Old World with a very high crest and a long sharp beak One species, *Upupa epops*, lives in Europe and others in the Oriental region, Africa, and Madagascar. (A W L)

HOPLOCARIDA. The mantis shrimps, Crustacea.

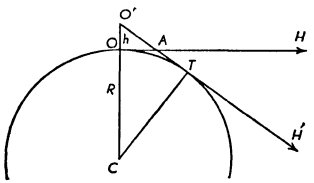
HOPLONEMERTEA. Nemertea.

HOPLOPHONEUS. Fossil mammals; and Oligocene

HOPS. Mulberry Family.

HORIZON. The visible horizon is the line where "earth and sky meet" In astronomy the term horizon is used to describe the great circle cut out on the **celestial sphere** by a plane perpendicular to the direction of **gravity** In case this plane is tangent to the surface of the earth, the horizon so described is the apparent horizon, if the plane passes through the center of the earth, we have the geocentric horizon

The difference in direction between the visible and the apparent astronomic horizon is known as the dip of the horizon In the figure, $O'H'$ represents the direction of the visible horizon from an observer at a station O' elevated above the surface of the earth by an amount h OH represents the direction of the astronomic horizon as defined above for the observer on the surface of the earth at O The angle HAH' is the dip of the horizon and may be shown to be very approximately given by the relation the dip of the horizon (expressed in minutes of arc) is equal to the square root of the height of the observer above the surface of the earth (expressed in feet) The distance



Visible and astronomical horizons

$O'T$ from the observer to the visible horizon is approximately given by The distance of the visible horizon (expressed in miles) is given by the square root of 3/2 the height of the observer above the surface of the earth (expressed in feet) This distance is frequently very much increased by an effect known as looming of the horizon, produced by **refraction** of light in heated (or cooled) layers of the air near the surface Both the expressions for the dip and distance of the horizon are applicable only when the point of observation of the visible horizon (the point T) is actually on the surface of the earth, e g the sea horizon (W K G)

HORIZONTAL COORDINATE SYSTEM The horizontal coordinate system is a system of **spherical coordinates** on the **celestial sphere** which uses the **horizon** as a fundamental plane Planes perpendicular to the horizon cut out great circles on the celestial sphere known as **vertical circles** The fundamental direction selected in the fundamental plane is true south The **azimuth** of a point on the celestial sphere is the angular distance, measured in the plane of the horizon, from the true south direction to the point of intersection of the vertical circle through the object with the horizon There are several different methods for expressing azimuth, but the astronomical method is to measure azimuth from the south through the west through 360° The **altitude** of a point on the celestial sphere is the angular distance, measured along the vertical circle through the point, from the plane of the horizon to the point

The horizontal system of spherical coordinates is frequently referred to as the altazimuth system (W K G)

HORMONE. In zoology and physiology, a hormone is a distinct chemical substance formed by one organ which acts in a specific manner on the function of another organ of the body Hormones or internal secretions are carried by the blood stream

There are many known hormones and during recent years many new ones are being discovered The formulae of some hormones are known, thus allowing synthetic hormones to be produced in the pure state. When such synthetic hormones are given to a subject, deficiency states of the **gland** can be corrected Thus in recent years a vast new field has been opened up, and an understanding of many obscure disease-conditions and their treatment will in the future be understood

Under certain conditions there occurs a diminution or absence of the internal secretion of the gland This is seen in illness, from improper development, exhaustion or tumor formation of the gland or operative removal Such a condition is called hypofunction. An example of this is seen in **myxedema** or hypothyroidism.

It is treated by giving thyroid substance by mouth or the chemical pure hormone, thyroxine, by mouth or by injection. Overactivity of a gland, or hyperfunction produces the reverse clinical picture. An example of this is hyperthyroidism which is cured by operative removal of a part of the gland. This procedure is also done in hyperinsulinism and hyperparathyroidism.

Hormones are liberated by other glands than those of the endocrine system. They are also liberated from glands that have an external secretion, as, for example the testicles, pancreas, and probably the liver. When certain substances enter the duodenum a hormone called secretion is liberated in the blood which stimulates the flow of pancreatic digestive juice into the intestine.

The principal hormones of the glands of internal secretion discovered at the present time are as follows:

(1) Pituitary hormones—See **Pituitary Gland.**
(2) Adrenal hormones
  (*a*) Medullary hormone—See **Adrenalin.**
  (*b*) Cortical hormone—Cortin $C_{20}H_{30}O_5$.
    This is used in certain deficiency states of the suprarenal glands as may be seen in **Addison's disease.**
(3) Thyroid hormone—Thyroxin—See **Thyroid Gland.**
(4) Pancreatic hormone—See **Insulin.**
(5) Gonad hormones (Produced by ovary or testicle —See **Sex Hormones**).
(6) Parathyroid hormone.

Hormones are also known to the botanist, occurring in minute quantities in various parts of the plant. Their presence, usually not where they are formed, produces very definite results. Growth substance, formed in the tips of plants, and especially in young seedlings, seems to be the cause of the great sensitiveness the plant has to light (See **Movements in Plants**). It seems to stimulate cells on the unlighted side of the plant to elongate greatly and so causes the plant to bend towards the light. Other hormones, called wound hormones, seem to be formed wherever the tissues of a plant are injured. Because of the presence of these hormones, cells in the vicinity of the wound are stimulated to rapid division, which causes tissue to form over the wound and close it. (R.S.M., R.M.W.)

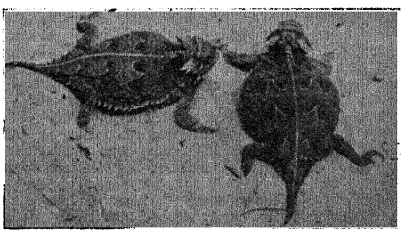
HORN. A hard translucent material formed by the development of epidermal cells containing a substance known as **keratin.** The outer layers of the skin are keratinized and the nails, claws and hoofs of mammals are formed of similar material. Horn is also developed in large amounts in the appendages of the head which go by the same name. Horns may be bony cores sheathed in horn or solid bony growths. The former occur in cattle and the latter in deer. (A.W.L.)

HORNBILL. Aves, Coraciiformes. Large birds (**Aves**) African and Oriental regions, characterized by the very large beak, in many species with a large prominence above the base of the upper mandible extending back onto the head. (A.W.L.)

HORNBLENDE. The mineral hornblende is a complex **silicate** which is probably an **isomorphous** mixture of three molecules, a **calcium-iron-magnesium** silicate, an **aluminum**-iron-magnesium silicate and an iron-magnesium silicate. Manganese and alkalies are sometimes present as is also **titanium.** It is **monoclinic,** with prismatic crystals, often pseudo-**hexagonal.** Bladed, fibrous, columnar, granular and compact massive varieties also are common. It has a perfect prismatic **cleavage;** hardness, 5–6; specific gravity, 2.9–3.4; color, green, greenish brown, brown and black; luster, vitreous to silky; transparent to opaque. Hornblende is a common constituent of many of the **igneous** rocks such as **granite, syenite, diorite,** or **gabbro,** of **gneisses** and **schists** and is the principal mineral of the **amphibolites.** **Hornblende** alters easily to **chlorite** and **epidote.** A variety of hornblende that contains little (less than 5%) of iron oxides is gray to white in color and named edenite, from its locality in Edenville, N. Y. Very dark brown to black hornblendes which contain titanium ordinarily are called basaltic hornblende from the fact that they are usually a constituent of basalts and similar rocks. Well known localities for hornblende are in Czechoslovakia, Mt. Vesuvius, Italy; Norway, Sweden and in the United States in Massachusetts, New Hampshire and New York. Black hornblende is found in Renfrew County, Canada. The word hornblende is derived from the German *horn,* and *blende,* to blind or dazzle. The term blende was often used to refer to a brilliant non-metallic luster, for example, zinc-blende. (E.C.E.S.)

HORNBLENDITE. A coarse grained rock related to **gabbro** which consists almost wholly of **hornblende. Olivine** being present, this rock may grade into a hornblende-peridotite (cortlandtite). Hornblendite is a rare rock type and of relatively little importance. (E.S.C.S.)

HORNED TOAD. Reptilia, Sauria. *Phrynosoma.* Small spiny **lizards** of the southwestern states and Mexico. They have short broad bodies and short tails, hence the confusion of terms in the **common name.** Horned lizard is a better term.



Horned toads. (Courtesy of *New York Zoological Society*)

Horned toads are desert animals and are capable of living for incredibly long periods without food or water. They cannot, however, survive for the long periods of years which have sometimes been claimed. (A.W.L.)

HORNER'S METHOD. Horner's method is a method of successive approximations for finding the approximate value of an irrational **root** of a **polynomial equation** to any desired degree of accuracy.

It may be summarized in general terms as follows: Locate the root between successive integers; the smaller integer is the integral part of the root. Now **transform** the given equation $P(x) = 0$ into another equation $P_1(x) = 0$, whose roots are those of $P(x) = 0$ diminished by the integral part of the root, so that $P_1(x) = 0$ has a root between 0 and 1. Locate this root between successive tenths; the smaller tenth is the tenths part of the root. Next, transform the equation $P_1(x) = 0$ into a new equation $P_2(x) = 0$, whose roots are those of $P_1(x) = 0$ diminished by the tenths part of the root, so that $P_2(x) = 0$ has a root between 0 and 0.1. Locate this root between successive hundredths; the smaller hundredth is the hundredths part of the root. Continue this process as far as necessary to obtain the desired degree of accuracy. Special devices may be used in the location of the root between consecutive tenths or hundredths, etc. **Synthetic division** should be used for the various transformations. (L.L.S.)

HORNET. Insecta, Hymenoptera. A name loosely applied to many of the larger **wasps,** particularly the species which build paper nests. (A.W.L.)

HORNFELS. A more or less general term applied to fine-grained, massive, and frequently speckled rock, the result of contact **metamorphism** developed in **slates** by **granitic** intrusions. (R.M.F.)

HORNSTONE. Old English synonym for **flint** and **chert.** (R.M.F.)

HORN-TAIL. Insecta, Hymenoptera. Large **saw-flies** whose **larvae** bore in the trunks of trees. The adults have a cylindrical body and in the female sex a short strong ovipositor which is the source of the name horn-tail. With this organ holes are drilled into the wood of the tree for the deposition of the eggs. (A.W.L.)

HORSE. Mammalia, Perissodactyla. Hoofed animals with a single toe on each foot, encased in a massive *hoof.* The teeth are very high crowned grinding structures. The term applies properly not only to the domestic horse, *Equus caballus*, but also to any member of the family Equidae though many of the wild species are commonly known by other names. Of these species the best known are the **zebras,** a number of species of animals marked with conspicuous stripes. The **quagga** or couagga is striped only on the anterior half of the body. Both zebras and quagga live in Africa. Wild **asses** occur in northeastern Africa and in the deserts of Asia, among them the **kiang** or kulan of Mongolia and Tibet and the **onager** or ghorkhar of western India and adjacent areas. These animals are among the fleetest and hardiest known. Two wild species of central Asia, the **tarpan** and Prejevalski's horse, *Equus przewalskii,* are most closely related to the domestic horse and probably represent the original stock from which it was derived.

Although much of the evolutionary history of the horses is known from North American fossils, no horses existed on this continent when it was discovered by Europeans and the wild horses of the west are entirely feral.

Under domestication many varieties of horses have been developed for riding, driving, draft animals and other uses. They have also been crossed with the domestic ass to produce mules for various purposes, and have been hybridized experimentally with other species. (A.W.L.)

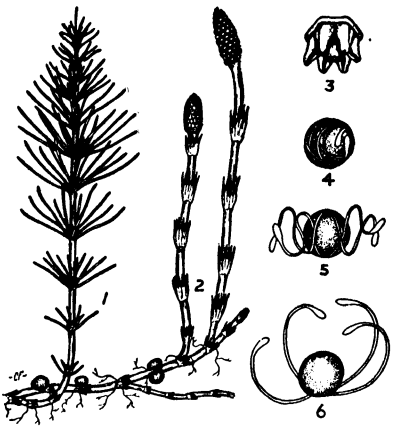
HORSEHAIR WORM. Nematomorpha.

HORSE POWER. The survival of this old unit of **power** recalls the crude beginnings of the **English system** of measures. James Watt, in seeking for a means of expressing the power of steam engines and water wheels at the dawn of the industrial revolution brought about by the extensive use of machinery, turned to the horse as a familiar source of power and one in terms of which power values would be easily comprehended. It is said that he actually experimented with horses, using the best draft animals available, and that it was as a result of his observations that the horse power has now become standardized as 550 **foot-pounds** of work per second. This is equivalent to about 746 **watts,** so that a kilowatt is approximately 1⅓ horse power. (L.D.W.)

HORSES. A term used by miners to describe fragments of the wall rock included in the ore-bearing vein. (R.M.F.)

HORSESHOE CRAB. Xiphosura.

HORSETAILS, OR SCOURING RUSHES. Equisetales. The horsetails, or Equisetales, form a small section of the **Pteridophytes.** They are erect plants of various habit. Many species have erect columnar stems and minute, scale-like leaves. Other species are much branched. In the outer part of their stems there is usually a thick deposit of silica. (See **Silicon.**) Therefore these plants were often used in early times for scouring pots and pans, and so gained their appellation of scouring rushes.



One of the horse-tails, *Equisetum arvense.* 1, a vegetative shoot; 2, spore-bearing shoots, with a portion of the rhizome and a few roots; each shoot is terminated by a strobilus; 3, a portion of the strobilus much enlarged; the small white sacs are sporangia borne on scale-like sporophylls; the powdery dark masses beneath these are composed of spores; 4, 5 and 6, spores much enlarged; in 4 the elaters are closely coiled around the spore; in 5 and 6 the elaters are partially uncoiled.

At the tips of the ordinary stems or of special reproductive stems the **sporangia** are borne. These sporangia occur beneath the edges of small umbrella-shaped stalks which are aggregated into small cones. The **spores** are all alike. Each has four long flat appendages, called elaters, which curl and uncurl with changes of humidity, causing tangled masses of spores to be liberated. The spore develops into a small, much branched **prothallus** or gametophyte. On the upper surface of the prothalli **antheridia** containing **sperms** or **archegonia** containing eggs are borne. The sperms, multiciliate spiral cells, swim to the archegonia and unite with the egg to form a **zygote.** This at once develops into a new horsetail. (See also **Paleobotany.**) (R.M.W.)

HORST. Fault.

HOST. An animal which is used as a source of food by a parasite. The parasite may live on the surface of the body or within it and may be harmless or harmful, but in all cases the host is the source of its food. (A.W.L.)

HOT-BULB. The semi-Diesel **engine** is not a true compression engine in that the instroke of the **piston** does not compress the air sufficiently so that the resulting temperature rise is high enough to cause ignition in a cold engine. The semi-Diesel engine, however, does not use electrical **ignition** in the manner of the gasoline engine. It has a hot-bulb, which is a certain mass of metal incorporated in the cylinder head in such a way that a portion of it projects slightly in the combustion space. Before starting the semi-Diesel, the hot-bulb is thoroughly heated by applying a blow torch to its exterior surface. It thus provides a focal center of high temperature which produces ignition during the starting of this type of engine. (F.T.M)

HOT WATER HEATING. Heating.

HOTWELL. A hotwell is a tank or container in which heated liquid collects. An example is the hotwell attached to and made part of a steam **condenser** of the surface type. As the steam is condensed, the condensate drops to the bottom of the condenser shell and flows into the hotwell, from which it is pumped. (F.T.M.)

HOUR ANGLE. The hour angle of a celestial object is the **spherical coordinate,** in the equatorial system of coordinates, which is measured in the plane of the celestial **equator** from the local **meridian,** in the direction of apparent rotation of the celestial sphere, to the intersection of the hour circle through the object with the equator. Since **time** and **hour angle** are practically synonymous (e.g. the hour angle of the **mean sun** is local mean time) the determination of hour angle is vitally necessary for the determination of local time and hence **longitude.**

At sea hour angle is determined by measuring the **altitude** of the object by means of the **sextant,** reducing the observed altitude to true **geocentric,** and solving the **astronomical triangle.** For the solution of the triangle both the **declination** of the object and the **latitude** of the observer must be known. The declination may be immediately obtained from the tabulated **coordinates** of the object, but the latitude can be obtained only by some previous observation. In case the ship is in motion the latitude must be obtained by **dead reckoning** from the previously determined position. (W.K.G.)

HOUR CIRCLE. Equatorial coordinates.

HOUSE FLY. Insecta, Diptera. A true **fly,** *Musca domestica,* well known for its habit of frequenting houses and alighting on all kinds of food. Since it also visits filth of any kind it is an important carrier of disease, especially typhoid fever, and has been the object of public health crusades for many years. With the improvement of sanitation the danger has been lessened, although it has not been entirely eliminated.

The house fly breeds in horse manure and in various kinds of decaying organic matter. Proper disposal of such wastes is an important measure in the control of the insect. (A.W.L.)

HOWLER. Monkey.

HUBARA. Bustard.

HÜBERNITE. Wolframite.

HUCHO. Pisces, Teleostei. A European fish (**Pisces**), *Hucho hucho,* related to the trout and salmon. (A.W.L.)

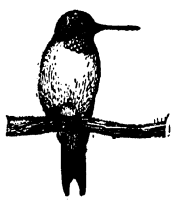
HUCKLEBERRY. Heath Family.

HUIA. Aves, Passeriformes. A New Zealand bird, (**Aves**), related to the starlings. The male has a short straight beak while that of the female is long and curved. (A.W.L.)

HUMIDIFIER. Air Conditioning and Humidity.

HUMIDITY. The most obvious way of expressing the humidity or moisture content of the **air** is to state the percentage, by weight, of water vapor in its composition. This is the absolute humidity, and can be determined by passing a measured quantity of air through a tube containing an absorbing substance which removes all the vapor and may be weighed before and after the absorption. For many purposes, however, a more useful quantity is the relative humidity, which expresses the vapor content as a fraction or percentage of the concentration necessary to render the vapor saturated at the given temperature. (See **Vapors.**) Specifically, the relative humidity of the air at any temperature is the ratio of the actual vapor pressure of the water vapor contained therein to the maximum or saturated vapor pressure of water vapor at the same temperature. At the **dew point,** the relative humidity is 100 per cent. A rise of temperature without the addition of more vapor reduces the relative humidity (but not the absolute humidity), while a fall of temperature increases it and may bring about saturation. Various forms of **hygrometer** have been devised to measure relative humidity. (L.D.W.)

HUMMINGBIRD. Aves, Micropodiformes. Small birds (**Aves**) of the New World whose wings are moved so rapidly in flight that they produce a low-pitched sound. They are capable of hovering in one spot in the air, and habitually poise before the flowers which they visit for nectar and insects. Most species of hummingbirds inhabit tropical America but they range to Patagonia and several species enter the United States. Only one, the ruby-throated hummingbird, enters the eastern states. (A.W.L.)



Ruby-throated hummingbird, *Archilochus colubris.* Shiny green above, dusky underparts, with ruby-red throat in male but not in female. Length, three and three-quarter inches.

HUMUS. Soil.

HUNTING. The tendency of rotating mechanism which normally should operate at constant speed to pulsate in speed above and below the normal point, is known as hunting. It may occur in prime movers controlled by **governors** which are too isosynchronous, or in electric apparatus where rotating and stationary parts are electrically coupled. The nature of such **coupling** is essentially elastic, and may, under certain circumstances, lead to hunting action on the part of the rotor. Governors which hunt must be corrected by the use of **dash pots** or other damping devices, and the introduction to the governor characteristic of a slight amount of speed regulation. (F.T.M.)

HUTIA. Mammalia, Rodentia. Large arboreal **rodents** of the West Indies. They resemble rats but have a blunt muzzle and a moderately long tail. Related to the coypu. (A.W.L.)

HUYGENS' PRINCIPLE. A well-known method of analysis applied to problems of wave propagation. It recognizes that each point of an advancing wave front is in fact the center of a fresh disturbance, and the source of a new train of waves; and that the advancing wave as a whole may be regarded as the resultant of the secondary waves arising from points in the medium already traversed. This view of wave propagation facilitates the study of various phenomena, such as **diffraction.** For example, if two rooms are connected by an open doorway, and sounds are produced in a remote corner of one room, a person in any part of the other will hear the sounds as proceeding from the doorway, which is indeed the case. So far as the second room is concerned, the vibrating air in the doorway is the source, and from it sound waves enlarge in all directions through the second room. The same is true of light reaching a slit or passing the edge of an obstacle, though it is not quite so easily observed because of the short wave length. The **interference** of light from variously distant areas of the moving wave front accounts for the maxima and minima observable as diffraction fringes. (L.D.W.)

HYACINTH. Lily Family; and Zircon.

HYADES. The Hyades is an open V-shaped cluster of stars in the **constellation** of **Taurus.** References to this group are to be found in all of the ancient

literatures, Virgil referring to them as the "rainy Hyades" The group is exceedingly rich in **double stars**, and even with a small telescope and low **magnifying power**, they present a beautiful appearance

The Hyades form one of the best known of the so-called moving star **clusters**. The brightest star of the Hyades, **Aldeberan**, is not a member of the cluster, but has an independent motion through space and just happens to be in its present position at this time (W K G)

HYALITE. Opal.

HYBRID. An organism produced by parents belonging to different species or to different strains of the same species A hybrid combines characteristics derived from the two parent stocks and in some cases is more desirable than either Beauty of flowers, productivity of various plants, and appearance and hardiness of animals have been enhanced by controlled **hybridization.**

When a hybrid is once secured its propagation is hampered by the fact that the diverse hereditary characters are reassorted in hereditary transmission by sexual reproduction Hybrids are often infertile but even when they are capable of producing offspring they rarely breed true The **mule** is the only animal hybrid of great value and it is produced always by parents of the two species, horse and ass Plant hybrids are not subject to this limitation for they can usually be propagated by **bulbs, cuttings,** or **grafts.** (A W L)

HYBRIDIZATION. The cross breeding of different strains or species of organisms The crossing of species is interspecific hybridization and the interbreeding of strains of the same species is intraspecific Since the differences between species are greater than variation within a species, intraspecific hybridization is rarely impossible but crosses between species are usually possible only if the species are closely related

The difficulty of making an interspecific cross is sometimes due to anatomical differences or mental reactions which prevent mating and sometimes to the failure of **germ cells** of the two species to unite normally in **fertilization** If neither of these obstacles prevents, a hybrid individual results Usually it shows some of the characteristics of each parent species A familiar example is the mule Crosses of this kind sometimes occur between closely related species in nature but most of the recorded examples have been produced under experimental conditions

Intraspecific crosses between breeds of animals and varieties of plants are constantly being carried out by animal and plant breeders for the production of new forms Among plants especially the new varieties offered each year are usually produced in this way (A W I)

HYDATID The bladderworm or cysticercus of a species of **tapeworm** (*Echinococcus granulosus*) which forms a large fluid filled cyst in the liver or other organs of the hoofed animals and man It may grow to a diameter of six inches and contains many scolices The adult lives in the dog (A W L)

HYDATOGENESIS A term used by **petrologists** to designate the process by which rocks are formed from highly aqueous solutions Some petrologists limit the use of the term to rocks which have been deposited from water-rich **magmatic** solutions (R M F)

HYDNOCERAS. Invertebrate Paleontology.

HYDRANTH. A form of individual which receives and digests food in colonies of **hydrozoan** coelenterates It is a **polyp** attached to the remainder of the colony at its base and with a mouth surrounded by a circlet of tentacles at the free end (A W L)

HYDRARGYRUM. Mercury.

HYDRARIAE. Hydrozoa.

HYDRASTINE. Alkaloids.

HYDRASTININE. Alkaloids.

HYDRATES. Water.

HYDRATUBA. The attached form, resembling a polyp, which develops from the first larval stage of some **jellyfishes.** It may bud off other similar individuals and at certain seasons is subdivided by constrictions to form **ephyrae** which become jellyfishes (A W L)

HYDRAULIC FILL. An embankment or other fill in which the materials are deposited in place by a flowing stream of water, with the deposition being selective, is termed hydraulic fill Gravity, coupled with velocity control, is used to effect the selected deposition of the material

Where **borrow pits** containing suitable material are accessible at an elevation such that, after being washed from the bank by a powerful stream from a large, high-pressure **nozzle**, the earth can be sluiced to the fill, hydraulic fill is likely to be the most economical construction Even where the elevation is not realized, the material can be washed into pools, then elevated to the **sluice** with a dredge pump In the construction of a hydraulic fill **dam**, the edges of the dam are defined by low embankments or dykes which are carried upwards as the fill proceeds The sluices are carried parallel to and just inside these dykes The sluices discharge their water-earth mixture at intervals, the water then fanning out and flowing towards the central pool which is maintained at the desired level by discharge control While flowing from the sluices, the coarse material is first deposited, then, as the central pool is reached, the water velocity is diminished and the fine materials are deposited to form an impervious central section The water flow must be well controlled at all times, otherwise the central section may be bridged by tongues of coarse material which would allow the water a free passage through the dam (F T M)

HYDRAULIC FRICTION Fluid Friction.

HYDRAULIC PRESS Hydrostatics.

HYDRAULIC RADIUS The theory of **hydraulics** indicates that the ratio of the frictional area to the thickness of the fluid stream is an important dimension governing the friction loss The hydraulic radius, which expresses this fact, is the cross-sectional area of flow divided by the wetted perimeter of a cross-section of the **conduit.** The hydraulic radius of a circular pipe flowing full of water is one-fourth of the diameter The hydraulic radius of an open canal is the cross-sectional area of the stream divided by the wetted perimeter of the cross-section excluding the length in contact with the air (F T M)

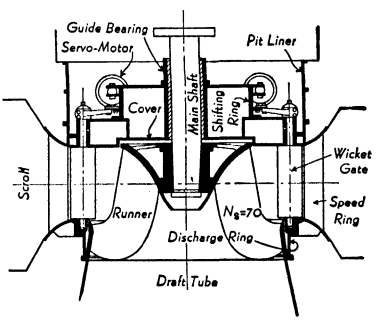
HYDRAULICS. Hydraulics is the dynamics of liquids (hydrodynamics), especially applied to the practical problems of engineering Although this general definition is entirely correct, in common usage hydraulics is the study of water at rest or in motion This conception of hydraulics is used in this article A basic proposition of hydraulics is that water is incompressible While this condition is not completely met in fact, the compressibility of water is so small as to be negligible for practically all propositions of hydraulics The viscosity of water varies with the temperature and is one reason for change of conditions of water flow in pipes with changing temperature The unit weight of fresh water is usually taken as 62 4 pounds per cubic foot

The science of hydraulics is divisible into **hydrostatics** and **hydrokinetics.** Hydrostatics is the hydro-

dynamics of liquids considered apart from their motion: hydrokinetics is the hydrodynamics of moving, especially flowing liquids. Among the subjects included in any study of hydrostatics are the following: (a) the pressure on a submerged area of any shape or inclination; (b) the measurement of pressure on water at rest by manometers or pressure gages; (c) buoyancy and flotation. Practical application of (a) is to be found in problems associated with water gates, large valves, pressure against dams, tanks, hydraulic presses, etc.

Hydrokinetics includes a great many different phases of hydraulics. Most of these will be found treated in specialized articles, references to which are given below. The flow of fluids supplies a great many cases for the application of hydraulic science. Flows of steady, uniform, unsteady and non-uniform types, and the friction losses occasioned thereby, in closed or open conduits; the measurement of flows and the discharges under given conditions, are part of this phase of hydraulics; also, there is to be considered the flow of water through openings, such as **orifices, nozzles,** and **weirs.** The flow of water in pipe lines offers a great many problems in addition to friction: the discharge through different sections of branching and looping pipes, siphons, fittings, valves, etc., are included. Measurement of discharge of large amounts of water, as in stream and river flow, offers problems different from those met in closed conduits. Furthermore, the forces occasioned by deviated flows of water, as met in hydraulic turbines, the pump, and other hydraulic machinery, are fit subjects to be included in any study of hydromechanics. See **Fluid Flow, Fluid Friction, Dams, Hydrostatics, Hydrokinetics, Flow Meter, Orifice, Weir, Hydraulic Turbine, Head.** (F.T.M.)

HYDRAULIC TURBINE. The fundamentals of the turbine were incorporated into the wheels built before the turn of the nineteenth century, but its principal development has occurred since that time. Beginning with Fourenyon and his outward flow turbine, Jonval, Boyden, Swain, and Francis rapidly brought the reaction turbine to an advanced stage of development. By 1875 the inward flow turbine, as perfected by Francis, and which now bears his name, had established itself in the lead, a position which it maintained until about 1900 when the impulse, or Pelton, type of wheel had progressed to the point of dominating the high head field.



Cross section showing component parts of a Francis turbine.

The inherent slow speed of the Francis type runner on low heads was a fault that the propeller type runner was designed to cure. During the decade 1910-1920 progress was made with this type of wheel and by 1920 the propeller type runner, often called the Nagler runner, was definitely established in the hydroelectric field. Later it was arranged so that the blades could be adjusted and set at different angles to accommodate changes in elevation of the forebay level without undue loss of efficiency. The success of the propeller type turbine encouraged American adoption of the Kaplan turbine, on which the blade adjustment is performed automatically, being under the same control as the turbine gates.

Hydraulic turbines have been built for very high heads as well as large capacities. Heads as high as 5000 feet have been utilized (3000 feet in the U. S.) and runners have been constructed to develop as much as 70,000 horsepower. At present though, a 30,000-horsepower turbine is a large one, and ordinary sizes range from 1000 to 10,000 horsepower.

As between impulse and reaction types, the action in the impulse turbine is easiest to understand. There is no difficulty in visualizing the transformation of pressure head into velocity head at the nozzle, nor of understanding the push, or impulse, that is given to the buckets by the stream of water. The jet is directed upon the rotor tangentially, and hence this type is also called the tangential turbine. The velocity of the jet of water is only slightly less than the free spouting velocity under the effective head h. Impulse buckets are divided into two halves by a "splitter" and the axial thrusts which would otherwise have to be borne by special bearings are equalized.

The essential difference between the impulse and reaction types is that, in the former the entire energy received by the wheel is in the velocity form, while in the latter it may be partially in the velocity form, but is also, in a large measure, still in the pressure form. The reaction of conversion of residual pressure into velocity in the runner is the source of much of the torque delivered to the reaction turbine. If the turbine were blocked stationary and had its gates opened, the water would issue from the turbine as from a nozzle. Now, by removing the blocking, let these nozzles begin to rotate and the absolute velocity of water leaving them is found to be diminishing, the energy having been absorbed by the runner. At the best speed the final velocity will be just sufficient to enable the water to clear the runner. At this time the wheel may be absorbing from 90% to 95% of the energy that the water had in the pressure form just before reaching the turbine gates.

Poncelet correctly stated the requirements for highest turbine efficiency, viz.:

1. Influx without shock, requiring that the relative velocity of the water be at the same angle as the vanes.
2. Efflux without whirl, requiring that the runners be so curved that velocity of whirl is completely absorbed in passing through them.
3. Flow through blades without turbulence. Smooth, curved passages without abrupt changes accomplish this.

In a Francis turbine the water flows inward, then downward and into the draft tube.

The various types of hydraulic turbines are classified according to the kind of runner each employs. This is logical because the runner is the most important part of the turbine. Turbine runners are made of bronze, plate steel, cast steel, and cast iron.

The Pelton wheel is either a solid or open disk, to the rim of which are attached buckets upon which a jet of water is played from a stationary nozzle. A horizontal shaft is the usual arrangement but vertical shaft units have also been put into operation. The advantage of using the vertical arrangement is that more than one jet can be played on the buckets; this is obtained, however, at the expense of some loss of efficiency. The Pelton wheel is overhung on the bearing and often, for additional capacity, two wheels are overhung on the same generator. Variable power demand is met by decreasing the amount of water in the jet, by deflecting the jet from the buckets, or both. Some turbines of this type have a relief jet which opens as the main jet closes. Afterwards, a **dash pot** slowly closes the relief

jet—slowly enough to prevent a large pressure rise in the penstock The same thing is also accomplished by deflecting the jet from the wheel upon loss of load, then slowly closing the valve controlling the jet

The Francis turbine is rarely a horizontal shaft machine, except in small sizes and where it is desired to avoid the expense of excavation for a vertical setting The standard runner consists of two crowns between which the buckets or blades are placed It is best adapted to vertical setting In order to pass the large discharges possible in a high **specific speed** wheel, the buckets are curved downward Some axial flow action is present in runners of high specific speed Water is admitted to the runner through guide vanes and gates

Loss of efficiency at part load is sometimes a serious fault as, for instance, where only one or two units are installed in an isolated plant The feature of the Kaplan turbine is that the blade angles and gates are adjusted simultaneously by the governor mechanism so that the blades are always in the position best suited for full utilization of the flow, through the reduction of eddying and shock losses The result is that the efficiency at part loads holds up remarkably well

Conveying the water from the **penstock** and directing the proper amount of it correctly against the runner requires first, a scroll case, second, a speed ring, and third, turbine gates

The scroll case for medium and high head development is circular in form In plan, it leads from the penstock and wraps, in spiral form, around the speed ring The cross section of the spiral at any point should be such that the water flows with uniform velocity This leads to the spiral form because the water is being delivered to the turbine uniformly around the entire circumference

The speed ring is that part of the turbine which joins the discharge ring with the turbine cover and pit liner The ribs between the top and bottom portions must be strong enough to support the dead weight above the casing, consisting of concrete, generator, and turbine rotative parts, hence the speed ring is a very important part of the turbine

Inside the speed ring and rigidly bolted to it is the inlet gate mechanism The mechanism is operated by the governor which, by opening or closing the gates, can maintain a control of speed under variable load Gates are of the guide vane type and, while various types of gates have been used, the wicket gate is in general use at the present time Its principal advantage is its efficiency Shock losses at part gate opening are reduced to a minimum in the wicket gate It is not particularly tight and has many wearing parts, most of which are bronze bushed and grease lubricated. (F T M)

HYDRAZINES, HYDRAZONES AND OSAZONES. Hydrazine ($H_2N\ NH_2$) is a colorless, fuming liquid, melting point 1° C, boiling point 113° C, when heated to about 350° C decomposes into **nitrogen** and **ammonia,** burns when ignited in air with violet colored flame, forms hydrate with water ($H_2N\ NH_2\ H_2O$), which hydrate yields hydrazine and water in a vacuum or upon heating moderately, and at about 180° C nitrogen and ammonia Hydrazine is a base, slightly weaker than **ammonium** hydroxide, and forms two series of salts (a) hydrazine monohydrochloride ($H_2N\ NH_2\ HCl$), mononitrate ($H_2N\ NH_2\ HNO_3$), hemisulfate ($H_2N \cdot NH_2\ ½H_2SO_4$), (b) hydrazine dihydrochloride ($H_2N \cdot NH_2\ 2HCl$), dinitrate ($H_2N\ NH_2\ 2HNO_3$), monosulfate ($H_2N\ NH_2\ H_2SO_4$), all soluble in water except the last Hydrazine azide ($H_2N\ NH_2\ HN_3$) is a soluble solid, melting point 65° C Hydrazine hydrate attacks glass, rubber, cork, and therefore silver vessels are preferred in its manipulation

Hydrazine may be made by converting one-half of a given amount of ammonia into chloramine (NH_2Cl) by sodium **hypochlorite** solution in the presence of a **colloid** such as glue or gelatine, by heating The remaining one-half of ammonia reacts with chloramine to form hydrazine The product is then cooled to 0° C and **sulfuric acid** added in amount to react with the hydrazine to form hydrazine monosulfate ($H_2N\ NH_2\ H_2SO_4$), insoluble solid, melting point 254° C ($H_2N\ NH_2\ ½H_2SO_4$ is soluble in water)

Hydrazine is a powerful reducing agent, for example, **cupric** salt solutions changed to **cuprous** oxide, silver salt solutions to **silver,** mercuric salt solutions to **mercury, sulfur trioxide** to sulfur sesquioxide (S_2O_3)

DIAGRAM SHOWING RELATIONSHIP OF HYDRAZINES

	PRIMARY	SECONDARY	TERTIARY	QUATERNARY
1 Hydrazine M P 1° C B P 113° C.	2 Phenylhydrazine M P 20° C B P. 243° C	3 1,1-diphenylhydrazine M P 34° C	5 Triphenylhydrazine M P 142° C	6 Tetraphenylhydrazine M P 148° C.
		4 1,2-diphenylhydrazine (Hydrazobenzene) M P 131° C		
	7. Methylhydrazine B P 87° C (745 mm)	8 1,1-dimethylhydrazine B P. 81° C (747 mm)		
		9 1,2-dimethylhydrazine B P 62° C. (717 mm)		

DIAGRAM SHOWING RELATIONSHIP OF HYDRAZINES—*Continued*

	Other Hydrazines	Formula	Melting Point ° C	Boiling Point ° C.
10	Ethylhydrazine	$C_2H_5NHNH_2$		100 (710 mm)
11	Diethylhydrazine	$(C_2H_5)_2NNH_2$		97
12	1,2-Diethylhydrazine	$C_2H_5NH\ NHC_2H_5$		
13	1,1-Ethylphenylhydrazine	C_2H_5 C_6H_5 >NNH_2		237
14	1,2-Ethylphenylhydrazine	$C_2H_5NH\cdot NHC_6H_5$		
15	Benzylhydrazine	$C_6H_5CH_2NHNH_2$	26	135 (30 mm)

Phenylhydrazine is a colorless liquid, slightly soluble in water, miscible in all proportions with alcohol or ether, forms salts with acids, e g, phenylhydrazine hydrochloride ($C_6H_5NH\ NH_2\ HCl$) melting point 241° C approx, is a powerful reducing agent, with alkaline **cupric** salt solution (Fehling's solution) yields cuprous oxide precipitate, reacts with carbonyl group (= CO) of **aldehydes** or **ketones** yielding phenylhydrazones, white solids, of definite melting point and utilized in identification of aldehydes and ketones, e g, acetaldehyde phenylhydrazone ($CH_3CH\ NNHC_6H_5$)

Phenylhydrazone of	Melting Point ° C	Boiling Point ° C
Acetaldehyde	99	236 (20 mm)
Acetone	27	163 (50 mm)
Acetophenone	105	
Benzaldehyde	155	
Benzophenone	137	
Benzoin, alpha	156 appr	
Benzoin, beta	106	
d-Glucose, alpha	159	
d-Glucose, beta	140	
l-Arabinose	152	

Phenylhydrazines, as hydrochloride solution plus **sodium** acetate react with polyhydroxy aldehydes or ketones yielding osazones or diphenylhydrazones, yellow solids, of definite melting point and utilized in identification of sugars, e g, phenyl-d-glucosazone ($CH_2OH(CHOH)_3C\ (NNHC_6H_5)CH\ (NNHC_6H_5)$) plus aniline ($C_6H_5NH_2$) plus ammonia Glucose and fructose yield identical osazones, melting point 205° C decom The specific rotatory power of the osazone is also an important consideration

Osazone of	Melting Point ° C.
Glucose	205
Fructose	205
Mannose	205
Galactose	214
Maltose	205
Lactose	200
Arabinose	167
Xylose	115–158
Sacrose (none)	
Raffinose (none)	

Attention should be directed to the difference between osazones and osones An osone is formed by reaction of an osazone with hydrochloric acid, e g, glucosone ($CH_2OH(CHOH)_3CO\ CHO$)

Phenylhydrazine is made by reduction of benzene diazonium chloride ($C_6H_5N_2Cl$) by **stannous** chloride ($SnCl_2$) plus **hydrochloric acid**, the **diazonium** chloride being formed by reaction of **aniline** and **nitrous acid** cold

1,1-Diphenylhydrazine is a white solid, slightly soluble in water, soluble in alcohol or ether, forms salts with acids, is a reducing agent, reacts with aldehydes or ketones yielding 1,1-diphenylhydrazones, and with polyhydroxy aldehydes or ketones yielding osazones, of definite melting point. 1,1-Diphenylhydrazine is made by reduction of diphenylnitrosamine ($(C_6H_5)_2N\ NO$) by zinc plus acetic acid, the nitrosamine being formed by reaction of diphenylamine ($(C_6H_5)_2NH$) and nitrous acid

1,2-Diphenylhydrazine (hydrazobenzene) is a white to pale yellow solid, very slightly soluble in water, soluble in alcohol or ether, upon standing or upon heating changes into azobenzene, red to orange, solid, melting point 68° C, the hydrogens of the amino groups (= NH) are replaceable by acetyl (CH_3CO—) or nitroso (NO—) groups as for secondary **amines.** 1,2-Diphenylhydrazine reacts (1) with oxidizing agents, e g, **ferric** chloride or air to form azobenzene, (2) with strong reducing agents, e g, **sodium** amalgam, to form aniline, (3) with strong acids, to form **benzidine** hydrochloride ($(4')H_2N\ C_6H_4\ C_6H_4\ NH_2(4)\ HCl$) 1,2-Diphenylhydrazine is formed by reduction of **nitrobenzene** by zinc plus **sodium** hydroxide solution

Tetraphenylhydrazine is a white solid, soluble in chloroform, acetone, benzene, or toluene, and upon standing is changed into triphenylamine plus azobenzene In solution, tetraphenylhydrazine dissociates into nitrogen **diphenyl** ($(C_6H_5)_2N$), free **radical,** which in toluene at 90° C reacts with nitric oxide (NO) Tetraphenylhydrazine is formed by oxidation of diphenylamine ($(C_6H_5)_2NH$) by lead dioxide (R K S)

HYDRAZOATES. Hydrazoic Acid and Azides.

HYDRAZO-COMPOUNDS. Aniline, and Azo-, Diazo- and Related Compounds; and **Hydrazines.**

HYDRAZOIC ACID AND AZIDES. Hydrozoic acid (HN_3) is a colorless, odorous, poisonous liquid, boiling point 37° C, soluble in water, volatile in steam, made anhydrous by removal of water from 91 per cent hydrazoic acid by **calcium** chloride, explosive Hydrazoic acid reacts (1) with metals, e g, magnesium, aluminum, zinc, iron, to form azides or hydrazoates (or trinitrides), (2) with heavy metal salt solutions to form insoluble azides, e g, silver azide (AgN_3), mercurous azide (HgN_3), lead azide (PbN_6) Silver, mercurous, **cuprous** azides decompose in the light to form nitrogen gas plus the metal Lead azide is used as a detonator for the **explosive** trinitrotoluene (T N T), (3) with **ammonium** hydroxide, to form ammonium azide ($NH_4\ N_3$), (4) with **hydrazine,** to form hydrazine azide ($N_2H_4\ HN_3$), (5) with **sodium** hypochlorite plus **acetic acid,** to form chlorazide (ClN_3), explosive, (6) with sodium amalgam (sodium dissolved in mercury), to form **ammonia** mainly (and some hydrazine), (7) with **potassium** permanganate, to form **nitrogen** gas plus water

Hydrazoic acid is formed (1) by reaction of ethyl or amyl **nitrite** in sodium hydroxide solution (sodium azide

formed), then acidifying with dilute **sulfuric acid** and distilling Hydrazoic acid is recovered mainly in the early portion of the condensate, (2) by reaction of ammonia gas and sodium metal heated to about 300° C (sodamide formed), and then treating the residue with dry nitrous oxide gas at about 200° C The product is dissolved in water, then acidified and distilled as above

The azide group (—N_3) resembles the halogen groups (—Cl, —Br, —I) in several reactions, and in the properties of several compounds

Soluble azides react with **ferric** salt solutions to produce a red color, similar to that of ferric **thiocyanate.** Sodium azide is not explosive, even on percussion, and nitrogen may be evolved upon heating With **iodine** dissolved in ether cold, silver azide forms iodine azide (IN_3), yellow explosive solid

Ester methyl azide (CH_3N_3), boiling point 20° C, explosive when heated to about 500° C (R K S)

HYDRAZONES. Hydrazines, Hydrozones, and Osazones, and **Azo-, Diazo- and Related Compounds.**

HYDRIDES. Hydrides are binary compounds of **hydrogen** and some other element (R K S)

HYDRIODIC ACID AND IODIDES. Hydriodic acid (HI) is a colorless solution formed when hydrogen iodide gas is dissolved in water, commercially of strength 10% HI, frequently colored brown by **iodine** There is a maximum constant boiling point 127° C (774 mm) at 57% HI (distillate) for mixtures of hydriodic acid Hydriodic acid is used in the preparation of iodides, and as an important reagent in organic chemistry

All metallic iodides except **silver** iodide, **mercurous** iodide, mercuric iodide, **lead** iodide, **cuprous** iodide, **thallium** iodide, and **palladium** iodide, are soluble The iodides of **antimony, bismuth, tin** require a little free acid to keep them in solution

Dilute hydriodic acid reacts with hydroxides, oxides, carbonates, sulfides, metals in a manner chemically analogous to dilute **hydrochloric acid**, with solutions of some salts, e g, silver nitrate, to yield the corresponding iodide, e g, silver iodide, precipitate Higher strengths of hydriodic acid react with oxygen of the air upon standing to yield free iodine, which imparts a brown color to the solution, thus indicating the reducing character of the acid

Hydriodic acid is made by the reaction (1) of iodine and **hydrosulfuric acid** (or **sulfurous acid**), (2) of **phosphorus** plus iodine plus water, with subsequent distillation in all cases

Two common tests for iodides are as follows

1 Silver nitrate produces a yellow precipitate insoluble in **nitric acid**, slightly soluble in **ammonia** and soluble in **potassium** cyanide and **sodium** thiosulfate

2 On treatment with **chlorine** water and shaking with **carbon disulfide** a violet color due to free iodine is produced in the carbon disulfide layer (R K S)

HYDROBIOLOGY. Limnology.

HYDROBROMIC ACID AND BROMIDES. Hydrobromic acid (HBr) is a colorless solution formed when hydrogen bromide gas is dissolved in water, commercially of strength 48% HBr Sometimes colored yellow to red by **bromine** There is a maximum constant boiling point 126° C (760 mm) at 48% HBr (distillate) for mixtures of hydrobromic acid and water Hydrobromic acid is used in the preparation of bromides, and as an important reagent in organic chemistry

Dilute hydrobromic acid reacts with hydroxides, oxides, carbonates, sulfides, metals in a manner chemically analogous to dilute **hydrochloric acid**, with solutions of some salts, e g, silver nitrate, to yield the corresponding bromide, e g, **silver** bromide, precipitate Higher strengths of hydrobromic acid react with oxygen of the air upon standing to yield free bromine, which imparts a yellow to red color to the solution, thus indicating the reducing character of the acid

Hydrobromic acid is made by the reaction (1) of **phosphorus** tribromide and water, (2) of bromine and **sulfurous acid** (or hydrosulfuric acid), with subsequent distillation in all cases

Metallic bromides except silver bromide and mercurous bromide are soluble in water, but **lead** bromide, **cuprous bromide** and thallium bromide are only slightly soluble

Two common tests for bromides are as follows:

1 Silver nitrate produces a yellow precipitate insoluble in nitric acid and soluble in **ammonia, potassium** cyanide, and **sodium** thiosulfate

2 On treatment with **chlorine** water and shaking with **carbon disulfide** a brown coloration due to free bromine appears in the **carbon disulfide** layer (R K S)

HYDROCARBONS. Hydrocarbons are compounds of **carbon** and **hydrogen** only They possess, as a whole, a considerable range of properties This is illustrated by the following selections·

SELECTED REPRESENTATIVE HYDROCARBONS

Hydrocarbon	Physical State	Density	Melting Point, °C.	Boiling Point	Solubility in		
					Water	Alcohol	Ether
1 Methane	Gas	Air = 1 00 0 56	−184	−161	Slight	Solub	Solub
2 Ethane	Gas	1 36	−172	−88	Slight	Solub.	Solub.
3. Ethylene .	Gas	0 98	−169	−104	Mod Slight	Solub.	Solub.
4 Acetylene.	Gas	0 91	−82	−84	Very Slight	Solub.	Solub.
5 Normal-hexane	Liquid	Water = 1 000 0 661	−94	69	Insol.	Solub.	Infin.
6 Cyclohexane	Liquid	0 779	6 5	81	Insol.	Infin	Infin.
7. Benzene .	Liquid	0 878	5 5	79 6	Insol.	Infin	Infin.
8 Toluene	Liquid	0 866	−95	110 5	Insol.	Infin.	Infin.
9 Cymene ..	Liquid	0 857	−73 5	176	Insol.	Solub.	Solub.
10. Limonene	Liquid	0 842	−97	177	Insol	Infin	Infin.
11 Pinene	Liquid	0 878	−55	154	Very Slight	Infin.	Infin.
12 Biphenyl ...	Solid	1 041	69	255	Insol.	Mod Solub	Solub.
13. Diphenylmethane.	Solid	1 006	27	262	Very Slight	Solub.	Solub.
14 Naphthalene .	Solid	1 145	80	218	Insol.	Slight	Solub
15 Anthracene .	Solid	1 25	218	342	Insol	Insol	Very Slight

These particular hydrocarbons (in the table on preceding page) are characterized as to:

1 Density: The four gases, from 0 56 (methane) to 1 36 (ethane) (Air = 1 00) and other hydrocarbon gases above 1 36, e g, normal-butane 2 05
The seven liquids, from 0 661 (normal-hexane) to 0 878 (benzene, pinene) (water = 1 000).
The four solids from 1 006 (diphenylmethane) to 1 25 (anthracene) (water = 1 000)
2. Melting point. From —184° (methane) to 218° C (anthracene)
3 Boiling point From —161° (methane) to 342° C (anthracene)
4 Solubility in water Practically insoluble, except ethylene.
5 Solubility in alcohol Soluble, except naphthalene, anthracene.
6 Solubility in ether Soluble, except anthracene

Further remarks on solubility· In **acetone, acetylene** is very soluble In **chloroform,** cymene is very soluble Other solvents of note are **carbon tetrachloride, carbon disulfide.** Hydrocarbons, speaking generally, are soluble in each other.

BEHAVIOR ON TREATMENT WITH BROMINE (IN CCl_4)

Hydrocarbon	No Gas Evolved but red color disappears	Hydrogen Bromide Evolved and red color disappears (white fog when breathed upon)	No Change
1 Methane			√
2. Ethane			√
3 Ethylene	√		
4 Acetylene	√		
5 Normal-hexane			√
6 Cyclohexane			√
7 Benzene		√	
8 Toluene		√	
9 Cymene		√	
10 Limonene	√		
11 Pinene	√		
12 Biphenyl		√	
13 Diphenylmethane		√	
14 Naphthalene		√	
15 Anthracene		√	

In general, on treatment with **bromine** in **carbon tetrachloride,** and warming.

1 Unsaturated hydrocarbons cause disappearance of the red color and no gas evolved Reaction is addition, e g, ethylene forms ethylene dibromide, acetylene forms acetylene tetrabromide
2 Benzenoid hydrocarbons cause disappearance of the red color and white fog, when breathed upon, of **hydrogen bromide.** Reaction is substitution,—bromination, e g, toluene forms chlorotoluene (ortho or para, or both)
3 Saturated hydrocarbons, chain or cyclic, cause no change, e g, normal-hexane, cyclohexane
4 Chlorine behaves similarly to bromine.

BEHAVIOR ON TREATMENT WITH FUMING SULFURIC ACID (AT ROOM TEMPERATURE)

Hydrocarbon	Soluble, Heat Evolved	No Change
1. Methane		√
2 Ethane		√
3. Ethylene	√	
4 Acetylene	√	
5. Normal-hexane		√
6 Cyclohexane		√
7. Benzene	√	
8. Toluene	√	
9 Cymene	√	
10 Limonene	√	
11. Pinene	√	
12 Biphenyl	√	
13. Diphenylmethane	√	
14. Naphthalene	√	
15. Anthracene	√	

With **sulfuric acid** fuming.

1. Unsaturated hydrocarbons react. Reaction is addition, e g, **ethylene** forms ethyl hydrogen sulfate, or reaction is **polymerization,** e g, pinene.

2. Benzenoid hydrocarbons react Reaction is substitution,—sulfonation, e g, **naphthalene** forms naphthalene sulfonic acid (alpha or beta, or both, or disulfonic acid)

3 Saturated hydrocarbons, chain or cyclic, cause no change, e g, normal-hexane, cyclohexane

BEHAVIOR ON TREATMENT WITH FUMING NITRIC ACID (AT ROOM TEMPERATURE)

Hydrocarbon	Soluble, Heat Evolved	No Change
1 Methane		√
2 Ethane		√
3 Ethylene	√	
4 Acetylene	√	
5 Normal-hexane		√
6 Cyclohexane		√
7 Benzene	√	
8 Toluene	√	
9 Cymene	√	
10 Limonene	√	
11 Pinene	√	
12 Biphenyl	√	
13 Diphenylmethane	√	
14 Naphthalene	√	
15 Anthracene	√	

With **nitric acid** fuming.

1 Unsaturated hydrocarbons react Reaction is addition, e g, pinene and limonene to form nitrosites and nitrosates, cleavage frequently occurs at the unsaturated bond.

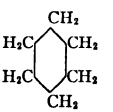
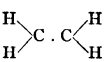
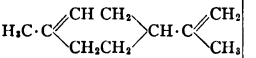
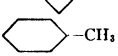
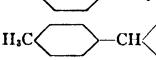
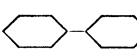
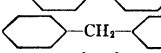
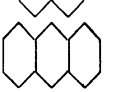
2. Benzenoid hydrocarbons react. Reaction is substitution—nitration, e g, toluene forms nitrotoluene (mono-, 1,2 or 1,4, or di- 1,2,4 or 1,2,6, or tri- 1,2,6), **oxidation** frequently occurs, e g, **anthracene** forms anthraquinone.

3 Saturated hydrocarbons, chain or cyclic, cause no change, e g, normal-hexane, cyclohexane, secondary and tertiary hydrocarbons moderately easily oxidized to **ketones** and tertiary **alcohols,** respectively.

The most important hydrocarbons are classified in accordance with their composition as follows:

CLASSIFICATION OF HYDROCARBONS

(Upon Basis of Composition)

Class	Examples	Individual Formula	Structural Formula	Class Formula
1. Paraffin	Methane	CH_4		C_nH_{2n+2}
	Ethane	C_2H_6	$H_3C \cdot CH_3$	
	Normal-hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$	
2. Cycloparaffin	Cyclohexane	C_6H_{12}		C_nH_{2n}
3. Olefin (one double bond)	Ethylene	C_2H_4		C_nH_{2n-4}
4. Cyclo-diolefin	Limonene	$C_{10}H_{16}$		C_nH_{2n-4}
5. Acetylene (one triple bond)	Acetylene	C_2H_2	$HC \vdots CH$	C_nH_{2n-2}
6. Benzenoid	Benzene	C_6H_6		C_nH_{2n-6}
(*a*) one ring	Toluene	C_7H_8		
	Cymene	$C_{10}H_{14}$		
(*b*) two rings or more, not doubly adjacently interlocked	Biphenyl	$C_{12}H_{10}$		C_nH_{2n-14}
	Diphenyl methane	$C_{13}H_{12}$		
(*c*) two rings or more, doubly adjacently interlocked	Naphthalene	$C_{10}H_8$		C_nH_{2n-12}
	Anthracene	$C_{14}H_{10}$		C_nH_{2n-18}

The most fundamental classification on the basis of reactivity appears to be into benzenoid and non-benzenoid (and mixed, e g, toluene, which in many reactions behaves as a benzenoid, but in some others as a non-benzenoid hydrocarbon).

CLASSIFICATION OF HYDROCARBONS
(Upon Basis of Reactivity)

	Paraffin Class			Melting Point	Boiling Point °C.
1	Methane	CH_4			−161
2	Ethane	C_2H_6	$H_3C\ CH_3$		−88
3	Propane	C_3H_8	$CH_3\ CH_2\ CH_3$		−45
4	Normal-butane	C_4H_{10}	$CH_3(CH_2)_2CH_3$	−135	0 6
5.	Iso-butane (2-Methylpropane) (Trimethylmethane)	C_4H_{10}	$(CH_3)_3CH$	−145	−10
6	Normal-pentane	C_5H_{12}	$CH_3(CH_2)_3CH_3$		36
7.	Tetramethylmethane (2,2-Dimethylpropane)	C_5H_{12}	$(CH_3)_4C$		9 5
8	Normal-hexane	C_6H_{14}	$CH_3(CH_2)_4CH_3$		69
9.	Normal-heptane	C_7H_{16}	$CH_3(CH_2)_5CH_3$		98
10	Normal-octane	C_8H_{18}	$CH_3(CH_2)_6CH_3$		125
11	Normal-nonane	C_9H_{20}	$CH_3(CH_2)_7CH_3$		150
12	Normal-decane	$C_{10}H_{22}$	$CH_3(CH_2)_8CH_3$		174
13	Hexacontane	$C_{60}H_{122}$	$CH_3(CH_2)_{58}CH_3$	101	
	Mixed Paraffin-Benzenoid Class				
14	Toluene and successors (see benzenoid)				
15	Bibenzyl	$C_{14}H_{14}$	$C_6H_5CH_2CH_2C_6H_5$	52	284
16	Diphenyl methane	$C_{13}H_{12}$	$(C_6H_5)_2CH_2$	27	262
17	Triphenyl methane	$C_{19}H_{16}$	$(C_6H_5)_3CH$	92	359
18	Tetraphenyl methane	$C_{25}H_{20}$	$(C_6H_5)_4C$	282	431
19.	Tetraphenyl ethane	$C_{26}H_{22}$	$(C_6H_5)_2CH\ CH(C_6H_5)_2$	209	383
	Cycloparaffin Class				
20	Cyclopropane (Trimethylene)	C_3H_{63}	$(CH_2)_3$		−34 (750 mm)
21	Cyclobutane	C_4H_8	$(CH_2)_4$		12 (725 mm)
22	Cyclopentane	C_5H_{10}	$(CH_2)_5$		50
23	Cyclohexane	C_6H_{12}	$(CH_2)_6$		81
24	Cycloheptane	C_7H_{14}	$(CH_2)_7$		118
	Dicycloparaffin Class				
25	Camphane	$C_{10}H_{18}$	$CH_3\ C_7H_9(CH_3)_2$	152	160
	Olefin Class				
26	Ethylene	C_2H_4	$H_2C\ CH_2$		−104
27	Propylene	C_3H_6	$CH_3CH\ CH_2$		−48
28	Alpha-butylene (1-butene)	C_4H_8	$CH_3CH_2CH\ CH_2$		−5
29	Beta-butylene (2-butene)	C_4H_8	$CH_3CH\ CHCH_3$		1
30	Iso-butylene (Methylpropene)	C_4H_8	$(CH_3)_2C\ CH_2$		−6
31	Normal-amylene (alpha)	C_5H_{10}	$CH_3(CH_2)_2CH\ CH_2$		40
32	Normal-amylene (beta)	C_5H_{10}	$CH_3CH\ CHC_2H_5$		36
33	Iso-amylene (alpha)	C_5H_{10}	$(CH_3)_2CHCH\ CH_2$		25
34	Iso-amylene (beta)	C_5H_{10}	$(CH_3)_2C\ CHCH_3$		38
35	1-Hexene	C_6H_{12}	$CH_3(CH_2)_3CH\ CH_2$		64
36	1-Heptene	C_7H_{14}	$CH_3(CH_2)_4CH\ CH_2$		99
37	Melene	$C_{30}H_{60}$			380
38	Tetramethyl ethylene	C_6H_{12}	$(CH_3)_2C\ C(CH_3)_2$		73
	Mixed Olefin Benzenoid Class				
39	Phenyl ethylene (styrene)	C_8H_8	$C_6H_5CH\ CH_2$		146
40	Propenyl benzene	C_9H_{10}	$C_6H_5CH\ CHCH_3$		175
41	Sym-diphenyl ethylene (stilbene)	$C_{14}H_{12}$	$C_6H_5CH\ CHC_6H_5$	124	
	Cyclo-olefin Class				
42	Cyclobutene	C_4H_6	$CH_2CH_2CH : CH$		3
43	Cyclopentene	C_5H_8	$CH_2CH_2CH_2CH\ CH$		45
44	Cyclohexene	C_6H_{10}	$CH_2CH_2CH_2CH_2CH\ .\ CH$		
45.	Cycloheptene (suberene)	C_7H_{12}	$CH_2CH_2CH_2CH_2CH_2CH : CH$		114

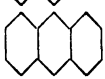
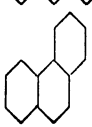
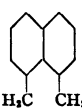
CLASSIFICATION OF HYDROCARBONS—*Continued*

(Upon Basis of Reactivity)

Paraffin Class			Melting Point	Boiling Point °C
Diolefin Class				
46 Allene (propadiene)	C_3H_4	$CH_2 \cdot C \cdot CH_2$	−32	−3
47. Bivinyl (1,3-butadiene) (biethylene)	C_4H_6	$CH_2 \quad CH \quad CH \cdot CH_2$		
48. Biallyl (1,5-hexadiene)	C_6H_{10}	$CH_2 \quad CHCH_2CH_2CH \cdot CH_2$		60
49 Isoprene (3-methyl-1, 3-butadiene)	C_5H_8	$CH_2 \cdot CHC(CH_3) \cdot CH_2$		34
Cyclo-diolefin Class				
50 Cyclohexadiene (1,2)	C_6H_8			78 5
51 Cyclohexadiene (1,3)	C_6H_8			80 5
52. Cyclohexadiene (1,4)	C_6H_8			85 5
53 Limonene . . (1-methyl-8(9)-isopropylenecyclohexene-1)	$C_{10}H_{16}$	$(1)CH_3 \cdot C_6H_8 \cdot C_3H_6(4)$		177
Dicyclo-olefin class				
54. Alpha-pinene (2,7,7-trimethylbicyclo[3 1 1] heptene-2)	$C_{10}H_{16}$	$(2)CH_3 \cdot C_7H_7(CH_2)_2(7,7)$		154
55 Camphene (1,1-dimethyl-3-methylene-bicyclo[2 2 1]heptane)	$C_{10}H_{16}$	$(1)CH_2 \quad C_7H_8(CH_2)_2$	50	160
56 Terpenes (discussed below along with cycloölefin hydrocarbons)				
Acetylene Class				
57 Acetylene	C_2H_2	$CH \cdot CH$		−84
58 Methyl acetylene (allylene)	C_3H_4	$CH_3C : CH$		−27
59 Ethyl acetylene	C_4H_6	$CH_3CH_2C : CH$		19
Mixed Acetylene Benzenoid Class				
60. Sym-dimethyl acetylene . (crotonylene)	C_4H_6	$CH_3C : CCH_3$		29
61 Phenyl acetylene	C_8H_6	$C_6H_5C : CH$		142
62 Sym-diphenyl acetylene (tolane)	$C_{14}H_{10}$	$C_6H_5C \cdot CC_6H_5$	60	300
Diacetylene Class				
63 Biacetylene (Butadiyne)	C_4H_2	$CH : CC : CH$		
64 Bipropargyl (1,5-hexadiyne)	C_6H_6	$CH : CCH_2CH_2C : CH$		85
Benzenoid Class				
(*a*) one ring				
65 Benzene . .	C_6H_6	$(CH)_6$	5 5	79 6
66 Toluene .	C_7H_8	$C_6H_5 \cdot CH_3$	−95	110 5
67. Ortho-xylene ..	C_8H_{10}	$(1)CH_3 \cdot C_6H_5 \cdot CH_3(2)$	−27	144
68. Meta-xylene	C_8H_{10}	$(1)CH_3 \cdot C_6H_5CH_3(3)$	−54	139
69. Para-xylene	C_8H_{10}	$(1)CH_3C_6H_5 \cdot CH_3(4)$	−15	138
70 Ethyl benzene	C_8H_{10}	$C_6H_5 \cdot CH_2CH_3$		136
71 Isopropylbenzene (cumene) .	C_9H_{12}	$C_6H_5 \cdot CH(CH_3)_2$		153
72. Para-methylisopropyl-benzene (cymene)	$C_{10}H_{14}$	$(1)CH_3 \cdot C_6H_4 \cdot CH(CH_3)_2(4)$		175
(*b*) Two or more rings, not doubly adjacently interlocked				
73 Biphenyl	$C_{12}H_{10}$	$C_6H_5 \cdot C_6H_5$	69	255
74 Diphenyl methane	$C_{13}H_{12}$	$(C_6H_5)_2CH_2$	27	262
75 Sym-diphenyl ethane (bibenzyl)	$C_{14}H_{14}$	$C_6H_5CH_2 \cdot CH_2C_6H_5$	51	284
76 Triphenyl methane	$C_{19}H_{16}$	$(C_6H_5)_3CH$	93	359
77. Tetraphenyl methane	$C_{25}H_{20}$	$(C_6H_5)_4C$	285	431
78. Sym-tetraphenylethane	$C_{26}H_{22}$	$(C_6H_5)_2CH \cdot CH(C_6H_5)_2$	207	380
79 Unsym-tetraphenyl ethane	$C_{26}H_{22}$	$(C_6H_5)_3C \cdot CH_2(C_6H_5)$	144	
80 Dibenzylmethane (alpha-gamma-diphenyl propane)	$C_{15}H_{16}$	$C_6H_5(CH_2)_2C_6H_5$		299
81. Dibenzylethane (alpha-delta-diphenyl butane)	$C_{16}H_{18}$	$C_6H_5(CH_2)_4C_6H_5$	52	
82. Para-diphenylbenzene . (diphenylphenylene)	$C_{18}H_{14}$	$(1)C_6H_5 \cdot C_6H_4 \cdot C_6H_5(4)$	205	427
83. Diphenylene methane (fluorene) .	$C_{13}H_{10}$	$C_6H_4 \quad CH_2 \quad C_6H_4$	116	295

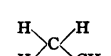
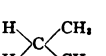
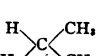
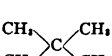
CLASSIFICATION OF HYDROCARBONS—*Continued*

(Upon Basis of Reactivity)

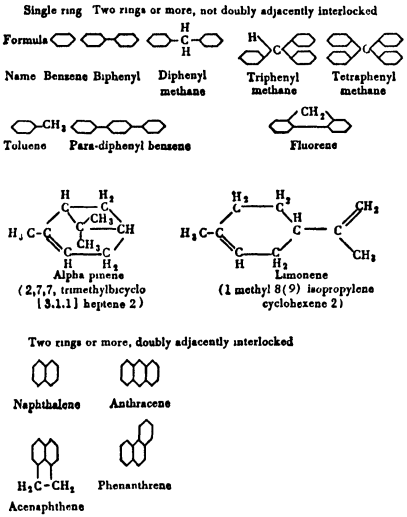
Benzenoid Class			Melting Point	Boiling Point °C.
(*c*) Two or more rings, doubly adjacently interlocked				
84. Naphthalene	$C_{10}H_8$		80	218
85. Anthracene	$C_{14}H_{10}$		218	342
86. Phenanthrene	$C_{14}H_{10}$		100	340
87. Naphthalene ethylene (acenaphthene)	$C_{12}H_{10}$		95	278
Not Benzenoid				
88. Dihydronaphthalene(1,4)	$C_{10}H_{10}$		15	212
89. Tetrahydronaphthalene (1,2,3,4)	$C_{10}H_{12}$			207
90. Decahydronaphthalene	$C_{10}H_{18}$			190 (approx.)
91. Dihydroanthracene (9,10)	$C_{14}H_{12}$		108	313
92. Hexahydroanthracene (1,2,3,4,9,10)	$C_{14}H_{16}$		63	290
Miscellaneous				
93 Carotene (yellow) (Dicyclic and olefin linkages)	$C_{40}H_{56}$			

Class of Hydrocarbons	Characteristics of the Carbon Linkages		
Paraffin	No ring	Saturated	All single linkages
Cycloparaffin	One closed ring	Saturated	All single linkages
Olefin	No ring	Unsaturated	One or more double linkage
Cycloölefin	One or more closed rings	Unsaturated	One or more double linkage
Acetylene	No ring	Unsaturated	One or more triple linkage
Benzenoid	One or more closed rings	Unsaturated	Oscillating double linkages in groups of three

In hydrocarbons of no ring, the chain of carbons may be single or branched, the limit of branching of the chain being two branch carbons to any one chain carbon.

Formula					
Name	Methane	Methyl methane Ethane	Dimethyl methane Propane	Trimethyl methane	Tetramethyl methane
Boiling Point °C	−161	−88	−45	−10	9.5
Designation		Primary Normal	Secondary Iso	Tertiary	Quaternary

In hydrocarbons having more than one closed ring, the attachments may be of various types.



All hydrocarbons are combustible, and many of them have preferred uses as fuels, e g , methane, ethylene, acetylene, paraffins, benzene, and as solvents, e g , benzene, toluene, xylenes, paraffins, terpenes These and others have special importance individually

PARAFFIN HYDROCARBONS Paraffin hydrocarbons are characterized in general by lack of marked chemical reactivity, and by having the lowest specific gravity of the liquid hydrocarbons (paraffin range about 0 62 to 0 77) Paraffin hydrocarbons occur in natural gas and petroleum, and are the predominant constituents in the hydrocarbon portion when coal is destructively distilled at low temperatures By the fractional distillation of petroleum there is obtained a wide range of mixtures of paraffins, illustrated by the following table

Distillate	Typical Yields by Distillation of Crude Petroleum from		
	Pennsylvania	Texas	California
Gasoline	28%	22%	22%
Naphtha	10	9	9
Kerosene	8	12	12
Gas or stove oil	7	42	42

From the remaining portion other distillates are obtained by further **distillation** at atmospheric pressure and by the use of vacuum

By means of the comparatively recent perfection of processes, any type of petroleum oil, kerosene distillate, gas oil, fuel oil residue, or crude oil may be converted into **gasoline** with yields of 50% to 75% Those so-called cracking processes result in the decomposition, upon heating under high pressure, of the raw material into gases, gasoline distillate, and petroleum coke

Gasoline is a liquid hydrocarbon mixture obtained from three main sources (1) straight-run gasoline, by the fractional distillation of crude petroleum, (2) cracked gasoline, by heat-pressure decomposition of crude petroleum or any distillate fraction, (3) natural gas or **casinghead gasoline**, by condensation under pressure or by absorption of the liquefiable constituents of natural gas. The production of each in the United States is of the order of 55%, 35%, 10%, respectively, and the percentage of cracked gasoline has shown rapid increase, with accompanying economy in the utilization of crude petroleum for gasoline production Specifications for various types of gasoline more or less commonly used in commerce are laid down involving color, odor, gums, distillation range, doctor test (for certain sulfur compounds), corrosion (of copper) test, acidity, and sulfur (total) Of these, the most important is the distillation test, which is a measure of the volatility and the range of volatility of the gasoline Various grades, based upon different distillation ranges, are recognized The necessity for such specifications is demanded by the extensive use of gasoline in internal combustion engines for motive power in automobiles, trucks, and airplanes

The knocking power of gasoline is an important consideration The knocking sound, or **detonation**, is produced in high-compression engines or in ordinary **internal combustion engines** when under heavy load ascending grades or when accelerating rapidly The knocking property is dependent upon the composition of the **fuel** Knocking indicates that the combustion of the fuel vapor in the cylinder is taking place too rapidly for complete utilization of the power by the cylinder of the engine Benzene is non-knocking under any practicable pressure, paraffins are most conducive to knocking, while the olefins and cycloparaffins are intermediate in effect Since cracked gasoline contains a smaller percentage of paraffins than straight-run, the former is now considered, contrary to earlier ideas, the better gasoline for power Benzene is blended with gasoline to improve the anti-knocking quality, and the addition of very small amounts of tetraethyl lead (which acts to retard the speed of combustion) is also utilized to produce the same result

The knock characteristics of motor fuels are compared in a standard motor under standard test conditions of operation, using a standard test fuel, and the rating is reported in terms of octane number The standard test fuel is composed of definite mixtures of "anti-knock" isooctane

$$\left(\text{2,2,4-trimethylpentane, } CH_3\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}\text{—}CH_2\text{—}\underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\underset{|}{\overset{|}{C}}}}\text{—}CH_3\right),$$

commonly referred to as octane, plus "knock," normal-heptane ($CH_3(CH_2)_5CH_3$) The octane number of a motor fuel is the same number as the percentage of iso-octane in the standard test fuel which matches the tested fuel in knock characteristics On account of the high cost of these two standard hydrocarbons, certified secondary standards are generally used in routine testing

Federal Specification for United States Government Motor Gasoline includes *Corrosion test* F S B *[1] method 530 22 A clean copper strip shall not show more than extremely slight discoloration when submerged in the gasoline for 3 hours at 122° F

Distillation range A S T M *[2] method D86-30 When the thermometer reads 75° C (167° F) not less than 10% shall be evaporated

When the thermometer reads 200° C (392° F) not less than 90% shall be evaporated

The residue shall not exceed 2%

Per cent evaporated shall be found by adding the **distillation** loss to the amount collected in the receiver at each specification temperature

The Government reserves the right to reject material during the months of December, January, February, and March in those localities where the normal mean minimum temperature during the month of January is less than 27° F. if when the thermometer reads 65° C. (149° F) less than 10% shall be evaporated.

Sulfur A S T M.*[2] method D90–30T. **Sulfur** shall not exceed 0 10%

Vapor pressure A S T M*[2] method D323–30T The **vapor pressure** at 37 8° C (100° F) shall not exceed 12 pounds per square inch

The Government reserves the right to reject material (a) in those localities where the normal mean minimum temperature during the month of January is greater than 27° F if the vapor pressure at 37 8° C (100° F) exceeds 10 pounds per square inch, (b) during the months of June, July, August, and September if the vapor pressure at 37 8° C (100° F) exceeds 8 pounds per square inch

Knock characteristics F S B *[1] method 600 11, A S T M *[2] D357–34T Specification not regularly demanded

Color F S B *[1] method 10 12 Specification not regularly demanded

Gravity F S B *[1] method 40 1 Specification not regularly demanded

Flash point F S B *[1] method 110 11 Specification not regularly demanded

Freezing point F S B *[1] method 141 1 Specification not regularly demanded

Gum content F S B *[1] methods 330 1 and 330 2. Specification not regularly demanded

Acidity F S B *[1] method 510 2 Specification not regularly demanded

Doctor test F S B *[1] method 520 31 Specification not regularly demanded

Federal Specification for United States Government Lubricating Oil, class D, for Internal Combustion Engines other than Aircraft and Diesel

Viscosity A S T M *[2] method D88–30. The Saybolt universal viscosities of the six grades (S A E *[3] numbers 20 to 70) shall lie within the limits

	Seconds at 130° F		Seconds at 210° F	
S A E *[3] Number	Not Less Than	Less Than	Not Less Than	Less Than
20	120	185		
30	185	255		
40	255			75
50			75	105
60			105	125
70			125	150

Flash point F S B *[1] method 110 32 The flash point shall not be lower than the minimum for each grade.

S A E *[3] Number	Flash Point Minimum for Passing
20	340° F
30	350
40	370
50	395
60	425
70	460

Pour point F S B *[1] method 20 12 The pour point shall not be higher than 40° F In the case of S A E *[1] 20 and S A E *[3] 30 oils, the Government reserves the right to require a pour point of not higher than 15° F, or under adverse climatic conditions, a pour point of not higher than 0° F

Color F S B *[1] method 10 2 The color shall not be darker than the darkest for each grade

S A E *[3]	Darkest A S T M *[2] Color Number
20	7 5
30	8
40	6 dil
50	7 dil
60	8 dil
70	8 dil

*[1] Federal Specifications Board
*[2] American Society for Testing Materials
*[3] Society of Automotive Engineers.

Carbon residue A S T M *[2] method D189–30 The carbon residue shall not be higher than the maximum for each grade

S A E *[3]	Maximum A S T M *[2] Carbon Residue
20	0 60%
30	0 80
40	1 00
50	1 70
60	2 00

Oxidation number F S B *[1] method 340 1 The Sligh oxidation number shall not be higher than 50 The oxidation number is the number of milligrams of precipitate from 100 grams of oil after subjection to the specified treatment with oxygen

Neutralization number F S B *[1] method 510 31 The neutralization number shall not be higher than 0 30 The neutralization number is the number of milligrams of potassium hydroxide required for neutralization of 1 gram of oil

Corrosion F S B *[1] method 530 31. **A clean, freshly** polished copper strip shall not show more than extremely slight discoloration when submerged in the oil for three hours at 212° F

The use of petroleum products is well described by the American Petroleum Institute, in "Petroleum Facts and Figures," pp 158–160 (1929), from which the following is quoted

"Among these are fuel gas, which is utilized for burning under boilers in the refineries, and another derivative, gas black, which is used in the making of rubber tires, inks and paints A series of **alcohols**, including isopropyl, secondary butyl, secondary amyl and secondary hexyl are also recovered from these gases, which are utilized as solvents for the making of **lacquers, soaps** and **essential oils** Liquefied gases, also yielded from the hydrocarbon gases, are utilized in metal cutting and for illumination Another product, petroleum ether, is used for priming motors and for laboratory work Natural gasoline, also thus, derived, yields light naphthas which, in turn, yield gas-machine gasoline, pentane, used for candle-power standardization, hexane, utilized in laboratories, and chemical solvents for drug extraction

"So-called white distillates, next derived from the refining of crude petroleum, include the naphthas and kerosene From the naphthas are derived aviation gasoline, motor gasoline, commercial solvents, blending naphtha, varnishmakers' and painters' naphtha and dyers' and cleaners' benzine The refined oils, including kerosene, are used for illuminating oil, stove oil, tractor oil, signal oil by railroads and lighthouses, and mineral seal oil for coach and ship illumination and gas absorption

"The next important product is furnace oil, used as a fuel in oil-burning furnaces in office buildings and homes

"Intermediate distillates, next derived, yield gas oil and absorber oil Gas oil is used by gas manufacturing plants in the carburetion of water gas, is an important metallurgical fuel, yields gasoline by the "cracking" process and also Diesel fuel oil Absorber oil enters into gasoline and benzol recovery

"From the heavy distillates next derived come technical heavy oils, waxes and lubricating oil Technical heavy oils, upon treating, are made into a variety of products From one of these—white oils—is derived so-called technical oil, used for lubricating special machinery, such as bakers' and candymakers' machinery, and for packing fruit and eggs, also medicinal oil for internal and external use and for the manufacture of **salves, creams** and ointments Ink oils are derived

*[1] Federal Specifications Board
*[2] American Society for Testing Materials.
*[3] Society of Automotive Engineers.

from technical heavy oil, also **saturating oil**, which enters into wool and twine manufacture, emulsifying oil, electrical oils, used for transformers and switches, and flotation oils, used in metal recovery processes

"From heavy distillates are derived waxes which are used for making candles, chewing gum and candy Wax also enters the laundry as a detergent and as an iron wax, has a wide use for sealing purposes, such as for the preserving of fruits and vegetables, and is used by etchers Saturating wax is applied to cardboard, matches, and paper

"Lubricating oils derived from petroleum are used wherever there is machinery, special oils or compounds being made for different types

"From the residues of distillation are derived greases, such as gear grease, switch grease, and cup grease By a refining process petrolatum is derived from greases This enters the medicinal field, compounded with other products, in the form of salves, creams and ointments and as petroleum jelly It is also used for metal coating and lubrication Residual fuel oil is used for burning under boilers in industrial plants, on ships and in railroad locomotives Fuel oil is also used for making gasoline by "cracking" processes Road oil is a residual product of petroleum, as are asphalts and pitches used for roofing, paving, felt saturating, briquetting, rubber making and plastic composition Another product is coke used for making carbon brushes, carbon electrodes, and also consumed as fuel

"From refinery sludges are made acid coke used as a fuel, sulfonic acid, utilized as a saponification and de-emulsifying agent, oils and pitches, and **sulfuric acid**, used in **fertilizer** manufacture"

CYCLOPARAFFIN HYDROCARBONS Cycloparaffin hydrocarbons are characterized in general by lack of marked chemical reactivity, and by moderately low **specific gravity** of the liquid hydrocarbons (cyclohexane 0 78) Cycloparaffins resemble paraffins, except that in the former the ratio of **carbon** to **hydrogen** is slightly less than in the latter, and there is one or more closed rings of carbon atoms in the former and none in the latter Cycloparaffin hydrocarbons occur in certain petroleum fields, notably Baku, Russia When the **calcium** salt of a higher dibasic **acid** in the oxalic acid series is subjected to dry **distillation**, a cyclic **ketone** is formed by the separation of calcium carbonate, and this ketone can be reduced to the corresponding cycloparaffin hydrocarbon By the action of **sodium** on dichloro (or dibromo) paraffins (**chlorine** or **bromine** not attached to the same or adjacent carbon atoms), sodium chloride separates upon heating and cycloparaffin hydrocarbon is also formed

OLEFIN HYDROCARBONS Olefin hydrocarbons are characterized by marked chemical reactivity, as shown by the behavior of such reagents as (1) **bromine** in carbon tetrachloride The red-colored solution is decolorized by olefins by addition of bromine at the olefin linkage (>C C<), (2) **sulfuric acid**, fuming Olefins react, generating heat, by addition or polymerization, (3) **nitric acid**, fuming Olefins react violently, (4) **potassium** permanganate in sodium carbonate solution The purple-colored solution is decolorized by olefins, (5) **hydrogen**, in the presence of finely divided nickel at 150° C Olefins form paraffins by addition of hydrogen at the olefin linkage, finally, (6) olefins react, by addition at the olefin linkage, with **hydrogen iodide**, **hydrogen bromide**, **hypochlorous acid**, **hypobromous acid**, **ozone**

The olefin hydrocarbon ethylene is a constituent of coal and gas (up to 8%), and in larger percentage (up to 30%) in the gases from petroleum subjected to the cracking process Cracking process gas contains propylene (up to 20%), and butylenes (up to 9%)

Olefin hydrocarbons are formed (1) by the **destructive distillation** of coal, and the **cracking** of petroleum, (2) by the removal of water from **alcohols**, by passing the alcohol vapor over heated **bauxite**, or by heating with concentrated sulfuric or **phosphoric acid**, (3) by heating paraffin chlorides, bromides, or iodides with **sodium** hydroxide in alcoholic solution, (4) by heating dihalogen saturated hydrocarbons with **zinc**, (5) by **electrolysis** of the **sodium** salts of dibasic acids, which in the case of **succinic acid** (COOH CH_2 CH_2·COOH) yields **ethylene** plus **carbon dioxide** (2 volumes) and **hydrogen** (1 volume) The part played by olefin hydrocarbon in internal combustion engines is mentioned under gasoline above, in the discussion of paraffin hydrocarbons

CYCLOOLEFIN AND TERPENE HYDROCARBONS Cycloolefin hydrocarbons are characterized by marked chemical reactivity, as shown by the behavior of such reagents as (1) **bromine** in **carbon tetrachloride** The red-colored solution is decolorized by cycloolefins by addition of bromine at the olefin linkage (>C C<), (2) sulfuric acid, fuming Cycloolefins polymerize and dissolve in the reagent, (3) nitric acid, fuming Cycloolefins react violently, sometimes with explosive violence, (4) **potassium** permanganate in **sodium** carbonate solution The purple-colored solution is decolorized by cycloolefins, (5) hydrogen, in the presence of finely divided nickel at 150° C Cycloolefins form cycloparaffins by addition of hydrogen at the olefin linkage

Cycloolefin hydrocarbons predominate in the hydrocarbon secretions of plants known as essential or **volatile oils**, the terpenes ($C_{10}H_{16}$) These are found in **coniferous** trees, especially pine, from which **turpentine** is obtained, and in the skin of **citrus fruits**, which yield limonene Terpenes, especially turpentine, are desirable solvents of many organic materials such as **resins** and **gums** and find application as such in preparing **paints**, varnishes, **lacquers**.

Cymene, para-methylisopropyl benzene ($C_{10}H_{14}$) or (1) CH_3 C_6H_4 $C_3H_7(4)$ contains the carbon skeleton of the terpenes, limonene ($C_{10}H_{16}$), which is a monocyclo-1(2),8(9)-diene and alpha-phellandrene ($C_{10}H_{16}$), which is a monocyclo-1(2),5(6)-diene Completely hydrogenated cymene is known as menthane ($C_{10}H_{20}$)

The terpene, alpha-pinene ($C_{10}H_{16}$) is a dicyclo-2-(3)-ene compound having three methyl groups (2,7,7) attached to two (2,7) of its seven carbon atoms The three bridges of the dicyclo heptene nucleus (between the two carbon atoms common to each ring) contain respectively 3,1,1 carbon atoms (expressed [3 1 1])

ACETYLENE HYDROCARBONS Acetylene hydrocarbons are characterized by marked chemical reactivity, as shown by the behavior of such reagents as (1) **bromine** in **carbon tetrachloride** The red-colored solution is decolorized by acetylenes by addition of bromine at the acetylene linkage (—C≡C—), (2) **sulfuric acid**, concentrated Acetylenes dissolve in the reagent, (3) **nitric acid**, fuming Acetylenes react violently, (4) **hydrogen** in the presence of finely divided nickel at 150° C. Acetylenes form olefins or paraffins by addition of hydrogen at the acetylene linkage, (5) ammonio-**cuprous** (or **silver**) salt solution Acetylene having the group —C≡CH yield precipitates, explosive when dry

Acetylene hydrocarbons are formed (1) by reaction of metallic acetylides or certain metallic carbides with acids or water **Calcium** carbide and water yields acetylene plus calcium hydroxide, (2) by heating dihalogen saturated hydrocarbons with sodium ethoxide, (3) by **electrolysis** of the sodium salts of the **fumaric acid** type, which in the case of fumaric acid (COOHCH CH COOH) yields acetylene plus **carbon dioxide** (2 volumes) and **hydrogen** (1 volume)

BENZENOID HYDROCARBONS Benzenoid hydrocarbons are characterized by moderate reactivity, as shown by the behavior of such reagents as (1) **bromine** in **carbon tetrachloride**, usually on warming The red-colored solution is decolorized by benzenoids by substitution of bromine for **hydrogen** of the benzenoid with the simultaneous separation of **hydrogen bromide**, which is evolved as a colorless gas and recognized by the fog formed when breathed upon, (2) **sulfuric acid**, fuming,

usually on warming Benzenoids react by substitution of the sulfonic acid group (—SO_3H) for hydrogen of the benzenoid with the simultaneous formation of water (not visible), (3) **nitric acid**, fuming, frequently on warming. Benzenoids react by substitution of the nitro group (—NO_2) for hydrogen of the benzenoid with the simultaneous formation of water (not visible), (4) with methyl (or other) chloride, bromide, iodide, in the presence of **aluminum** chloride anhydrous Benzenoids react by substitution of the methyl (or other) group for hydrogen of the benzenoid with the simultaneous separation of hydrogen chloride, bromide, iodide, (5) with **acetyl** (or other) **chloride**, bromide, in the presence of **aluminum** chloride anhydrous Benzenoids react by substitution of the acetyl (or other) group for hydrogen of the benzenoid with the simultaneous separation of hydrogen chloride, bromide

Benzenoid hydrocarbons are the predominant constituents in the hydrocarbon portion when **coal** is **destructively distilled** at high temperatures This source furnishes **benzene, toluene, xylenes, naphthalene, anthracene** of commerce (R K S)

HYDROCAULUS. The common stalk bearing the individuals of a colony in the **hydrozoan** coelenterates (A W L)

HYDROCELE A localized collection of fluid about the **testicle** within the membrane (*tunica vaginalis*) enveloping the testicle It is cured by surgery (R S M)

HYDROCEPHALUS. A disorder of the normal circulation and absorption of cerebrospinal fluid within the cavities (ventricles) of the **brain** The blocking of the cerebrospinal circulation within the cavities of the brain is caused by the tumor formation, congenital deformities, infection or injury

This condition occurs early in childhood and is characterized by progressive and extreme enlargement of the skull, atrophy of the brain through pressure, mental impairment, and convulsions Unless the process is arrested, imbecility, blindness, and eventual death resulting from malnutrition or some intercurrent infection results

Aside from those cases which will respond to medical treatment (as in those cases due to syphilis), surgery offers the only hope, although it is only successful in a small percentage of cases (R S M)

HYDROCHLORIC ACID AND CHLORIDES. Hydrochloric acid, "muriatic acid" (HCl), is a colorless solution formed when hydrogen chloride gas is dissolved in water, commercially of strength 18° Baumé (specific gravity at 60° F, water at 60° F, 1 1417, 27 92% HCl); 20° Baumé (specific gravity at 60° F, water at 60° F, 1 1600, 31 45% HCl), specific gravity 1 19 (approximately 36% HCl). Sometimes colored yellow by **ferric** iron There is a maximum constant boiling point 108 58° C (760 mm), at 20 22% HCl (distillate) for mixtures of hydrochloric acid and water

A commonly used strength for dilute hydrochloric acid is 18 25 grams HCl per 100 milliliters of solution (5 normal) Dilute hydrochloric acid reacts (1) with many hydroxides, e g, **sodium** hydroxide, to yield the corresponding chloride, e g, sodium chloride, solution, (2) with many ordinary oxides, e g, **magnesium** oxide, to yield the corresponding chloride, e g, magnesium chloride, solution, (3) with many carbonates, e g, **calcium** carbonate, to yield the corresponding chloride, e g, calcium chloride solution plus carbon dioxide gas, (4) with many sulfides, e g, **ferrous** sulfide, to yield the corresponding chloride, e g, ferrous chloride, solution plus **hydrogen sulfide** gas; (5) with many metals, e g, **zinc** (but not copper) to yield the corresponding chloride, e g, **zinc** chloride, solution plus hydrogen gas; (6) with some special oxides, e g, lead or manganese dioxide, to yield **lead** or **manganese** chloride plus chlorine gas, (7) with solution of some salts, e g, silver nitrate, to yield the corresponding chloride, **silver** chloride, precipitate Higher strengths of hydrochloric acid usually react similarly to the dilute Hydrochloric acid sometimes reacts as a reducing acid, e g, (6) above

The uses of hydrochloric acid have been suggested by the chemical reactions previously cited, and the largest quantities are used for reaction with metals, e g, zinc recovery from galvanized iron scrap, in the production of chlorides, and, previous to the electrolytic production of **chlorine**, for chlorine

All metallic chlorides, except **silver** chloride and mercurous chloride, are soluble in water, but **lead** chloride, **cuprous** chloride and **thallium** chloride are only slightly soluble Metallic chlorides when heated melt, and volatilize or decompose, e g, **sodium** chloride, melting point 804° C, **calcium, strontium, barium** chloride volatilize at red heat, **magnesium** chloride crystals yield magnesium oxide residue and hydrogen chloride, **cupric** chloride yields cuprous chloride and chlorine

Two common tests for chlorides are as follows·

1 An aqueous solution gives a precipitate with **silver** nitrate which is insoluble in **nitric acid** but soluble in **ammonia, sodium** thiosulfate, or **potassium** cyanide

2 On treatment with **chlorine** water and shaking with **carbon disulfide** no dark coloration is produced as is the case for the bromides and the iodides (R K S)

HYDROCLADIUM. Small branches bearing sessile polyps in **hydrozoan** coelenterates of the family Plumularidae (A W L)

HYDROCORALLINAE. Hydrozoa.

HYDROCYANIC ACID AND CYANIDES. Hydrocyanic acid, prussic acid (HCN), is a solution of hydrogen cyanide gas in water of characteristic odor and very poisonous, is soluble in all proportions in water, alcohol, or ether, and anhydrous liquid hydrogen cyanide is a solvent for many salts and organic substances Hydrogen cyanide reacts with **hydrogen** at 140° C in the presence of a **catalyzer**, e g, **platinum** black, to form methyl **amine** (CH_3NH_2), when burned in air, produces a pale violet flame, when heated with dilute **sulfuric acid** forms formamide ($HCONH_2$) and ammonium formate ($HCOONH_4$), when exposed to sunlight with **chlorine** forms cyanogen chloride (CNCl), plus **hydrogen chloride** An important reaction of hydrogen cyanide is that with **aldehydes** or **ketones**, whereby cyanhydrins are formed, e g, acetaldehyde cyanhydrin (CH_3 CHOH CH), and the resulting cyanhydrins are readily converted into alpha-hydroxy acids, e g, alpha-hydroxypropionic acid (CH_3 CHOH COOH)

Metallic cyanides are (1) soluble, e g, **sodium** cyanide (NaCN), **potassium** cyanide (KCN), **calcium** cyanide ($Ca(CN)_2$), **mercuric** cyanide ($Hg(CN)_2$), **aurous** cyanide (AuCN), (2) insoluble, e g, **silver** cyanide (AgCN), **cuprous** cyanide (CuCN), (3) complex, (a) decomposed by dilute **sulfuric acid** and not affected by dilute **sodium** hydroxide, e g, sodium silver cyanide ($NaAg(CN)_2$) solution, sodium cuprous cyanide (NaCu $(CN)_2$) colorless solution, (b) changed only to the acid by dilute sulfuric acid and reactive with dilute sodium hydroxide, e g, **potassium** ferrocyanide ($K_4Fe(CN)_6$) yields, with dilute sulfuric acid, **hydroferrocyanic acid, cupric** ferrocyanide ($Cu_2(Fe(CN)_6)$) yields, with dilute sodium hydroxide, cupric hydroxide

Sodium cyanide solution dissolves certain metals (a) with absorption of oxygen, e g, gold, silver, mercury, lead, (b) with evolution of hydrogen, e g, copper, nickel, iron, zinc, aluminum, magnesium, and solid sodium cyanide, when heated with certain oxides, e g, **lead** monoxide (PbO), **stannic** oxide (SnO_2), yields the metal of the oxide, e g, lead, tin, respectively, and sodium **cyanate** (NaCNO) Two classes of **esters** are known, cyanides or nitriles, and iso-cyanides, iso-nitriles or carbylamines, the latter being very poisonous and of marked nauseating odor

Methyl cyanide (CH_3CN), boiling point 82° C, formed by reaction of (1) methyl iodide and **potassium** cyanide, (2) acetamide and phosphorus pentoxide Methyl iso-cyanide (CH_3NC), boiling point 60° C, formed by reaction (1) of methyl iodide and **silver** cyanide, (2) of methyl **amine**, **chloroform** and **sodium** hydroxide solution warmed Ethyl iso-cyanide (C_2H_5NC), boiling point 78° C Phenyl iso-cyanide (C_6H_5NC), boiling point 78° C at 40 mm pressure

Hydrogen cyanide is made by reaction of **sodium** cyanide and dilute **sulfuric acid** Its uses are for fumigation of ships, cars, rooms, and fruit trees Sodium cyanide is used for recovering gold and silver from ores (cyanide process) The detection of hydrogen cyanide is accomplished (1) by evaporation to dryness with yellow **ammonium** sulfide, whereby **thiocyanate** is formed, which yields red-colored solution upon addition of **ferric** salt solution It is said that 1 part of cyanide may thus be detected in 4,000,000 parts of solution, (2) by boiling with ferrous plus ferric salt solution to which sodium hydroxide has been added Upon addition of excess dilute sulfuric acid to the product, a blue precipitate forms, if cyanide was present, or a blue solution if the amount was small Cyanides are also detected by the formation, with **silver** nitrate solution, of a white precipitate that is soluble in excess of the reagent On treatment of cyanides with dilute sulfuric acid, the characteristic almond-like smell of hydrogen cyanide (poisonous) is produced (R K S)

HYDRO-ELECTRIC POWER. There have been many popular fallacies attached to hydro-electric power One of the most persistent of these is that hydro-electric power is much cheaper than power from any other source because it exists as the free gift of nature and in a very usable state Another, but one upon which the light of accurate public information has shone with beneficial effect, is that all available hydro-electric power should be developed and the natural resources of fuels conserved until hydro development is complete The fundamentals underlying the economics of power development serve to show that, unless the hydro site is a favorable one, the cost of hydro-electric energy can be, and oftentimes is, higher than for steam In most hydro systems the generation element forms a minor part of the total expense, hence the cost of fuel does not stand out as the most important item Authorities have repeatedly stated that if all the available hydro-electric energy of the country were developed, the resulting power capacity would be only a fraction of that required

The desirability of a hydro site rests not only upon its topography and stream flow, but also upon the cost of fuel, the trend of fuel cost, and the load factor to be expected When coal prices are rising rapidly more attention will be given to the hydro projects than when coal prices are on the decline The length and cost of transmission lines from plant to load also present problems of some moment in any consideration of hydro-electric development On the other hand, it can be said for hydro developments that many of them serve more than one purpose and sometimes the power development is of secondary importance Construction of impoundment areas for flood control or for irrigation frequently offers the possibility of producing electrical energy as a by-product Another feature commending hydro development is the ability to store energy, in the hydraulic form, over long periods of time in a reservoir, also the adjustment, through correct impoundment volumes, of a variable stream flow to meet a variable load demand

Hydro-electric plants can be classified as follows.

A Extent of impoundment volume.
  1 Storage plants
  2 Run-of-river plants
B Status in the power system
  1 Peak load plant
  2 Base load plant
  3 Isolated plant
C Head
  1 High-head development
  2 Medium-head development.
  3 Low-head development

The low-head plant has a characteristic design differing in all essentials from the high-head plant The medium-head plant may partake of the characteristics of either the high- or low-head plants as its working head approaches either the high- or low-head range There is no definite line of demarcation between high, medium, and low heads, however, a head of more than 500 feet can be considered a high-head development, and one lower than 50 feet a low-head development Briefly, the characteristics of the low-head plant are vertical, reaction type, runners using large volumes of water and requiring large water passages Substructure is both extensive and expensive, and intake works are large and complicated Large diameter generators are made necessary by the low rotational speeds Characteristics of the high-head plant are horizontal impulse turbines, small volumes of water at high pressures, plant at some distance from the dam The advantage of smaller and simpler substructure is offset by the presence of a long water conduit, or penstock, between dam and plant The turbines are high-speed and allow smaller generator diameter The high speed is accounted for by the high heads used Inherently, the impulse turbine has a low characteristic speed

The possible hydro-electric development sites along the flow of a stream are of two types, namely, those suitable for run-of-the-river plants and those offering natural impoundment basins for storage plants In general, the run-of-the-river plant is cheaper than the storage plant of equal capacity, but it suffers seasonal variation of output more or less proportional to the variation of stream flow

If all the run-of-river plants were located upstream from the storage plants they would be operated continuously on a base load plan, because, were they idle, their small reservoirs would quickly overflow and water would be wasted over the crest gates If, however, they are located between storage plants, the run of the river, as far as they are concerned, is just what the storage plants are passing on to them So, located downstream from a storage plant, a run-of-river plant will produce an increase in output when the storage plant increases its output

In the hydro-electric plant the turbines and generators are the main items of equipment The hydro-electric superstructure, as usually laid out, has one large building housing the main units and an electrical bay, or wing, of one or more stories in which are located the switching equipment, offices, storerooms, and most of the auxiliary equipment

Hydro sites that are developed to use but part of the normal stream flow are exceptions to the general rule Only rarely is a development made where conservation of the water and its use in the most efficient manner is not a paramount feature of operation Failure to give due cognizance to this feature may wipe out the net operating profit, hence a continuous, watchful scrutiny of all natural factors which can affect the station operation is a duty of the operating personnel

A **hydraulic turbine** suffers loss of efficiency at heads above or below the designed value because of shock losses At the correct head there will be one point of best efficiency, somewhere between 80% and 95% of full load When a number of units are installed in a plant, and when steam reserve is available, it is generally possible to operate the units near the point of best efficiency. There are four faults of operation and maintenance which can reduce the maximum energy production of a plant They are

1 Waste of water over spillways.
2 Improper distribution of the load between the station units.

3 Water leakage through valves, gates, dam or flow line
4 Wear on moving parts, especially corrosion or erosion of the runner

The relative simplicity of hydro-electric equipment makes hydraulic efficiency of the turbine the principal consideration (F T M)

HYDROFERRICYANIC ACID AND FERRICYANIDES. Hydroferricyanic acid ($H_3Fe(CN)_6$) is a brownish-green non-volatile solid, soluble in water to form a strongly acidic brown-colored solution, which decomposes in the light **Potassium** ferricyanide ("red prussiate of potash," $K_3Fe(CN)_6$), red soluble solid, the ordinary source of ferricyanide, is made by reaction of potassium ferrocyanide ($K_4Fe(CN)_6$), obtained as a by-product of coal gas works, and **chlorine** in solution, and then crystallization **Potassium** ferricyanide, unlike potassium ferrocyanide, is soluble in alcohol From potassium ferricyanide concentrated solution, by treatment with **sulfuric acid**, solid hydroferricyanic acid may be obtained, and then dried in vacuum When potassium ferricyanide and dilute sulfuric acid are warmed, **hydrogen cyanide** is evolved, but, with concentrated sulfuric acid warmed, **carbon monoxide** is evolved When potassium, sodium, or ammonium ferricyanide solution is added to certain metallic salt solutions, characteristic results are obtained

With **silver** nitrate, silver ferricyanide ($Ag_3Fe(CN)_6$), brick red precipitate, with **cadmium** nitrate, cadmium ferricyanide ($Cd_3(Fe(CN)_6)_2$), orange precipitate, with **cupric** sulfate, cupric ferricyanide ($Cu_3(Fe(CN)_6)_2$), yellowish-green precipitate, with **ferrous** sulfate, ferrous ferricyanide ("Turnbull's blue," $Fe_3(Fe(CN)_6)_2$), deep blue precipitate or colloidal solution (This is a common test for ferricyanides), with **ferric** sulfate, no precipitate but brown to green solution With **nitric acid** or acidified solution of **sodium** nitrite, potassium, or sodium ferricyanide, solution is changed to nitroferricyanide ("Nitroprusside," $Na_2Fe(NO)(CN)_5$), recoverable by crystallization (R K S)

HYDROFERROCYANIC ACID AND FERROCYANIDES. Hydroferrocyanic acid ($H_4Fe(CN)_6$) is a white, non-volatile soluble solid **Sodium** or **potassium** ferrocyanide ("yellow prussiate of potash," $Na_4Fe(CN)_6$) is obtained as a by-product of coal gas works by fixing the **cyanogen** compounds of the gas by reaction with **ferrous** compounds and then boiling with **calcium** hydroxide suspension Soluble calcium ferrocyanide is converted to soluble sodium or potassium ferrocyanide by reaction with sodium or potassium carbonate, and then filtering off calcium carbonate precipitate and evaporating the filtrate From sodium ferrocyanide solution, by treatment with **sulfuric acid**, hydroferrocyanic acid may be obtained by extraction with ether, and then evaporating the ether solution When sodium ferrocyanide and dilute sulfuric acid are warmed, **hydrogen cyanide** is evolved, but, with concentrated sulfuric acid warmed, **carbon monoxide** is evolved When sodium, potassium, or ammonium ferrocyanide solution is added to certain metallic salt solutions, characteristic results are obtained with **silver** nitrate, silver ferrocyanide ($Ag_4Fe(CN)_6$), white precipitate slowly turning blue; with **cadmium** nitrate, cadmium ferrocyanide ($Cd_2Fe(CN)_6$), white precipitate, with **cupric** sulfate ($Cu_2Fe(CN)_6$), reddish-brown precipitate, with **ferrous** sulfate, ferrous ferrocyanide ($Fe_2Fe(CN)_6$), white precipitate when pure ferrous but usually pale blue precipitate, with **ferric** sulfate, ferric ferrocyanide ($Fe_4(Fe(CN)_6)_3$ or $Fe_3(Fe(CN)_6)_2$), deep blue precipitate ("Prussian blue") (This is a common test for ferrocyanides) Sodium and other soluble ferrocyanides are oxidized to ferricyanides, when in acid solution, by **chlorine, nitric acid, nitrous acid, hydrogen peroxide,** dichromate **permanganate, lead** dioxide, **manganese** dioxide. (R. K S.)

HYDROFLUORIC ACID AND FLUORIDES. Hydrofluoric acid (HF or H_2F_2) is a colorless solution formed when hydrogen fluoride gas is dissolved in water, commercially of strengths 30% HF, and 60% HF There is a maximum constant boiling point 111° C (750 mm) at 43% HF (distillate) for mixtures of hydrofluoric acid and water Since hydrofluoric acid attacks glass, the container must be resistant, e g, of lead or ceresine

Hydrofluoric acid is used (1) to etch and frost glass, (2) to volatilize **silicon** oxide, (3) in the preparation of fluorides, fluosilicates, fluoborates (See **boron**)

Metallic fluorides are soluble as follows **sodium, potassium, ammonium, silver, mercurous, mercuric, thallum,** the remaining fluorides are insoluble

A common test for fluorides is treatment (of the dry sample) with hot concentrated sulfuric acid This produces hydrogen fluoride, which can be identified by its property of etching (R K S)

HYDROGEN. Symbol· H Atomic number 1. Atomic weight 1 0081 Density 0 0899 gram per liter 0° C, 760 mm, or 0 070 when air equals 1 000 Formula of hydrogen gas H_2 Melting point —259 1° C Boiling point —252 7° C Critical temperature. —239 9° C Critical pressure 12 8 atmospheres

Hydrogen is a colorless, odorless, tasteless gas, suffocating but not toxic **Palladium,** finely divided, adsorbs 1000 to 3000 times its own volume of hydrogen, and most of the gas is retained at a temperature as high as 100° C Also, when finely divided as by reduction of the oxide powder, the following metals adsorb appreciable quantities of hydrogen **cobalt, gold, nickel, iron** Hydrogen was recognized as a distinct substance by Cavendish in 1766, who called it "inflammable air" Isotopes (1) (99 98%), (2) (0 002%) (deuterium), (3) (small percentage) (tritium) Used (1) in the oxyhydrogen and atomic hydrogen flames for high temperature **welding,** cutting and melting of metals, (2) in the fixation of **nitrogen** as **ammonia,** (3) in the **hydrogenation** of fatty oils, unsaturated hydrocarbons, coal tar, coal, (4) in the formation of methyl **alcohol** by reaction with **carbon monoxide** in the presence of a **catalyzer** In **fuel** gas mixtures, such as coal gas, water gas, and producer gas, hydrogen is a fuel constituent of low fuel value, namely, 320 British Thermal Units per cubic foot

Hydrogen occurs chiefly combined with **oxygen** in water, with **carbon** in hydrocarbons, with carbon and oxygen (without and with nitrogen) in a vast variety of organic substances

When ignited, hydrogen burns in air with a pale blue to colorless, non-luminous flame, when mixed with air or oxygen and ignited, is explosive, combines violently with **chlorine** in sunlight or magnesium light to form **hydrogen chloride** (HCl), when heated with **sodium, calcium,** or related metals, yields the corresponding hydride, reacts with **nitrogen** to form **ammonia** (NH_3) in the presence of a **catalyzer,** with **sulfur,** to form **hydrogen sulfide** (H_2S) upon heating, with **cupric** oxide, cuprous oxide, **ferric** oxide, ferroferric oxide, ferrous oxide to form copper metal in the cases of the first two and iron metal in the cases of the last three plus water in all cases Similar reactions take place with oxides of **nickel, tin, lead,** but not with oxides of zinc, aluminum, magnesium, with unsaturated organic compounds, to form corresponding saturated compounds, e g, **oleic acid** ($C_{17}H_{33}COOH$) to form **stearic acid** ($C_{17}H_{35}COOH$), in the presence of a catalyzer

Hydrogen is prepared (1) by the **electrolysis** of water solutions of salts, e g, sodium chloride, of bases, e g, sodium hydroxide, of acids, e g, sulfuric acid, (2) by the reaction of dilute hydrochloric or sulfuric acid and a metal, such as **zinc** or **iron,** but not copper or mercury, (3) by the reaction of heated steam and a metal, such as zinc or iron, forming zinc oxide and ferroferric oxide respectively, but not copper or mercury, (4) by reaction of **silicon** or **aluminum** with **sodium** hydroxide solution heated, forming sodium silicate and sodium alumi-

nate, respectively, (5) from water gas, by separation from **carbon monoxide** by fractional liquefaction

"Heavy hydrogen," **deuterium**, hydrogen isotope 2, symbol D, atomic weight 2 01363, is ultimately obtainable by prolonged electrolysis of the residual water of electrolytic cells from which ordinary hydrogen (isotope 1) has been largely removed Approximately one part by weight of isotope 2 is present in ordinary water along with 5000 parts by weight of isotope 1 The discovery of deuterium made possible in **electron** bombardment studies the use of a projectile of atomic mass 2, intermediate between hydrogen of atomic mass 1 and helium of atomic mass 4 By means of its compounds, deuterium makes possible the extended study of chemical structure and reactions.

Below —220° C the specific heat of hydrogen is that of a monatomic gas like **helium** (He) Practically pure para-hydrogen may be obtained by adsorption of ordinary hydrogen, which is three-fourths ortho and one-fourth para, on charcoal at about —255° C The melting point of para-hydrogen is 0 13° C lower (ortho-hydrogen 0 04° C higher) than ordinary hydrogen, and the boiling point at 60 mm pressure is 0 13° C. lower (ortho-hydrogen 0 04° C higher) than ordinary hydrogen Para-hydrogen reverts slowly to ordinary hydrogen, but immediately in the presence of platinized asbestos

At high temperatures the loss of heat from a glowing wire in hydrogen is larger than expected on regular assumptions This believed to be due to dissociation of ordinary hydrogen into atomic hydrogen (H)

	Dissociation of Hydrogen	
Temperature	At 760 mm	At 1 mm
1730	0 33%	8 7%
2230	3 1	57 5
2730	34	99 3

When hydrogen is passed through an electric arc between tungsten poles, a considerable transformation into atomic hydrogen occurs, and when a stream of this gas strikes a surface a large evolution of heat takes place through recombination to ordinary hydrogen This atomic hydrogen flame is of temperature sufficiently high to melt **tungsten** (melting point 3370° C) The half-life period of the hydrogen atom is one-third second at 0 5 mm pressure

Triatomic hydrogen (H_3) is produced when an electric glow discharge is passed through a mixture of hydrogen and water vapor with a potential drop of some 5000 volts at the cathode

Acids Hydrogen is present in all solutions of acids. See **Acids**, general

Hydrocarbons. See **Hydrocarbons**

Hydrogenation See **Hydrogenation**

Hydrides Of oxygen—H_2O, water, H_2O_2, hydrogen peroxide

Of Non-metals			Of Metals	
Boron	B_2H_6	and others	Lithium	LiH
Carbon	CH_4	and others	Sodium	NaH
Silicon	SiH_4	and others	Potassium	KH
Nitrogen	NH_3	and others	Rubidium	RbH
Phosphorus	PH_3		Cesium	CsH
Arsenic	AsH_3		Calcium	CaH_2
Sulfur	H_2S		Strontium	SrH_2
Selenium	H_2Se		Barium	BaH_2
Tellurium	H_2Te		Cuprous and others	Cu_2H_2
Fluorine	H_2F_2			
Chlorine	HCl		Germanium and others	GeH_4
Bromine	HBr			
Iodine	HI		Cerium	CeH_3
			Antimony	SbH_3
			Columbium	CbH_3

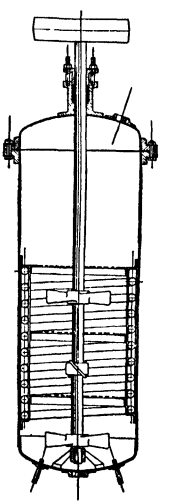
Oxides: See **Water**; and **Hydrogen Peroxide**

(R K S)

HYDROGENATION. Nickel, prepared in finely divided form by reduction of nickel oxide in a stream of hydrogen gas at about 300° C, was introduced by Sabatier (1897) as a **catalyzer** for the reaction of **hydrogen** with unsaturated organic substances to be conducted at about 175° C Nickel, while not the only catalyst, has proved one of the most successful in such reactions **Platinum** black or **palladium** black is sometimes used at lower temperatures, and finely divided **copper** metal or nickel oxide at higher temperatures. The unsaturated organic substances that are hydrogenated are usually those containing the olefin linkage (C.C), but those containing a triple bond (—C⋮C—) and (—C.N) may also be hydrogenated

Ethylene (or **acetylene**) with hydrogen—all properly purified, as the catalyzer is easily poisoned—reacts in the presence of properly prepared nickel at the properly controlled temperature to form **ethane**, **benzene** (C_6H_6) to form hexahydrobenzene (C_6H_{12}), styrolene ($C_6H_5CH.CH_2$) or phenylacetylene (C_6H_5C CH) to form ethyl cyclohexane (C_6H_{11} CH_2CH_3), phenol (C_6H_5OH) and di- and trihydroxylphenols to form the respective hydroxycyclohexanes with change of properties from those of **phenols** to those of tertiary **alcohols**; **napthalene** ($C_{10}H_8$) to form tetra- or decahydronaphthalene, **anthracene** ($C_{14}H_{10}$) to form di-, hexahydroanthracene, **aniline** ($C_6H_5NH_2$) to form cyclohexylamine ($C_6H_{11}NH_2$) a strong base, methyl cyanide (CH_3CN) to form ethyl amine ($CH_3CH_2NH_2$), oximes to corresponding amines; nitrobenzene ($C_6H_5NO_2$) to aniline ($C_6H_5NH_2$)

The reaction is applied on a large scale to the hydrogenation of oleate ester fats under the influence of high pressures, advantage thereby being taken of the decrease in volume upon the fixation of hydrogen by the fat (See **Equilibrium.**) **Oleate** ester fats are hydrogenated to **stearate** ester fats of lower melting point and the product may be obtained of intermediate hydrogenation—and consequently of intermediate melting point—as desired Artificial shortenings are thus prepared from liquid fatty oils such as cottonseed, peanut, corn oil Oleic acid behaves similarly



Apparatus used in the hydrogenation of oils under pressure

The catalyzer may be supported on such a material as kieselguhr The method of preparation of the catalyzer and the avoidance of impurities are the two greatest difficulties of the process Nickel is more active when reduced at 320–350° C unsupported and at 500° C on a support than when higher temperatures are used, nickel reduced at 700° C. is almost inactive

Great interest has attached to the extension of the hydrogenation reaction to the technical field of unsaturated liquid hydrocarbons such as petroleum and coal tar fractions, and also to the hydrogenation of coal Temperatures of the order of 450° C and pressures of the order of a hundred atmospheres are utilized A British report states that 100 tons of dry ash-free coal will yield 62 tons of "petrol," 28 tons of gas, and a residue containing ash and 6 tons of solid carbonaceous matter, and then an additional equal weight of coal is requisite to operate the process. (See **Methyl Alcohol** and **Ammonia**) (R K S)

HYDROGEN CHLORIDE. Hydrochloric Acid.

HYDROGEN CYANIDE. Hydrocyanic Acid and Cyanides.

HYDROGEN IONS. Reactions Involving Recombinations of Ions.

HYDROGEN PEROXIDE. Hydrogen peroxide, hydrogen dioxide (H_2O_2), is a colorless (blue in thick layers), odorless liquid, melting point —2° C., boiling point 152° C, decomposition (84° C) at 68 mm pressure (68° C at 26 mm), soluble in water in all proportions, usually encountered as a dilute solution (3% H_2O_2, "10-volume solution," that is, one volume of solution yields 10 volumes of oxygen) although available up to 30% strength Acetanilide is frequently added in small amount (0 002%) to decrease the decomposition on storage

Hydrogen peroxide is used (1) as a bleaching agent as stated, (2) as an antiseptic and disinfectant, (3) as an oxidizing agent

Hydrogen peroxide reacts (1) with **alkalis** to form peroxides, (2) with **potassium** iodide solution, in presence of ferrous sulfate, to liberate **iodine** This reaction serves to indicate the presence of as small an amount as 1 part by weight of hydrogen peroxide in 25,000,000 parts of water, (3) with **lead** sulfide (PbS), brown solid, to form lead sulfate ($PbSO_4$), white solid, and sometimes used to brighten the lead pigment of darkened oil paintings, (4) with lead dioxide to form lead oxide, (5) with **sulfites**, especially in alkaline solution, to form **sulfates**, (6) with nitrites to form nitrates, (7) with **arsenites** to form arsenates, (8) with **ferrous** compounds to form ferric, (9) with chromic compounds to form chromates (See **Chromium**), (10) with permanganates (See **Manganese**), in acid solution to form manganous plus oxygen gas of twice the volume available from the hydrogen peroxide used, (11) with dichromates in acid solution cold to form perchromic acid, blue solution, more soluble in ether than in acid, (12) with titanic salt solutions to form pertitanic acid, yellow solution (See **Titanium**), (13) with colored organic materials, e g, litmus, indigo, to destroy the color, and thus used for **bleaching** hair, silk, feathers, straw, ivory, teeth, bones, gelatin, flour When hydrogen peroxide solution is treated with finely divided **platinum** or other substances, or comes in contact with rough surfaces, e g, ground glass, **oxygen** is evolved (water also formed)

Hydrogen peroxide is prepared from **barium** peroxide by treatment with ice-cold dilute acid, when **sulfuric acid** is used barium sulfate insoluble may be separated by filtration Other peroxides, e g, sodium peroxide, react similarly with acids to form hydrogen peroxide plus the salt corresponding to the peroxide and acid used Hydrogen peroxide is formed when ether is exposed to sunlight, when a hydrogen-oxygen flame impinges on ice, and when water in a quartz vessel is exposed to **ultraviolet light** (R K S)

HYDROGEN SCALE. Thermometry.

HYDROGEN SULFIDE AND SULFIDES. Hydrosulfuric Acid and Sulfides.

HYDROGRAPH. By graphing the discharge of a stream as ordinate against time sequence as the abscissa, a hydrograph of the stream flow is obtained The hydrograph proves to be an important source of information in **hydro-electric power** design. The reliability of the information it contains increases as the period of time over which the hydrograph extends is lengthened Hydrographs extending over periods of less than ten years are liable to be deceptive in the information they convey regarding maximum and minimum flows The United States Geological Survey water supply papers form a valuable and important reference source for data upon which hydrographs are constructed (F T M)

HYDROID. One of the two forms of individuals in the coelenterates The polyp This form is a tubular or sac-like individual whose body wall is composed of two cellular layers separated by a thin mesogloea The latter contains some cells derived from the other layers but is not developed as a third cellular layer The hydroid is usually attached to the stalk of a colony or directly to a supporting surface Its cavity opens at the free end of the body, and the mouth is surrounded by a circlet of slender tentacles except in specialized individuals found in some colonial species The other form of coelenterate individual is the **medusa** (A W L)

HYDROKINETICS. The flowing of liquids is due to three principal causes pressure difference, gravity, and inertia **Bernoulli's law** expresses an ideal condition fulfilled by the three components of "head" corresponding to these three causes The value of this head (whether constant or not) is, at a given point (x, y, z) of the liquid

$$e + \frac{p}{\rho g} + \frac{v^2}{2g} = F(x, y, z). \qquad (1)$$

The terms of this expression represent lengths, usually given in centimeters or feet The assumption of constant density requires that the product of the speed of flow by the cross section of any conserved portion of the stream shall be constant and that the stream lines (paths of the moving particles) therefore converge as the speed increases If one could assume that the function F is really constant, or if it were possible to obtain F as a known function of the co-ordinates of the moving particle, then all hydrokinetic problems could be solved by applying suitable mathematics to the equation which would thus develop from (1)

Various attempts have been made to do this Useful formulae result from assuming F constant (Bernoulli's law) and applying the equation to special cases. But when such formulae are tested, the calculated results are found to be in error, in every case indicating that appreciable energy has been lost in friction While some improvement is obtained by introducing a friction factor, it has on the whole been found more satisfactory to employ empirical formulae adapted to each type of problem Thus we have the Darcy formula

$$v = D\sqrt{\frac{d(F_1 - F_2)}{l}}, \qquad (2)$$

for the speed of flow in a pipe of length l and diameter d, running full, and with a difference of total head $F_1 - F_2$ at the two ends, D being a constant to be determined by experiment Also the Chezy formula

$$v = C\sqrt{\frac{as}{u}}, \qquad (3)$$

giving the speed of flow in an inclined channel, like a ditch or a sewer, a being the cross section of the flow, u the length of channel perimeter covered by the liquid, s the fall per unit length, and C an experimental constant

The "hydraulic grade line" is a convenient concept in connection with flow through pipes This is an imaginary line so drawn that each point of it lies vertically above (or below) the pipe at a distance equal to the pressure head $p/\rho g$ at the corresponding point of the pipe In the case of a siphon, part, at least, of the conduit rises above this line, which means that the pressure in this portion is less than atmospheric

Among the more difficult problems are those of vortex motion (like a whirlpool) and turbulent flow, and the general treatment of flow through a cavity of given shape under given boundary conditions, which presents some analogies to the electric current and the conduction of heat. (L D W)

HYDROLOGIC CYCLE. Hydrology.

HYDROLOGY. The science, or study, of water, especially in relation to its occurrence in streams, lakes, underground structures, and as snow The study of glaciers, their origin and geological effects is usually

included under the heading of Glaciology. The term hydrology is derived from the Greek meaning water, and reason, hence the science of water, including its discovery, uses, control and conservation Since water ranks first of all the natural resources, the science of hydrology is of great practical importance The basis of hydrology is the hydrologic cycle All terrestrial (fresh) waters are derived from the great oceanic reservoirs through evaporation and precipitation as rain or snow, hail or sleet

The basis of rainfall data is the rainfall records collected by the United States Weather Bureau from its 106 climatological divisions Rainfall is expressed in inches per year, and the volume that has fallen in a given time is expressed in acre feet, meaning the volume which would cover an acre to the depth of one foot Most of the moisture that falls on the ground eventually returns to the sea by means of rivers This is called the run-off Stream flow past a stated point is measured in cubic feet per second, a term that is universally shortened to "second-feet" The difference between precipitation and run-off represents the amount of rain water which is, (1) Temporarily caught in local depressions, such as lakes and swamps (2) Added to the **ground water** reservoir (3) Returned to the atmosphere by evaporation, or the transpiration of plants

A great variation in rainfall in different parts of the country is to be noted, as is also the variation of precipitation at one point from year to year This might be expected on the basis of the physical factors which cause rainfall

The data of most importance to the study of water supply are the average annual precipitation, the minimum annual precipitation, and the frequency of occurrence of dry years There exists only an indirect, and sometimes unrecognizable, connection between rainfall and run-off Much depends on the topography of the watershed, its extent, and its geology Of the volume precipitated in a rainfall, a large amount is evaporated from the watershed surfaces, more is absorbed by plants and trees, some goes into natural ground storage, and that which remains after these demands of nature have been satisfied will appear as run-off in the streams draining the watershed The effect of a rainfall on stream flow must be interpreted in the light of the following conditions

1 The character of the rainfall If it is alternated with sunny periods, the evaporation will be large
2 Temperature The warmer the atmosphere, the more evaporated moisture it is able to contain
3 Porosity of the soil This governs the rate of percolation of the water from the surface to the depths
4 Inclination, depth, and character of the underlying rock strata This affects the amount of ground storage and its rate of flow to run-off

It has been estimated that nearly half of the people of the United States obtain their water from wells (underground water) Within recent years the shallow, hand-dug wells have been supplemented by deeper, drilled wells, each one of which penetrates one or more water-bearing strata call aquifiers When the water in a drilled well rises to the surface under its own pressure, it is called an artesian well Due to the acts of Man, as well as Nature, water contributes to such catastrophes as floods and epidemics A deficiency of water results in droughts It should be fairly obvious that a careful and continuous study of the hydrology of a country is highly essential to the general welfare of its people (RMF, FTM)

HYDROLYMPH. The watery body fluid or blood of lower invertebrates (AWL)

HYDROLYSIS. Reactions Involving Water.

HYDROMETER. A well known device for making quick, approximate measurements of the **densities** or **specific gravities** of liquids It consists essentially of a long, slender glass float weighted at the lower end, and provided with a scale so graduated that the depth to which the instrument sinks in the liquid indicates the specific gravity by direct reading on the scale The numbering of the scale necessarily increases from the top downward The instrument is sometimes so proportioned that the numbering begins with unity at the top, being applicable only to liquids of the density of water or heavier, in others it increases from the top to unity at the lower end and is thus for use with light liquids only; in some cases it has unity at the middle and applies to both light and heavy liquids To be very sensitive, the stem carrying the scale must be slender Obviously the scale intervals corresponding to equal increments of density cannot be equal if the stem is of uniform diameter; in fact, they are inversely proportional to the square of the density, being much smaller at the lower than at the upper end of the scale To avoid this, some hydrometers are graduated with an arbitrary scale having uniform spacing, like that of Baumé, the readings of which may be converted into true density by means of a table Nicholson devised a hydrometer for measuring the densities of small solids, the specimen being placed on the hydrometer first above and then below the surface of the water in which the instrument floats, and its volume deduced from the resulting change in buoyant force (LDW)

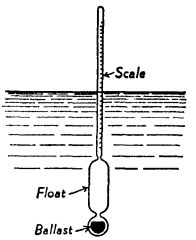


Figure 1 Ordinary hydrometer for liquids

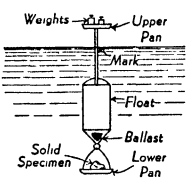


Figure 2 Nicholson's hydrometer for small solids

HYDROPHYTES OR WATER PLANTS. These plants, which can grow only where there is an abundance of water, form an interesting and very distinct group of plants Those hydrophytes which are members of the **Spermatophyta** are probably all plants which have reverted to an aquatic habitat, since it is assumed that all land plants originally evolved from plants growing in water The reverting land plants may first have become marsh plants and then gradually developed into definite hydrophytes

An aqueous environment presents conditions far more constant than an aerial one does In the tropics such conditions permit the plants to grow throughout the year In colder regions there is a definite winter period when growth must cease Many hydrophytes of temperate regions merely sink to the bottom and remain dormant during the winter Others accumulate food reserves in **rhizomes**, which remain rooted in the bottom and renew growth in the spring Still others form winter buds, consisting of large apical buds surrounded by many closely packed leaves containing much reserve food material A few hydrophytes form small tubers

The stems of hydrophytes contain a very small amount of **vascular** tissue, since support is largely afforded by the water and conduction is not a great problem In many of these plants the stem is very porous so that the plant floats in the water. The

leaves of hydrophytes are of two types Submerged leaves are thin and of various shapes, some, like **eel grass** leaves, are long and ribbon-like, others, like **bladderworts**, are finely dissected, while others are reduced to awl-shaped structures of small size Floating leaves are usually large, undivided, and with **stomata** on the upper surface Many hydrophyes show interesting leaf changes as the plant grows, leaves formed under water are finely dissected, when the stem emerges from the water it bears entire leaves By changing the water level as the stem grows it is possible to cause repeated alternation of dissected and entire leaves Once formed, the nature of the leaf cannot be changed

The submerged surface of most hydrophytes is slimy with a secretion of a mucilaginous substance which probably protects the plant against excessive diffusion of substances present in the cell-sap and also against external enemies

Reproduction in hydrophytes occurs both asexually and sexually The flowers of nearly all hydrophytes are wind and insect pollinated, apparently a hangover from the time when they lived on land A few have become modified to such an extent that **pollination** takes place on the surface of the water, the pollen floating about thereon and eventually reaching the stigma A small number of hydrophytes are pollinated under water

Nearly all **Algae** and many **Fungi** are hydrophytes, so also are several **Bryophytes** and a few **Pteridophytes** In the flowering plants there are many water plants, such as the water lilies, bladderworts, eel grass and pond-weeds Many are very interesting plants, several are aquarium plants serving to oxygenate the water, few are of any economic value (R M W)

HYDROQUININE. Alkaloids.

HYDRORHIZAE The rootlike processes by which colonies of **hydrozoan** coelenterates are attached to a supporting surface This term is in the plural The singular is hydrorhiza (A W L)

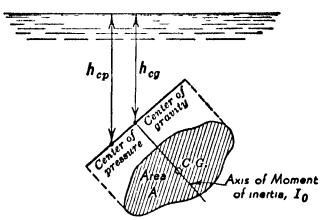
HYDROSPHERE The discontinuous envelop of **water**, both fresh and salt, which covers a major portion of the **lithosphere** The bulk of the hydrosphere is contained within the deeper depressions of the surface of the earth These depressions are termed ocean basins, and the water within them, oceans Since the ocean basins are not large enough, deep enough, to hold the entire hydrosphere the excess water is temporarily contained (geologically speaking) in fresh and salt water lakes, or as seas formed by the overflow of the oceanic waters on the continents Geologists classify seas as epicontinental (epeiric) or relict Technically, rivers and underground waters are also part of the hydrosphere In general therefore, the term hydrosphere is used mainly to distinguish the watery covering of the earth from the lithosphere on which, and in which, in part, it rests (R M F)

HYDROSTATIC PRESSURE. The pressure created by a superimposed layer of a liquid is hydrostatic pressure As the science of **hydraulics** is commonly understood, the fluid is water, and hydrostatic pressure is considered as pressure due to the existence above the point of measurement of the pressure of a head of water The intensity of hydrostatic pressure is commonly expressed as pounds per square inch A head of 2 31 feet of fresh water creates a hydrostatic pressure of one pound per square inch At a given depth of immersion in water, the pressure acts with equal intensity in all directions. that is, hydrostatic pressure is not directional in effect Hydrostatic pressures are measured by means of **pressure gages** of the Bourden tube type, or **manometers** of the U tube type (F T M)

HYDROSTATICS. This branch of physics has to do with the **equilibrium** of liquids and the laws relating to liquid **pressure.** A study of these laws makes it clear that the components of pressure in a liquid fall naturally into two classes, according to the way in which they are produced, namely, (1) pressures due to forces applied externally, as by the atmosphere or by the piston of a pump, and (2) those due to causes operating throughout the body of liquid, such as gravity or inertia

Pascal's law applies only to the first class, and states that any pressure in an enclosed liquid, originating in forces applied at its boundary, is communicated with unaltered intensity to all parts of the liquid A familiar illustration of this fundamental law is the hydraulic press, which consists of two communicating cylinders, usually of different diameter, fitted with pistons, the force acting upon one piston and the force exerted by the other being in proportion to their areas

The pressure in an enclosed liquid due to its own weight, on the other hand, increases uniformly with the depth below its highest point, and is equal to the product of the depth by the weight per unit volume For fresh water, the pressure at depth h feet is 62 4 h



Center of pressure on a submerged plane

pounds per square foot The pressure of water against a submerged plane area is equal to the average intensity of pressure times that area See **Center of Pressure.**

$$h_{cp} = \frac{I_o}{Ah_{cg}}.$$

Problems of flotation, draft, and buoyant stability, always involve the density of the liquid and the volume and shape of the floating object A floating body of weight W in a liquid of density ρ, will float with a volume v submerged, v determined by the relationship $v = \frac{W}{\rho}$ The buoyancy may be said to be the force which is equivalent to the weight of the liquid displaced by the submerged portion of the floating object Buoyancy is always equal to weight, but the two forces do not act through the same points The weight acts at the **center of gravity** of the floating object, the buoyancy through the center of gravity of the displaced liquid The relative positions of the buoyancy and the weight when a floating object is disturbed from an upright floating position, determines whether it is stable or unstable flotation If the vertical drawn through the center of buoyancy passes above the center of gravity of the body, there is a righting moment, and the body is stable, whereas if it passes below the center of gravity, it is unstable in that the buoyancy tends to tip the object still further The intersection of the line of buoyancy with the axis of symmetry of the floating body is the metacenter, and the distance from the metacenter to the center of gravity is the metacentric height The latter is used to measure the stability of a hull Another case of flotation is illustrated by the balance of the **hydrometer.** It is apparent from the above that with a given weight, the volume of immersion varies inversely with the density of the liquid In other words, a floating body rides higher in a denser liquid This fact is put to use in the hydrometer, which has a given weight and which is immersed in fluids to

measure their density. The hydrometer is calibrated to read the volume submerged directly in terms of density of the liquid

An important general principle of hydrostatics is that which determines the free liquid surface in equilibrium The direction of the surface at any point is perpendicular to the resultant of all forces acting upon a particle at that point Thus if only gravity is acting, the surface is horizontal or "level", but if there are capillary forces, or if the external pressure is not uniform, the surface is inclined An interesting case is that of a liquid rotating uniformly in a cylindrical tub, the surface then assumes the form of a paraboloid of revolution, symmetrical about the vertical axis (See **Capillarity, Barometer, Pumps, Pressure Gages,** etc) (I D W F T M)

HYDROSULFURIC ACID AND SULFIDES. Hydrosulfuric acid (H_2S) is a colorless solution formed when hydrogen sulfide is dissolved in water, decomposes slowly in the presence of air forming sulfur Hydrogen sulfide is removed completely from solution by boiling A strong reducing agent, usually with the separation of **sulfur,** e g , with **nitric acid** (nitric oxide formed), with concentrated **sulfuric acid** (**sulfur dioxide** formed), with **chlorine** (**hydrochloric acid** formed), with permanganate (**manganous** formed in the presence of acid), dichromate (**chromic** formed in the presence of acid)

Sulfides (See **Sulfur.**) (R K S)

HYDROTHERMAL METAMORPHISM. **Metamorphism.**

HYDROXYAZO COMPOUNDS. **Azo-, Diazo-, and Related Compounds.**

HYDROXYL IONS **Reactions Involving Recombinations of Ions.**

HYDROXYLAMINES AND OXIMES. Hydroxylamine (H_2NOH) is a white, odorless solid, melting point 33° C , boiling point 56° C at 22 mm, explosive, soluble in all proportions in water or alcohol Hydroxylamine is (a) a weak **base** forming with **acids** soluble salts that decompose more or less violently when heated, e g , hydroxylamine hydrochloride (hydroxylaminium chloride, $H_2NOH\ HCl$), melting point 151° C , nitrate ($H_2NOH\ HNO_3$), hemisulfate $H_2NOH\ \frac{1}{2}H_2SO_4$ Dihydroxylamine oxalate and trihydroxylamine phosphate, are insoluble in water Hydroxylamine hydrochloride is soluble in alcohol (b) a weak acid forming with bases soluble salts, e g , sodium hydroxylamate (H_2NONa)

Hydroxylamine salt solution is a powerful reducing agent, more especially in alkaline than in acid solution, for example, **cupric** salt solutions changed to cuprous oxide, **silver** salt solutions to silver, **mercuric** chloride solution to mercurous chloride, ferric salt solutions (in acid) to ferrous **Ferrous** hydroxide in sodium hydroxide is, however, oxidized by hydroxylamine to ferric hydroxide plus ammonia

Hydroxylamine reacts with carbonyl group (=CO) of **aldehydes,** ketones or quinones, yielding oximes, white solids, of definite melting point and used in identification of aldehydes and ketones, e g , acetaldehyde oxime ($CH_3CH\ NOH$)

Oximes of	Melting Point ° C.	Boiling Point ° C.
Acetaldehyde (acetaldoxime)	47	114
Acetone (dimethylketoxime)	60	136
Acetophenone (methylphenylketoxime)	59	dec.
Alpha-Benzaldehyde (anti) (benzaldoxime)	35	118 (15 mm.)
Beta-Benzaldehyde (syn)	129	
Benzophenone (diphenylketoxime)	143	
Alpha-Benzil monoxime	134	
Beta-Benzil monoxime	113	
Alpha-Benzil (syn) (benzyldioxime)	236	
Beta-Benzil (anti) (benzildioxime)	206 dec.	
Gamma-Benzil (anti) (benzildioxime)	165 (anhyd)	
Phloroglucinol (phloroglucinol-1,3,5-trioxime)	155 expl.	
Quinonemonoxime	125	144 dec.
Quinone-1, 4-dioxime	240 appr dec	
Anthraquinone-9-oxime	224 dec	

Hydroxylamine hydrochloride may be made by reduction of **nitric oxide** gas when the latter is passed into tin plus hydrochloric acid heated, then evaporating and dissolving hydrochloride in alcohol, which may be distilled off All the oxides and oxygen acids of **nitrogen,** except nitrous oxide, may be reduced to yield detectable amounts of hydroxylamine, ethyl nitrate (CH_3ONO_2) being used to advantage Better yields of hydroxylamine are reported as having been obtained by electrolytic reduction of nitrites or nitric acid

	Beta, or N-	Beta, Beta, or N, N-	Alpha, or O-
1 Hydroxylamine M P 33° C	2 Beta-phenylhydroxylamine M P 81° C.	3 Beta-beta-diphenylhydroxylamine M.P 60° C. dec.	4 Alpha-phenylhydroxylamine

Other Hydroxylamines	Formula	Melting Point ° C	Boiling Point ° C
5 Beta-Methylhydroxylamine	CH_3NHOH	42	62 (15 mm)
6 Alpha-Methylhydroxylamine	H_2NOCH_3		
7. Beta-ethylhydroxylamine	C_2H_5NHOH	59 dec.	
8 Alpha-ethylhydroxylamine	$H_2NOC_2H_5$		68
9 Beta-benzylhydroxylamine	$C_6H_5CH_2NHOH$	57	123 (50 mm.)
10 Alpha-benzylhydroxylamine	$H_2NOCH_2C_6H_5$		118 (30 mm)

Beta-phenylhydroxylamine, N-phenylhydroxylamine, is a white solid, slightly soluble in water, very soluble in alcohol or ether, forms salts with acids, e g , beta-phenylhydroxylamine hydrochloride ($C_6H_5CHNOH\ HCl$), upon exposure to air the water solution forms azobenzene ($C_6H_5N\ NC_6H_5$) Beta-phenylhydroxylamine reacts (1) with oxidizing agents, such as **chromic** acid or **ferric** chloride, to form nitrosobenzene (C_6H_5NO), (2) with reducing agents, such as tin plus hydrochloric acid, to form **aniline** ($C_6H_5NH_2$), (3) with alkaline **cupric** salt solution (Fehling's solution) at room temperature to form cuprous oxide, (4) with ammonio-**silver** salt

solution (Tollen's solution) at room temperature to form silver (5) in the presence of **hydrochloric acid** to form para-aminophenol ($HO \cdot C_6H_4 \cdot NH_2(1,4)$) See **Azo-, Diazo-, and Related Compounds.**

Beta-phenylhydroxylamine is formed by reduction of nitrobenzene (1) by zinc and calcium chloride or ammonium chloride solution, (2) by electrolysis in acetic acid plus sodium acetate solution

Diphenylhydroxylamine is prepared by reaction of nitrosobenzene and phenylmagnesium bromide in anhydrous ether, followed by treatment with water (magnesium hydroxybromide also formed) (R.K S)

HYDROZOA. A class of the phylum **Coelenterata** composed chiefly of small animals without common names Many species are colonial and the colonies of a few, such as the Portuguese man-of-war, are quite large

The class differs from the other coelenterates in the occurrence of both **hydroid polyps** and **medusae** in the same species, usually in alternating generations In many colonies additional specialization occurs among the polyps for the performance of different functions, the **gonozooids, gastrozooids,** and **dactylozooids** of the siphonophores are such individuals Hydrozoan medusae differ from the jellyfishes and are called **medusoids** In some cases they are specialized forms which remain attached to the colony and show no resemblance to medusae, but the free-swimming forms differ from medusae only in details of structure The medusoids are sexual reproductive individuals

Relatively few species of hydrozoans live in fresh water **Hydra,** the most widely known genus, includes a number of species without a medusa stage The polyps are solitary and carry on both asexual and sexual reproduction Several fresh water medusae are also known from lakes in Europe, Africa, and the Americas for which no polyp stage has been discovered The marine species are numerous

The following orders are recognized:

Order Hydrariae Small cylindrical polyps. Solitary. Mostly in fresh water

Order Hydrocorallinae Marine colonial forms with a calcareous covering which sometimes resembles coral

Order Tubulariae Mostly colonial forms Polyps without a protective sheath (hydrotheca) Medusae free or sessile, often ovoid or bell shaped

Order Campanulariae Colonial species with polyps of two kinds, **hydranths** and **blastostyles** A sheath called the perisarc invests the colony and extends about each individual polyp

Order Trachomedusae Polyps minute where known, in some species never discovered Medusae free swimming Marine and fresh water

Order Narcomedusae Marine species without known polyps Medusae with lobed margin

Order Siphonophora Free-swimming colonial species Polyps of several specialized types, in many species borne by a stalk which is expanded at one end to form a hollow float, the **pneumatophore. Portuguese man-of-war** and others (A W L)

HYENA. Mammalia, Carnivora *Hyaena* Large animals slightly resembling wolves but more closely related to the civets They live in Africa, India, and the eastern Mediterranean countries They are heavily built, with massive heads and disproportionately long front legs Hyenas are said to be cowardly and skulking but at times vicious (A W L)

HYGROMETERS. Any apparatus for measuring atmospheric **humidity,** either absolute or relative, is called a hygrometer The most common relative humidity instrument is the so-called wet-and-dry-bulb thermometer, or psychrometer Two exactly similar mercury thermometers are mounted side by side The bulb of one is wrapped in a wick dipping into water, and is thereby kept wet. This bulb is cooled by the evaporation, the rate of which, and hence the resultant cooling, depends in a definite manner upon the relative humidity of the air. A table accompanies the instrument, giving the humidity in terms of the actual air temperature as indicated by the dry-bulb thermometer, and the difference of temperature between the wet bulb and the dry bulb

The dew point hygrometer is an apparatus for indicating the **dew point,** from which the relative humidity can be calculated when the air temperature is known It usually consists of a small metallic cup or thimble, the outside of which is polished like a mirror The cup contains a small quantity of ether, into which dips a thermometer Air is bubbled through the ether, whose rapid evaporation lowers the temperature of the cup, when it reaches the dew point of the surrounding air, a film of moisture suddenly appears upon its surface

Various hygrometers have been designed which depend for their operation upon the longitudinal shrinkage of organic fibers or hairs in damp air, being arranged so that the shrinkage causes a pointer to move over a dial These instruments, called absorption hygrometers, have not, however, proved reliable and do not give consistent readings (L D.W)

HYMEN. A layer of membranous tissue which almost completely closes the outer opening of the **vagina** during virginity It may be quite tough or very delicate in structure ,In rare cases it completely closes the opening This latter condition requires surgical interference when menstruation begins (R S M)

HYMENOPTERA. One of the large orders of **insects,** including **ants, bees, wasps, saw flies,** and many species without common names The mouth is formed for biting or for biting and sucking and the wings, when present, are four in number and membranous Metamorphosis is complete The order includes plant-eating, parasitic, and predacious species, and in the ants and bees displays some of the finest examples of social organization The order includes about 70,000 species

Owing to its extent and diversity this division of the insects includes many species of economic importance Some of the saw flies and **gall wasps** are harmful to plants and on the other hand the fig insects are beneficial and the galls produced by some gall wasps are of commercial value Many parasitic species are of undoubted value in holding in check important insect pests Ants are sometimes very troublesome and the large carpenter bee sometimes damages wood in construction The most important single species is the honey-bee, which is of great value as a producer of honey and wax and in the cross pollination of fruit trees (A W L)

HYOCYAMUS. Potato **Family.**

HYOSCINE. Alkaloids.

HYOSCYAMINE. Alkaloids.

HYPABYSSAL. A general term sometimes used by structural geologists and petrologists to designate those igneous rocks such as **sills** and **dikes** which have congealed under less pressure than the **plutonic** or deep seated rocks, but under greater pressure than the effusive rocks (lavas) (R M F)

HYPERBOLA The hyperbola is one of the conic sections, and may be cut from a right circular cone by a plane which cuts both nappes of the cone

The hyperbola is the **locus** of a point which moves so that the difference of its distances from two fixed points is **constant.**

The fixed points are called the foci The curve consists of two open branches It is symmetric about the line through the foci, and about a line through the center perpendicular to the preceding line, the center is

the point midway between the foci It is also symmetric about the center (Figure 1)

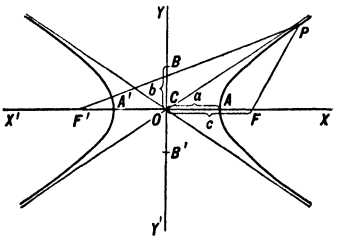


Figure 1 Hyperbola

The segment (or length) between the vertices is called the transverse axis, the vertices are the points where the curve is cut by the line through the foci The constant in the definition of the hyperbole is equal to the transverse axis length If this transverse axis is $2a$, and the distance between the foci is $2c$, then if $b^2=c^2-a^2$, $2b$ is called the conjugate axis (or sometimes the segment of this length symmetric about the center, and along the line through the center perpendicular to the line through the foci)

The latus rectum (or focal width) is the chord through the focus perpendicular to the transverse axis

The eccentricity of the hyperbola is the ratio c/a, it is > 1

If the origin of a system of **rectangular coordinates** is taken at the center of a hyperbola, and the X-axis along the transverse axis, the equation of the curve is

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1,$$

where a and b are the semi-transverse and semi-conjugate axes

The equation $\frac{x^2}{b^2} - \frac{y^2}{a^2} = 1$ $(a > b)$ represents a hyperbola with foci on the Y-axis.

The lines $x = \pm \frac{a}{e}$ are called the directrices of the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ They have the property that the ratio of the distance of any point of the hyperbola from a focus to the perpendicular distance of the point from the corresponding directrix is equal to the eccentricity

The equation $\frac{(x-h)^2}{a^2} - \frac{(y-k)^2}{b^2} = 1$ represents an hyperbola with center at (h, k) and axes of symmetry $x = h$, $y = k$.

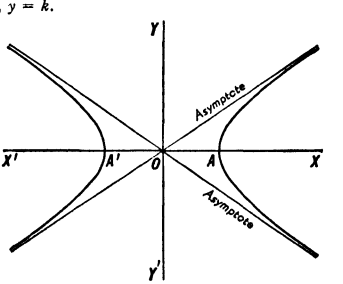


Figure 2 Hyperbola

The hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ has the lines $\frac{x}{a} + \frac{y}{b} = 1$ and $\frac{x}{a} - \frac{y}{b} = 1$ as **asymptotes** (Figure 2)

The branches of the hyperbola approach indefinitely near its asymptotes as the tracing point recedes to infinity

The asymptotes serve as a convenient guide in drawing the hyperbola

Two hyperbolas are called conjugate hyperbolas if the transverse and conjugate axes of one are, respectively, the conjugate and transverse axes of the other If $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ is one hyperbola, the conjugate is $\frac{y^2}{b^2} - \frac{x^2}{a^2} = 1$

Two conjugate hyperbolas have the same asymptotes

A construction (by continuous motion) based on the definition is the following (Figure 3) Fasten thumb

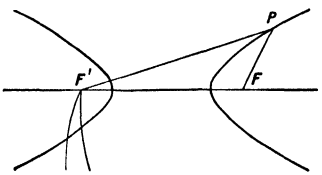


Figure 3 Construction of hyperbola

tacks at the foci Pass over F' and around F a string whose ends are held together If a pencil is tied to the string at P, and both strings are pulled in or let out the same length, the P will describe a hyperbola If the transverse axis is to be $2a$, the strings must be adjusted at the start so that the difference between PF' and PF is $2a$

An equilateral or rectangular hyperbola is one in which the transverse and conjugate axes are equal If its center is at the origin and its transverse axis is along the X-axis, its equation is $x^2 - y^2 = a^2$, where a equals the semi-transverse or conjugate axis

Its asymptotes bisect the quadrants and are therefore perpendicular.

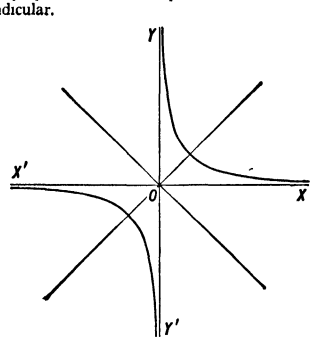


Figure 4 Hyperbola

If the hyperbola be referred to its asymptotes as rectangular coordinate axes, its equation becomes $2xy = a^2$. (Figure 4)

A construction often used for an equilateral hyperbola when the asymptotes and one point A on the curve are given is as follows (Figure 5)

Let OX and OY be the asymptotes and A the given point Draw any line through A to meet OX at M and OY at N Lay off $MP = AN$ Then P is a point on the required hyperbola

The simplest **parametric equations** of an hyperbola are

$$x = a \sec \phi, \qquad y = b \tan \phi,$$

where a and b are the semi-axes, and ϕ is an auxiliary angle

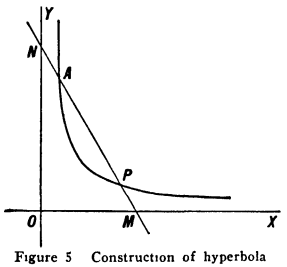


Figure 5 Construction of hyperbola

The equation of the **tangent** to the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ at the point (x_1, y_1) is $\frac{x_1 x}{a^2} - \frac{y_1 y}{b^2} = 1$.

The equation of the **tangent** of **slope** m to the hyperbola $\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$ is

$$y = mx \pm \sqrt{a^2 m^2 - b^2}$$

Applications of the hyperbola are Boyle's law in physics, and sound ranging (L L S)

HYPERBOLIC FUNCTIONS In many applications the **exponential functions** e^x and e^{-x} occur in certain combinations which have many analogies to the **trigonometric functions** Their geometric representation is related to a **rectangular hyperbola** in a way similar to that in which the trigonometric functions are related to a **circle** These combinations are therefore called hyperbolic functions

The hyperbolic functions are defined as follows

$$\sinh x = \tfrac{1}{2}(e^x - e^{-x}),$$
$$\cosh x = \tfrac{1}{2}(e^x + e^{-x}),$$
$$\tanh x = \frac{\sinh x}{\cosh x} = \frac{e^x - e^{-x}}{e^x + e^{-x}},$$
$$\coth x = \frac{\cosh x}{\sinh x} = \frac{1}{\tanh x} = \frac{e^x + e^{-x}}{e^x - e^{-x}},$$
$$\operatorname{sech} x = \frac{1}{\cosh x} = \frac{2}{e^x + e^{-x}},$$
$$\operatorname{csch} x = \frac{1}{\sinh x} = \frac{2}{e^x - e^{-x}}$$

From these definitions follows at once

$$\cosh x + \sinh x = e^x,$$
$$\cosh x - \sinh x = e^{-x}$$

Fundamental relations between these functions are

$$\cosh^2 x - \sinh^2 x = 1,$$
$$\tanh^2 x + \operatorname{sech}^2 x = 1,$$
$$\coth^2 x - \operatorname{csch}^2 x = 1$$

For the negative of the variable we have

$$\sinh(-x) = -\sinh x,$$
$$\cosh(-x) = \cosh x,$$
$$\tanh(-x) = -\tanh x,$$
etc

For the hyperbolic functions of the sum of two variables and of double and half the variable, we have the formulas

$$\sinh(x \pm y) = \sinh x \cosh y \pm \cosh x \sinh y,$$
$$\cosh(x \pm y) = \cosh x \cosh y \pm \sinh x \sinh y,$$
$$\tanh(x \pm y) = \frac{\tanh x \pm \tanh y}{1 \pm \tanh x \tanh y},$$
$$\sinh u + \sinh v = 2 \sinh \tfrac{1}{2}(u + v) \cosh \tfrac{1}{2}(u - v),$$
$$\sinh u - \sinh v = 2 \cosh \tfrac{1}{2}(u + v) \sinh \tfrac{1}{2}(u - v),$$
$$\cosh u + \cosh v = 2 \cosh \tfrac{1}{2}(u + v) \cosh \tfrac{1}{2}(u - v),$$
$$\cosh u - \cosh v = 2 \sinh \tfrac{1}{2}(u + v) \sinh \tfrac{1}{2}(u - v),$$
$$\sinh 2x = 2 \sinh x \cosh x,$$
$$\cosh 2x = \cosh^2 x + \sinh^2 x = 2\cosh^2 x - 1 = 2\sinh^2 x + 1,$$
$$\tanh 2x = \frac{2 \tanh x}{1 + \tanh^2 x},$$
$$\sinh \tfrac{1}{2}x = \pm \sqrt{\frac{\cosh x - 1}{2}},$$
$$\cosh \tfrac{1}{2}x = \sqrt{\frac{\cosh x + 1}{2}},$$
$$\tanh \tfrac{1}{2}x = \pm \sqrt{\frac{\cosh x - 1}{\cosh x + 1}}.$$

The inverse hyperbolic functions are defined as are all **inverse functions** Thus, if $x = \sinh y$, then we write $y = \sinh^{-1} x$

We find that the inverse hyperbolic functions can be expressed in terms of **natural logarithms**, as follows

$$\sinh^{-1} x = \log(x + \sqrt{1 + x^2}),$$
$$\cosh^{-1} x = \log(x \pm \sqrt{x^2 - 1}), \quad x \geqq 1,$$
$$\tanh^{-1} x = \tfrac{1}{2} \log \frac{1 + x}{1 - x}, \quad -1 < x < 1,$$
$$\coth^{-1} x = \tfrac{1}{2} \log \frac{x + 1}{x - 1}, \quad -1 < x < 1,$$
$$\operatorname{sech}^{-1} x = \log \frac{1 \pm \sqrt{1 - x^2}}{x}, \quad 0 < x < 1,$$
$$\operatorname{csch}^{-1} x = \log \frac{1 + \sqrt{1 + x^2}}{x}.$$

The **derivatives** of the hyperbolic functions and of the inverse hyperbolic functions are

$$\frac{d}{dx}(\sinh u) = \cosh u \frac{du}{dx}, \quad \frac{d}{dx}(\cosh u) = \sinh u \frac{du}{dx},$$
$$\frac{d}{dx}(\tanh u) = \operatorname{sech}^2 u \frac{du}{dx}, \quad \frac{d}{dx}(\coth u) = -\operatorname{csch}^2 u \frac{du}{dx},$$
$$\frac{d}{dx}(\operatorname{sech} u) = -\operatorname{sech} u \tanh u \frac{du}{dx},$$
$$\frac{d}{dx}(\operatorname{csch} u) = -\operatorname{csch} u \coth u \frac{du}{dx};$$
$$\frac{d}{dx}(\sinh^{-1} u) = \frac{1}{\sqrt{u^2 + 1}} \frac{du}{dx},$$
$$\frac{d}{dx}(\cosh^{-1} u) = \pm \frac{1}{\sqrt{u^2 - 1}} \frac{du}{dx},$$
$$\frac{d}{dx}(\tanh^{-1} u) = \frac{1}{1 - u^2} \frac{du}{dx},$$
$$\frac{d}{dx}(\coth^{-1} u) = \frac{1}{1 - u^2} \frac{du}{dx},$$
$$\frac{d}{dx}(\operatorname{sech}^{-1} u) = \pm \frac{1}{u\sqrt{1 - u^2}} \frac{du}{dx},$$
$$\frac{d}{dx}(\operatorname{csch}^{-1} u) = -\frac{1}{u\sqrt{1 + u^2}} \frac{du}{dx}.$$

Certain standard **indefinite integral** forms are conveniently expressed in terms of hyperbolic functions, thus

$$\int \frac{du}{\sqrt{u^2 + a^2}} = \sinh^{-1} \frac{u}{a} + C,$$
$$\int \frac{du}{\sqrt{u^2 - a^2}} = \pm \cosh^{-1} \frac{u}{a} + C,$$
$$\int \frac{du}{a^2 - u^2} = \frac{1}{a} \tanh^{-1} \frac{u}{a} + C$$

Expansion of the hyperbolic functions into **series** gives

$$\sinh x = x + \frac{x^3}{3!} + \frac{x^5}{5!} + \frac{x^7}{7!} + \cdots,$$
$$\cosh x = 1 + \frac{x^2}{2!} + \frac{x^4}{4!} + \frac{x^6}{6!} + \cdots$$

The hyperbolic functions are related to the trigonometric functions by the following formulas, in which $i = \sqrt{-1}$,

$$\sin(ix) = i \sinh x, \quad \cos(ix) = \cosh x,$$
$$\sinh(ix) = i \sin x, \quad \cosh(ix) = \cos x.$$

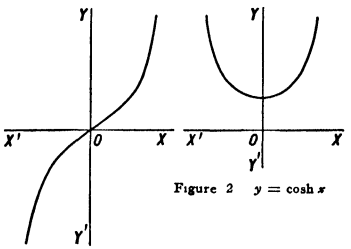


Figure 1. $y = \sinh x$

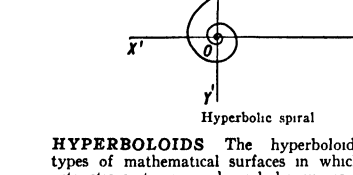


Figure 2 $y = \cosh x$

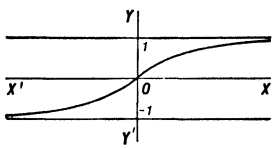


Figure 3 $y = \tanh x$

The graphs of the hyperbolic functions are shown in the Figures 1–3

The hyperbolic functions are related to the hyperbola as follows (Figure 4) Take the rectangular hyperbola $x^2 - y^2 = 1$, let $P(x, y)$ be any point on the hyperbola, and let u be the area of the sector OAP between the curve, the X-axis and OP Then

$$x = \cosh 2u, \quad y = \sinh 2u.$$

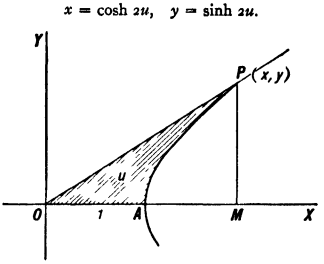


Figure 4 Hyperbolic sector

The function $\tan^{-1}(\sinh x)$ is called the gudermannian of x and is denoted by gd x Then

$$\frac{d}{dx}(\text{gd } x) = \text{sech } x, \quad \int \text{sech } x \, dx = \text{gd } x$$

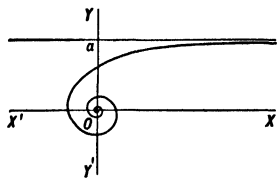
(LLS)

HYPERBOLIC GEOMETRY. Non-Euclidean Geometry.

HYPERBOLIC LOGARITHMS. Logarithms.

HYPERBOLIC PARABOLOID. Paraboloids.

HYPERBOLIC SPIRAL. The plane curve whose polar coordinate equation is $r\theta = a$ is called a hyperbolic spiral It is shown in the accompanying figure. (LLS)



Hyperbolic spiral

HYPERBOLOIDS The hyperboloids are certain types of mathematical surfaces in which certain characteristic sections are hyperbolic curves

The **surface** represented in **rectangular coordinates** by the equation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

is called an (elliptic) hyperboloid of one sheet, its sections parallel to the coordinate planes are one set **elliptic** and two sets **hyperbolic** (Figure 1)

If $a = b$, one set of sections becomes circular and we have a hyperboloid of revolution (of one sheet), which may be obtained by revolving a **hyperbola** about its conjugate axis

The surface represented in rectangular coordinates by the equation

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

is called an (elliptic) hyperboloid of two sheets, its sections parallel to the coordinate planes are one set elliptic and two sets hyperbolic (Figure 2)

If $b = c$, one set of sections becomes circular, and we have an hyperboloid of revolution (of two sheets), which may be generated by revolving an hyperbola about its transverse axis (LLS)

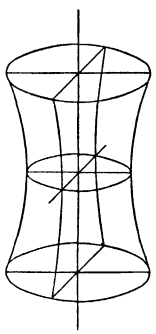


Figure 1 Hyperboloid of one sheet

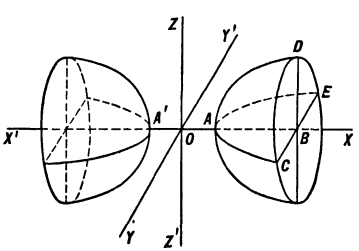


Figure 2 Hyperboloid of two sheets

HYPERBOLOIDS OF REVOLUTION. Hyperboloids.

HYPERCOMPLEX NUMBERS. A hypercomplex number is a number represented by a form $x = x_1e_1 + x_2e_2 + \quad + x_ne_n$, in which $x_1, x_2, \quad , x_n$ are ordinary real or complex numbers, and $e_1, e_2, \quad , e_n$ are n independent units (LLS.)

HYPERFINE STRUCTURE. Many spectrum lines, when examined under high resolution, turn out to be

"multiplets," i e, to be composed of two, three, four, or more, closely packed, fine lines (See **Atomic Spectra.**) This multiplicity is attributed to a quantization (successive, finite differences) in the energy of rotation of the atomic nucleus Abrupt changes in this energy take place simultaneously with the much larger electronic transitions which determine the location of the multiplet as a whole The rotational quantization thus results in slight differences in the total energy of the emitted quanta, and hence in a group of different frequencies Atomic spectra often have series of multiplets For example, the two D lines of sodium belong to a series of doublets Hartley (1883) found that all the multiplets of a given series have the same frequency separations between their components Kossel and Sommerfeld pointed out that the arc spectra of elements of even atomic number have odd multiplets, and *vice versa*. Thus sodium (**atomic number** 11) exhibits doublets, and zinc (30), triplets See also **Zeeman Effect** and **Stark Effect.** (L D W)

HYPERHARMONIC SERIES. The infinite series $\sum_{1}^{\infty} 1/n^p$ is called the hyperharmonic series, it is **convergent** when $p > 1$ and is **divergent** when $p \leq 1$ (L L S)

HYPERMASTIGIDA. Mastigophora.

HYPERMETROPIA. Vision.

HYPEROARTIA. Cyclostomata.

HYPEROTRETA. Cyclostomata.

HYPERSTHENE. The mineral hypersthene is an **orthorhombic pyroxene,** chemically a ferro-magnesian silicate, differing from enstatite in that the **iron** content is considerable (FeO being greater than 15%) It is usually found as a massive mineral, whose crystals tend to be prismatic or tabular in habit It has a distinct prismatic **cleavage, fracture,** uneven, brittle, hardness, 5–6, specific gravity, 3 4–3 5, luster, pearly to somewhat metallic, color, brownish green, brown, greenish black to grayish black, streak, grayish brown Translucent to opaque Hypersthene is often associated with **labradorite** in **gabbro** and **norite** and in extrusive rocks like **andesite.** It is occasionally encountered in **meteorites.** Hypersthene is associated with **pyrrhotite** in Bavaria, with labradorite on the Isle St Paul, Labrador It is also found in Montmorency County, Quebec, and in the United States in the rocks of the Cortlandt series in the Hudson River Valley, and the **andesites** of Colorado and northern California The word hypersthene comes from the Greek words meaning *strong* or *tough* (E S C S)

HYPERTHYROIDISM. Thyroid Gland.

HYPERTROPHY. This is the excessive growth or development of any part of an organ or organism (R M W)

HYPHA. Basidomycetes.

HYPIDIUM. Pleistocene.

HYPNOTIC. Any remedy or **drug** used to induce or maintain sleep Drugs of this order produce their effect by depressing the higher centers of the **brain.** It is the excitability of these higher centers which often prevents sleep. Natural sleep may follow the depression of these centers but the hypnotic does not directly or primarily induce natural sleep Because of the nervous factors involved in insomnia the taking of hypnotic drugs may easily lead to a mental drug habit Common drugs of this nature are· chloral, "veronal," "amytal," "allanol," bromides, "luminal," "dial," and "nembutol" (R S M)

HYPO. Sodium thiosulfate.

HYPOBROMITE. Hypobromous Acid and Hypobromites.

HYPOBROMOUS ACID AND HYPOBROMITES. Hypobromous acid (HOBr) is a yellow solution, of characteristic odor It is unstable and when distilled under reduced pressure solutions containing only less than 1% can be obtained, decomposes into **bromine** and **bromic acid,** completely at 60° C into bromine (and water)

Prepared by reaction (1) of bromine and mercuric oxide suspension in water, mercuric bromide being simultaneously formed, (2) of sodium hypobromite and an acid, excess acid yielding bromine

Sodium hydroxide solution reacts with bromine to form bromide and hypobromite

Sodium hypobromite solution reacts with ammonium salts or urea yielding nitrogen gas quantitatively. (R K S)

HYPOCHLORITE. Hypochlorous Acid and Hypochlorites.

HYPOCHLOROUS ACID AND HYPOCHLORITES. Hypochlorous acid (HOCl) is a yellow solution of characteristic odor It decomposes upon standing, the rate depending upon the concentration, the exposure to light, upon the presence of a **catalyst,** such as cobaltous hydroxide (See **Cobalt**), which promotes the evolution of oxygen, and upon the acidity or alkalinity A powerful oxidizing agent, e g, manganous chloride solution changed to **manganese** dioxide, insoluble, by calcium or sodium **hypochlorite,** and prolonged boiling yields green manganate solution or pink permanganate solution, and bleaching agent for many organic colors

Prepared by the reaction (1) of **chlorine** monoxide (Cl_2O) and water, (2) of sodium hypochlorite and an acid, excess acid yielding **chlorine** and oxygen, (3) of chlorine and mercuric (See **Mercury**) oxide suspension in water, mercuric chloride being simultaneously formed

All hypochlorites are soluble in water, and the solutions are decomposed at 100° C to form the corresponding chlorate and chloride The most important hypochlorites are those of sodium, calcium, and silver, which last substance decomposes quickly to form silver chloride, white precipitate, and silver chlorate in solution Sodium hydroxide solution reacts with chlorine to form chloride and hypochlorite Sodium hypochlorite solution reacts with ammonium salts or urea yielding nitrogen gas quantitatively A common means of detecting hypochlorites is the production of a blue color (caused by free **iodine**) with starch iodide paper by hypochlorites in weakly alkaline solution Again, **silver** nitrate solution precipitates part of the hypochlorite as white silver chloride (R K S)

HYPOCHONDRIA. Undue anxiety about one's own health, often accompanied by simulated symptoms of disease and some degree of melancholia (R S M)

HYPOCOTYL Seed.

HYPOCYCLOID. A hypocycloid is a type of mathematical plane curve defined as follows

If a circle of radius b rolls upon the interior of a fixed circle of radius a, a point on the first circle describes a

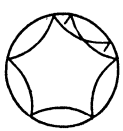


Figure 1.

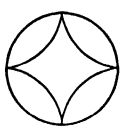


Figure 2.

Hypocycloids.

hypocycloid (Figure 1) Its **parametric equations** are

$$x = (a - b)\cos\theta + b\cos\left(\frac{a-b}{b}\theta\right),$$
$$y = (a - b)\sin\theta - b\sin\left(\frac{a-b}{b}\theta\right)$$

When $a = 4b$, we get the hypocycloid of four cusps also called the astroid (Figure 2) Its equation in **rectangular coordinates** is

$$x^{2/3} + y^{2/3} = a^{2/3}$$

It has **parametric equations** of the form $x = a\cos^3\phi$, $y = a\sin^3\phi$ (L L S)

HYPODERMIS The cellular layer of the integument (**integumentary system**) in the invertebrates, which secretes the outer **cuticula.** (A.W L)

HYPOGYNY. Fruit.

HYPOIODITE. Hypoiodous Acid and Hypoiodites.

HYPOIODOUS ACID AND HYPOIODITES. Hypoiodous acid (HOI) is a greenish yellow solution, of characteristic odor It is unstable, and cannot be distilled unchanged

Prepared by reaction (1) of **iodine** and mercuric oxide (See **Mercury**) suspension in water, mercuric iodide being simultaneously formed, (2) of sodium hypoiodite and an acid, excess acid yielding iodine

Sodium hydroxide solution reacts with iodine to form iodide and hypoiodite, the latter decomposing in a few hours at ordinary temperatures to form iodide and iodate (R K S)

HYPONITROUS ACID AND HYPONITRITES. Hyponitrous acid ($H_2N_2O_2$) is a white solid, explosive even at as low a temperature as 0° C, soluble in water, more soluble in ether, can thus be extracted from water solution by ether and the latter evaporated, water solution decomposes quickly into nitrous oxide plus water Hyponitrous acid is non-reactive with **hydriodic acid** (a strong reducing agent), but reactive with permanganic (See **Manganese**) acid (a strong oxidizing agent) to form **nitrous** or **nitric acid**

Prepared (1) by reaction of **silver** hyponitrite ($Ag_2N_2O_2$) and **hydrogen chloride** in anhydrous ether, and evaporation of the resulting solution, (2) by reaction of **hydroxylamine** (H_2NOH) plus **nitrous acid** (HONO)

Sodium hyponitrite ($Na_2N_2O_2$) is formed (1) by reaction of **sodium** nitrate or nitrite solution with sodium amalgam (sodium dissolved in mercury), after which **acetic acid** is added to neutralize the alkali Sodium stannite (See **Tin**), **ferrous** hydroxide, or **electrolytic** reduction with mercury cathode may also be utilized, (2) by reaction of hydroxylamine sulfonic acid and sodium hydroxide Silver hyponitrite is formed by reaction of silver nitrate solution and sodium hyponitrite (R K S)

HYPOPHARYNX. A protuberance on the floor of the mouth of **insects.** It is somewhat similar to the tongue of vertebrates and is sometimes called the lingua (A W L)

HYPOPHOSPHORIC ACID AND HYPOPHOSPHATES. Hypophosphoric acid ($H_4P_2O_6$ or $H_4P_2O_6$) is a solid, melting point 55° C, decomposing in solution to form **phosphorus** plus **phosphoric acids** Hypophosphoric acid is used in solution and is a reducing agent, but only with strong oxidizing agents, such as **potassium** permanganate, and the acid is unaffected by zinc and dilute **sulfuric acid** (distinction from phosphorous acid) Dehydration of hypophosphoric acid does not yield phosphorous **tetroxide;** hydration of phosphorous tetroxide does not yield hypophosphoric acid but phosphorus plus phosphoric acids

Hypophosphoric acid is formed by reaction (1) of yellow phosphorus and potassium permanganate in sodium hydroxide medium, (2) of red phosphorus and calcium hypochlorite solution, (3) also one of the products of slow oxidation at ordinary temperatures of phosphorus in moist air

There are recorded the following sodium hypophosphates Na_3PO_3 (or $Na_4P_2O_6$), $NaHPO_3$ (or $Na_2H_2P_2O_6$), $Na_3H(PO_3)_2$ (or $Na_3HP_2O_6$), $NaH_3(PO_3)_2$ (or $NaH_3P_2O_6$); and the dimethyl ester of hypophosphoric acid $(CH_3O)_2PO$ There is evidence in support of each of the formulas H_2PO_3, $H_4P_2O_6$ for hypophosphoric acid

Ester Dimethyl hypophosphate ($(CH_3)_2PO_3$ or $(CH_3O)_2PO$) (R K S)

HYPOPHOSPHOROUS ACID AND HYPOPHOSPHITES. Hypophosphorous acid (H_3PO_2, or $H\,PO_2H_2$) is a colorless liquid, melting point 26.5° C, density 1.493

Hypophosphorous acid is miscible with water in all proportions and a commercial strength is 30% H_3PO_2 Hypophosphites are used in medicine

Hypophosphorous acid is a powerful reducing agent, e.g., with **copper** sulfate forms cuprous hydride (Cu_2H_2), brown precipitate, which evolves hydrogen gas and leaves copper on warming, with **silver** nitrate yields finely divided silver, with **sulfurous acid** yields sulfur and some hydrogen sulfide, with **sulfuric acid** yields sulfurous acid, which reacts as above, forms **manganous** immediately with permanganate

Hypophosphorous acid is formed by reaction of **barium** hypophosphite and sulfuric acid, and filtering off barium sulfate By evaporation of the solution in vacuum at 80° C, and then cooling to 0° C, hypophosphorous acid crystallizes

Sodium hypophosphite ($NaPO_2H_2$), the only sodium hypophosphite, is formed (1) by reaction of yellow **phosphorus** and sodium hydroxide solution (phosphine simultaneously formed), (2) by reaction of hypophosphorous acid and sodium hydroxide, and evaporating Sodium hypophosphite, upon heating, yields sodium phosphate and sodium phosphide Common tests for the hypophosphites are as follows

1. Zinc reduces dilute **sulfuric acid** solution of hypophosphites to **phosphine** recognizable by odor (difference from phosphates)
2. **Barium** chloride produces no precipitate (difference from phosphites) (R K S)

HYPOPHYSIS. An **endocrine gland** attached to the ventral surface of the brain, also called the **pituitary gland** (A W L)

HYPOPUS A **larval** form of certain **mites.** It has eight legs but no mouth Ventral suckers enable it to attach itself to another animal for transportation (A W L)

HYPOPYGIUM. The protruding male genital organs of some flies In some species they form a conspicuous appendage at the tip of the abdomen, much like an additional segment (A W L)

HYPOSTOME. A projection at the free end of the body of a **hydroid** polyp in which the mouth opens (A W L)

HYPOSULFUROUS ACID AND HYPOSULFITES. Hyposulfurous acid ($H_2S_2O_4$) is a yellow solution rapidly oxidized in air to sulfurous acid and then to sulfuric acid

Hyposulfurous acid is a powerful reducing agent, e.g., with **copper** sulfate forms cuprous hydride (Cu_2H_2), brown precipitate, which evolves hydrogen gas and leaves copper on warming, with **silver** nitrate yields finely divided silver, with permanganate yields **manganous.**

Hyposulfurous acid is formed by reaction of sodium hyposulfite and an acid.

Sodium hyposulfite, sodium hydrosulfite ($Na_2S_2O_4 \cdot 2H_2O$) is formed (1) by reaction of **zinc** and **sulfurous acid** (or sodium hydrogen sulfite), yielding zinc hyposulfite and then converted by sodium chloride into sodium hyposulfite, (2) by **electrolysis** of sodium hydrogen **sulfite** and then addition of sodium chloride.

Sodium hyposulfite is used to bleach sugar, indigo, wood pulp. With moist **hydrogen sulfide, sulfur** is precipitated and sodium thiosulfate simultaneously formed. (R.K.S.)

HYPOTHYROIDISM. Thyroid Gland.

HYPOTRICHIDA. Ciliata.

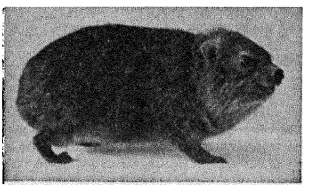
HYPOXANTHINE. Alkaloids.

HYRACODON. Oligocene.

HYRACOIDEA. The hyraces, less properly called the coneys. They are small animals, superficially resembling rodents. The fore feet have four toes and the hind feet three, part of them with nails instead of claws. The several species live throughout Africa and some extend north to Syria. An order of **mammals.** (A.W.L.)

HYRACOTHERIUM. (Eophippus). **Fossil Mammals.**

HYRAX. Mammalia, Hyracoidea. Any of the small



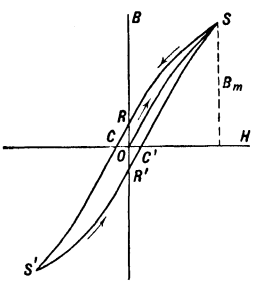
Hyrax. (Courtesy of *N. Y. Zool. Soc.*)

animals of this order. There are two genera, *Procavia*, which includes the **cony,** and *Dendrohyrax*. (A.W.L.)

HYSTERECTOMY. The operation of removing the **uterus.** This is usually done by a lower abdominal incision although in certain instances it has been removed by the vaginal route. Hysterectomy is usually done for **cancer** and fibroids of the uterus. (R.S.M.)

HYSTERESIS. This term usually refers to magnetic hysteresis, of importance in **alternating-current** machinery. When a ferromagnetic material such as iron is placed in a magnetic field, a certain amount of energy is involved in bringing about its magnetization. If the field is a rapidly alternating one, the material may become noticeably warm. It appears that the repeated changes of orientation in whatever it is within the substance that responds to the reversals of field are opposed by something like viscous friction.

A quantitative study of the process indicates that, as the field intensity H increases, the magnetic induction B also increases in a manner characteristic of the substance. This is conveniently represented by a graph, such as OS (see figure). Upon reducing the intensity H, the induction B does not fall off as it was built up, but follows a different course, SRC, so that there is some residual induction OR even when H has fallen to zero. A reverse intensity OC, called the coercive force, must be applied to demagnetize the material completely. From this point the cycle proceeds over the path $CS'R'C'S$, thus completing a closed curve called a hysteresis loop. The initial graph OS is not retraced. The amount of energy converted into heat during the cycle is proportional to the area of the loop. Steinmetz found that this energy is represented by the formula $aB_m^{1.6}$ in which B_m is the maximum induction during the cycle, and a is a constant for the given material, called the Steinmetz coefficient. An instrument known as a hysteresigraph has been devised to trace hysteresis loops automatically for any specimen of magnetic material under test.



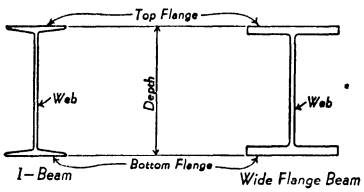
Typical B-H hysteresis curve for a ferromagnetic material.

Electric hysteresis is a somewhat analogous phenomenon exhibited by **dielectrics** in the electric field and gives rise to heating in alternating-current condensers. (L.D.W.)

HYSTERIA. A psychoneurotic state, often seen in woman, characterized by emotional instability, morbid fear or self-consciousness, simulation of symptoms of various diseases, lack of control over actions and exaggerated sensory impressions. Some of the signs and symptoms often found are pain, especially in abdomen, head and back, lack of sensation in various parts of the body, eye symptoms and choking sensations. In marked cases spasms, convulsions, paralysis, retention of urine in the bladder and even hallucinations, especially of a religious or sexual nature occur. (R.S.M.)

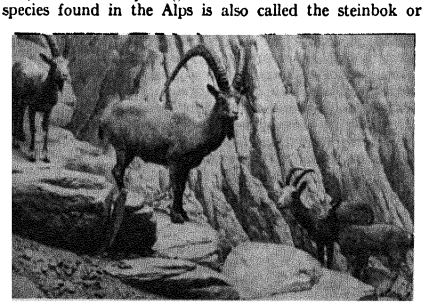
I

I-BEAM. An I-beam is a structural shape whose cross-section resembles the capital letter I. The I-beam is rolled from **steel** for ordinary use. **Aluminum** is sometimes used where the structure must be exceptionally light as in the case of bridge floors. Brass and other materials are also used. The size is designated by its overall depth from the top of the top **flange** to the bottom of the lower flange, and by its weight per foot of length. A beam of this shape has a disposition of material such as to allow the material to be stressed most efficiently, thus reducing waste due to inclusion of



slightly stressed material. A beam, carrying **load,** deflects slightly, which puts part of the beam in compression and part in tension. The farther a given amount of beam material is from the **neutral axis,** the more effective it is in resisting load. (See **Flexure** theory.) The I-beam with its two flanges, connected by a thin vertical web, provides the proper resistant to load with a minimum of material. When the proportions of width to depth are nearly equal the beam is known as an H beam. Another type of I-shape beam is called the wide flange beam. This is a popular shape for building columns and floor beams. (C.W.C., F.T.M.)

IBEX. Mammalia, Artiodactyla. **Goats** of several species, all with very large horns in the male sex. The species found in the Alps is also called the steinbok or



Alpine ibex. (Courtesy of the *Field Museum of Natural History.*)

bouquetin (*Capra ibex*) and the Arabian species is called the beden. Others live in Egypt and the Himalayas. (A.W.L.)

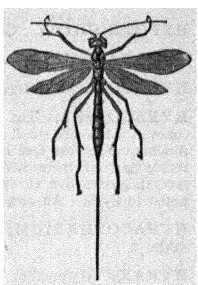
IBIS. Aves, Ciconiiformes. *Ibis.* Long-legged wading birds (**Aves**) with long curved beaks. Related to the storks. The numerous species occur in all continents. (A.W.L.)

ICE CALORIMETER. Calorimetry.

ICELAND MOSS. Lichens.

ICELAND SPAR. Calcite.

ICHNEUMON. 1. Insecta, Hymenoptera. Any **insect** of a large number of species which live as parasites on other insects in the larval stage. They resemble wasps in appearance. 2. Mammalia, Carnivora. The Egyptian **mongoose,** *Herpestes ichneumon.* (A.W.L.)



Ichneumon fly.

ICHTHYOLOGY. The science that deals with facts pertaining to fishes (**Pisces**). The species of fishes are so numerous that the classification of the group is an important part of this science, and their value as food is so great that the regulation of fisheries and measures for maintaining the supply of food and game fishes make up an important practical field. (A.W.L.)

ICHTHYOPSIDA. **Cyclostomes, fishes,** and **amphibians,** a division of vertebrates characterized by moist skin and by the presence of gills during part or all of the life. The eggs are usually deposited in the water and the embryo develops without an **amnion,** hence the name Anamnia is also applied to the group. (A.W.L.)

ICHTHYORNIS. Fossil birds.

ICHTHYOSAUR. Fossil Reptiles.

ICTERUS. Jaundice.

IDE. Pisces, Teleostei. A European fish (**Pisces**) *Idus idus,* related to the roach and dace. (A.W.L.)

IDEAL GAS LAW. An "ideal gas" would, if kept at a constant temperature, behave as respects volume and pressure in strict accord with **Boyle's law.** If now the temperature is also allowed to vary, we must combine the **law of Charles** (or of Gay Lussac) with Boyle's law, yielding the **Boyle-Charles law:**

$$pv = p_0v_0(1 + at), \qquad (1)$$

in which p_0v_0 is the value of the pressure-volume product pv when the temperature t is zero, a is the coefficient of expansion of the gas, practically the same for all gases, and in the ideal case equal to the reciprocal of the absolute temperature of the scale zero. If the centigrade scale is used, the value of a is approximately $1/273.2$ per degree. Substituting this, Eq. (1) may be written

$$pv = \frac{p_0v_0}{273.2^\circ}(t + 273.2^\circ), \qquad (2)$$

which is one expression for the ideal gas law.

The factor $t + 273.2^\circ$ will be recognized as the **absolute temperature** T of the gas. And since the gas obeys Boyle's law, the product p_0v_0 is constant however p_0 and v_0 may vary between themselves. We may thus denote the coefficient $p_0v_0/273.2^\circ$ by a single constant symbol, say R, and the ideal gas equation then takes the usual form

$$pv = RT. \qquad (3)$$

The value of R depends, of course, upon the quantity of gas used, since at any pressure p_0 it is proportional to the volume v_0 For one gram of air, R equals about $2{,}868{,}000 \frac{\text{g cm}^2}{\text{sec}^2 \text{ deg}}$ At the zero of temperature and at any given pressure p_0, the gram molecular weights, or mols, of all pure gases have equal volumes Hence if one mol of any pure gas is used, R will always have the same value, in c g s units about $83{,}136{,}000 \frac{\text{g cm}^2}{\text{sec}^2 \text{ deg}}$, which is called the "ideal gas constant" Many physical formulae involve a quantity which may be regarded as the ideal gas constant per molecule, that is, the above molar gas constant divided by the number of molecules in a mol, $6\,064 \times 10^{23}$, giving $1\,371 \times 10^{-16} \frac{\text{g cm}^2}{\text{sec}^2 \text{ deg}}$ This is the "Boltzmann constant"

Since actual gases, even those with the smallest molecules, hydrogen and helium, do not obey the ideal gas law exactly, various empirical **characteristic equations** have been devised to represent their behavior (L D W)

IDENTITIES. An identity is an **equality** in which both members are equal for all values of the symbols for which the members are defined

In an identity, either member can be transformed into the other by use of the fundamental rules of operation An identity involves a difference of form but not of value

An identity is frequently indicated by putting the symbol $\equiv$ between the two members Thus, $(a+b)(a-b) \equiv a^2 - b^2$ (L L S)

IDIOBLAST A term proposed by Becke, in 1903 for pseudo-idiomorphic crystals occurring in the **metamorphic** rocks (R M F)

IDIOCY. Complete congenital imbecility See **Mental Deficiency.** (R S M)

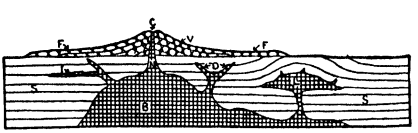
IDIOMORPHIC. The term proposed by Rosenbusch for those minerals in **igneous** rocks which are well crystallized and therefore display their **crystal** form with a high degree of perfection See also **Euhedral** and **Automorphic.** (R M F)

IDIOSYNCRASY. (1) Individual or peculiar susceptibility to any drug, food, or any physical or chemical agent (2) A habit or temperament peculiar to any individual (R S M)

IDOCRASE. **Vesuvianite.**

INDURATED. This term as used by petrologists signifies rocks which have been hardened by the action of heat (R M F)

IGNEOUS ROCK. Igneous rocks are rocks which have solidified (congealed) with, or without, **crystallization** from hot natural solutions such as **magma** or **lava.** Igneous Rocks are classified by their **texture, structure,** chemical (mineral) composition, and their field relationship or mode of occurrence Under mode of occurrence igneous rocks are classified as intrusive (**plutonic**) or extrusive (**effusive**). The intrusive rocks are classified according to the shape and size of the intrusive body, and its relation to the other formations which it intrudes Typical intrusives are **batholiths, laccoliths, sills** and **dikes.** The extrusive types are called **lavas.** Over 700 species of igneous rocks have been described, the bulk of which are intrusives. (R M F)



Diagrammatic structure section illustrating modes of occurrence of igneous rocks S, strata, B, batholith of plutonic rock, L, laccolith, D, dikes, I, intrusive sheet or sill, V, volcano, N, neck of volcano, F, lava flow, C, crater

IGNITION. Ignition is the initiation of **combustion.** Ignition is, of course, necessary for the inception of any flame or fire, and it is accomplished by the raising of the temperature of the combining substances, such as carbon and oxygen, to the "ignition temperature" This temperature may be defined as the lowest temperature which will cause combustion to start and spread through a combustible mixture The ignition temperature of different substances varies For example, the approximate ignition temperatures of some combustible materials are:

Carbon	750° Fahrenheit
Carbon monoxide	1250° Fahrenheit
Hydrogen	1090° Fahrenheit
Sulfur . .	470° Fahrenheit

The most common source of high temperature energy used for exciting molecular activity to the point of ignition is the ordinary match, but electrical and mechanical energy can be used for the same purpose Examples of these are the electric spark, and the flint and steel The rays of the sun, properly focused through a lens, are also capable of raising substances to their ignition point In certain technical apparatus, combustion is not continuous, and ignition must be intermittently accomplished The best known example of this is the combustion of **gasoline** in the cylinders of a gasoline engine Ignition must be repeated in the cylinder on every power stroke The successful operation of the gasoline engine is based upon a reliable automatically synchronized source of ignition, and this is provided by the **ignition system.** (F T M)

IGNITION SYSTEM. The ignition system here described is that used in engines operating on the **Otto cycle.** In the **Otto cycle,** an inflammable mixture is compressed just before each power impulse This mixture can not be compressed until it reaches the spontaneous ignition temperature (as is the case in the **Diesel cycle**) because the presence in the cylinder of the combustible mixture would cause ignition to be uncontrolled and irregular. This engine must, therefore, depend upon some system of ignition which is under control, and which is automatically synchronized with the action of the cycle Although early engines were operated on hot tubes and open flames, in these days ignition systems are universally electrical in nature In a **gasoline** engine the gasoline-air mixture has an **ignition temperature** varying somewhere between 650 and 850° Fahrenheit The ignition system must produce a focal point of heat sufficient to exceed this temperature and to provide it at exactly the right instant The average time allowable in a gasoline engine operating at about 2,000 revolutions per minute for ignition and explosion of the mixture following ignition, is only about one one-hundredth of a second Furthermore, it has been found necessary to vary the timing of ignition with respect to the cycle of operation in such a way that ignition occurs relatively earlier in the cycle the higher the rotative speed These conditions are well met by the electrical spark system of ignition, in which a high voltage spark jumps across a stationary spark gap Due to the high speed of electrical impulses in wires, there is no difficulty in accurately timing the ignition in an electrical system However, the high voltage jump spark method of ignition is not the only electrical form in use, and both the low tension and high tension ignition systems will be briefly described.

A low tension ignition system is one in which the voltage at the ignition points is insufficient to cause a

spark to jump a static gap. The **electrodes** of the gap are brought together, and then rapidly separated. In this way, a low voltage supply is able to cause an electric arc

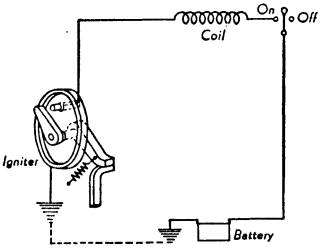


Figure 1. Low tension system for single cylinder stationary engine.

to follow the separation of electrodes. Figure 1 shows a system of this nature. It consists of a source of voltage (a battery), an induction coil, and ignition points. The ignition points and their operating mechanism constitute what is known as the igniter. The igniter is mounted in the **combustion** chamber, and is composed of one stationary, and one moving electrode. The moving member is mechanically operated from the crankshaft by means of a shaft extending through the cylinder wall, and in this way the igniter is synchronized with the cycle. When the igniter points are pushed together, making contact, an electric current flows through the coil, igniter points, and battery. If, then, the current is suddenly interrupted through rapid opening of the igniter points, the battery voltage, aided by self-induced voltage of the induction coil, will cause an arc to follow the opening of the points. This arc is the source of ignition. This low tension system is only occasionally used on engines, usually on relatively slow-moving, fixed, or semi-portable engines.

The high tension system, shown by Figure 2, is the system used on most gasoline and gas engines, and is familiar to many persons through its use as the ignition

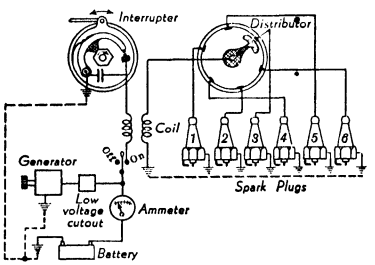


Figure 2. Typical high tension ignition system for a 6-cylinder automotive engine.

system of the automobile engine. It is well adapted to multi-cylinder engines, and is especially suitable where other electrical services are required; for example, lighting and electric cranking. Two systems of high tension ignition should be mentioned. One, the battery and coil system, is most popular today on automobiles; the other, the **magneto** system, is the more widely used on aeronautical and fixed, or semi-portable engines. The magneto system of ignition operates very much in the same manner as the coil and battery, except that, having all of the separate elements consolidated in one piece of apparatus, it is a much more compact ignition system. On the other hand, an automobile, with its need of a battery for purposes other than ignition, is best serviced with the coil and battery system.

Coil and battery electrical ignition will be explained in connection with the figure. A source of low voltage, i.e., the battery at 6 volts, is connected to the primary of an induction coil through an automatic switch which is opened at regular intervals by the engine itself. This automatic switch is called the interrupter or timer. Whenever the interrupter opens the circuit, the induction coil generates a high voltage which is sufficient to cause a spark momentarily to jump the static spark points which are in the combustion space of the cylinder. At the moment of ignition, the cylinder is filled with a compressed gas, some of which occupies the space between the spark points. The gap extends between 10 and 20 thousandths of an inch, so that it is apparent that the induction coil must generate a very high voltage in order for the secondary current to be able to overcome the resistance of the compressed gas between the points. These points are made part of a spark plug which is screwed into the cylinder, thus providing a way of attaching the points, one of which must be insulated. The use of a single coil to supply high voltage current to the spark plugs of a multi-cylinder engine, involves the use of another mechanically operated device, the **distributor.** The distributor picks up the high voltage impulse as it comes from the induction coil, and shunts it to the cylinder ready to receive ignition action. Depending upon the sequence with which high voltage leads are attached between spark plug and distributor, the engine will operate with a definite sequence of power strokes derived from the different cylinders. There are certain standard arrangements of this sequence for the common multiples of cylinders employed in gasoline engines. These arrangements are called the firing orders. The firing order must be well chosen to prevent rocking or galloping of the engine.

In the common **four-cycle** engine, one ignition impulse serves a cylinder for two complete revolutions. Because of this fact, the distributor rotates at one-half engine speed. Now the interrupter is usually driven by a **cam** which does not necessarily have to rotate at one-half crank shaft speed, but which can conveniently be made to do so, since a one-half speed shaft must be provided for the distributor. If the interrupter is operated by a cam revolving at one-half crankshaft speed, the cam must have as many lobes on it as there are cylinders in the engine. The adjustment of the instant of ignition in a cycle with due regard to the demands of variable speed operation, can be done through a slight rotative displacement of the contact carrying case of the interrupter. Formerly this action was accomplished manually, but at present progress in electrical ignition

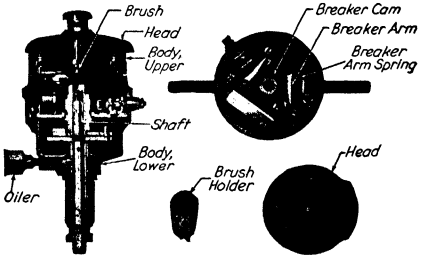


Figure 3. North-East ignition unit (Packard).

systems has enabled manufacturers to develop automatic spark advances, where centrifugal weights opposed by springs adjust the interrupter to a position of spark advance which will be best for the speed of the engine. A **condenser** paralleled across the interrupter points absorbs energy which would otherwise be manifested as a small

arc following the opening of the points. It is convenient to mount this condenser, interrupter, and distributor as a unit enclosed in a single case, and driven by a one-half speed shaft A unit of this type is shown in Figure 3 (F T M)

IGUANA. Reptilia, Sauria Large **lizards** of South America and the West Indies They eat vegetation and insects and are largely arboreal, although they are at home on land or in the water The eggs and flesh of some species are eaten

The name is applied to other lizards than the true iguanas, including members of the same family and others less closely related Among these species are a land lizard of the Galapagos Islands and a marine species of the same archipelago which eats seaweed, and the unrelated monitors of the Old World The family Iguanidae also includes the **basilisks,** anolis lizards, and **horned toads.** (A W L)

IGUANODON. (Duck-billed dinosaur) **Fossil Reptiles.**

IJOLITE Ijolite is a wholly crystalline, granular igneous rock consisting essentially of **nephelite** and **pyroxene.** (E C E S)

ILEUM. The two large bones of the **pelvis** They join the sacrum in back and the pubic and ischial bones in front on each side of the pelvis See **Skeletal System.** (R S M)

ILEUS Obstruction and distention of the intestine due either to a band, adhesion, growth or any mechanical agent It can also be due to the toxins present in an acute disease such as **peritonitis** or **pneumonia** which produce paralysis of the muscular coats of the intestine (R S M)

ILLINIUM Atomic number 61 Discovery announced by Harris, Yntema, and Hopkins in 1926 A member of the **cerium** sub-group of the rare earth metals (R K S)

ILLUMINATION. The illumination of a surface is the luminous flux which it receives per unit area The three most common units are the foot-candle, or one lumen per square foot, the phot, or one lumen per square centimeter, and the lux, or one lumen per square meter (See **Photometry**) The phot is thus equal to 10,000 luxes and to about 929 foot-candles, and is appropriate to only very intense illuminations, the milliphot (0 001 phot) is usually more convenient

Illumination obeys a cosine law, like the radiation from a surface and for similar reasons (See **Cosine Emission Law**) That is, if the illumination is I_0 for zero angle of incidence, then for any other angle θ it is $I = I_0 \cos \theta$. Since for perpendicular incidence the illumination from a concentrated source of luminous intensity L at distance r is $I_0 = kL/r^2$, the illumination at incidence angle θ is

$$I = k \frac{L}{r^2} \cos \theta$$

The value of the constant k depends on the units of I, L, and r, for example, if I is in foot-candles, L in candles, and r in feet, $k = 1$ (lumen per candle)

The illumination desirable at any point varies of course with the circumstances For reading tables or office desks a typical night-time illumination should be from 6 to 8 foot-candles Actual illuminations are measured by means of an illumination photometer or **illuminometer.**

The term illumination is also applied to the science of providing and directing light for a specific purpose associated with the activities of mankind The light itself is radiant energy whose wave length lies within a band to which the human eye is sensitive It is produced from an incandescent source such as that furnished by the sun or artificially by lamps The sources of incandescence employed most frequently are open flames and closed flames, electric arcs, incandescent filaments, and luminescent gas In point of historical precedence, the flames of open fires were undoubtedly the first artificial illumination employed by man This method was next improved on by selecting certain sticks of wood which contained resinous parts which provided torches that would remain alight while carried from point to point Then animal and vegetable fats and waxes were variously employed in candles and lamps, yielding a more portable type of illumination which could be employed for illumination only, and without the necessity of receiving large amounts of heat as well With the discovery and refining of **petroleum,** the kerosene lamp, which was so much more effective as a source of light than anything previous, came for a short period of time into almost universal use The kerosene lamp is still used in isolated homes removed from the conveniences of the more efficient kinds of lighting, and where lowest cost lighting is wanted Defects associated with odor, fire hazard, nuisance of maintenance, and inferiority of illumination, have discouraged the continued use of the kerosene lamp

A fuel gas may be employed as a means of securing illumination Among such gases might be mentioned ordinary artificial **illuminating gas, acetylene gas,** air gas (gasoline-air mixture), and natural gas The use of natural or illuminating gas is confined largely to cities and larger towns wherein is installed a gas distribution system For isolated homes, acetylene gas, which is generated from the action of water on **calcium** carbide, and air gas lamp units are available As a gas flame is practically transparent when the gas is completely burned by a suitable burner, illumination from gas can be obtained only by heating to incandescence finely divided particles or objects placed in the flame An ordinary slit type gas burner having an open flame produces a certain amount of carbon particles which, when heated in the flame, emit a yellow light This yields illumination of low intensity which is often unsteady, and is certainly inefficient The addition to plain open flame gas burners of a mantle consisting of a mineral which, when subjected to the heat of the burning gas, becomes white hot and emits a strong steady light, greatly improved gas lighting The standard Welsbach mantle is composed chiefly of thorium oxide supported on a cotton or artificial cellulose base which burns out when the mantle is first lit The luminous shell of mineral left must be very gently handled in order to prevent its destruction The fragility of the gas mantle has been its chief defect, as it is an efficient source of illumination, quiet and odorless Invention of the incandescent lamp, and the building up of electric service distribution networks which reach a large portion of the population, have made gas lighting an inferior and less desirable form of illumination Today in the United States most homes that are not illuminated by electricity have retained the kerosene lamp The above statement will hold true even though a great many rural homes will be found enjoying acetylene gas illumination The relatively high illuminating efficiency of electric lighting may be demonstrated by quoting the energy consumption per unit of illumination of a few illuminants The unit ordinarily employed in this field is the lumen per **watt** of input Open flame gas burners and kerosene lamps yield about one-quarter of a lumen per watt of power The mantle type gas lamp may provide as much as one and one-half lumens per watt, but the modern incandescent lamp can deliver 8 lumens per watt, and the mercury arc lamps 30 lumens per watt, or over 100 times as much illumination per unit of energy used See **Flame, Electric Lighting.**

The merits of an illumination system may be judged by the freedom from fluctuation of light, by color, by intensity of lighting on the working plane, and by diffusion which prevents glare Glare is due to excessive illumination of surfaces, the light reflected from which reaches the eye, and by the partial polarization of this light by reflection Glare is reduced or eliminated by diffusion, which can be obtained by special designs of

lighting units or by special treatment of the walls of an interior. There are three methods of supplying artificial illumination to the region in which the illumination is desired With specific reference to interior illumination, the region in which the illumination is most desired is the lower part of a room, in which persons live and move. Also, the source of light is usually above, as it has been customary to place lamps near the ceiling, with sufficient clearance so that they will not interfere with freedom of movement of the individual about the room The direct downward supply of light from the lamp is known as direct lighting Direct lighting is efficient as measured by **candles** of luminous intensity per watt of energy, but is likely to have some glare, and to illuminate different regions of the interior unequally Indirect lighting, the second lighting system to be mentioned, avoids glare, and incidentally loses considerable illuminating power by concealing the source of light from view, and directing it upon a reflecting surface, usually the ceiling, which reflects it in a diffused state throughout the interior being illuminated Shadows are softened, the general effect is more pleasing than in direct lighting, but freedom of choice of ceiling surface is somewhat restricted, the installation is more expensive, and high-powered lamps must be provided or portable lamps provided for direct illumination where high lighting intensity is needed The third system of lighting, known as the semi-indirect, is intermediate between direct and indirect Semi-indirect lighting is obtained by enclosing the lamp in a translucent bowl having a surface which diffuses the light as it is transmitted

The **candle power** of a lamp is what primarily determines brightness of the illumination provided by it The standard candle is the reference source for illumination, and is maintained in most of the national standardizing laboratories Since a lamp in space may provide illumination in all directions, it can be considered a spherical source of illumination The average candle power, taken in all directions from the lamp, is known as the mean spherical candle power Often the shape of a lamp, or of its accessories, interferes with transmission of light equally in all directions The candle power in a horizontal direction is frequently employed The average horizontal candle power is expressed in candles, output is expressed in lumens The luminous flux from a source of one spherical candle power is 12 57 lumens (4π) Recommended intensities of illumination for a number of different interiors are given in the accompanying table

INTENSITIES OF ILLUMINATION

	Foot-candles
Auditoriums, churches	2–4
Armories, exhibition halls	3–6
Corridors, stairways	1–2
Drafting rooms	10–15
Foundries, forge shops, boiler rooms	3–6
Industrial yards	0 2–0 5
Instrument shops . . .	6–15
Laundries, machine shops . .	5–10
Offices . . .	6–10
Schools, libraries	4–8
Show windows .	10–70
Stores	4–10
Tool rooms, press rooms, textile mills	8–16

The lumens which are actually received upon a working area are fewer in number than those which are emitted by the sources of illumination, because of the absorption by walls, ceiling, drapes, etc The ratio of the lumens reaching the working area to those emitted from the lamp or lamps is the utilization factor This factor is determined chiefly by the character of the walls and ceiling, the number of windows and hangings, and the type of reflectors or lighting fixtures in which the lamps are mounted The utilization factor affords a means for connecting the desired intensity of illumination with the lighting installation (L D W, F T M)

ILLUMINOMETER OR ILLUMINATION PHOTOMETER. The older, standard forms of this instrument employ a **photometer** of ordinary type to measure the luminous intensity due to light reflected from a white matt surface or diffused by a white translucent screen exposed to the illumination to be measured The balance may be secured as usual by the **bench photometer** method, by screening down the comparison lamp, or by turning the diffusing surface through a known angle and relying upon the cosine law (See **Illumination**) A different type, known as a foot-candle meter, utilizes the Bunsen screen principle, there being however a long row of translucent spots lighted from behind by a lamp at one end, hence unequally along the row At some point in the row this balances the illumination from in front, which is to be measured, and a scale indicates the foot-candles directly In a still more recent instrument the illuminated element is a copper oxide photovoltaic cell (See **Photovoltaic Effects**) connected to a sensitive current meter reading directly in foot-candles All of these instruments must, of course, be portable to be of practical use (L D W)

ILLUSION. Hallucination.

IMAGES. Geometrical Optics.

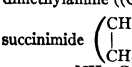
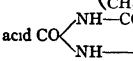
IMAGINAL DISK. Histoblast.

IMAGINARY NUMBERS. Numbers, also Complex Numbers.

IMAGO. An insect in the adult stage

IMHOFF TANK. The Imhoff tank is a chamber of special design suitable for reception and purification of sewage. It is used where sewage is to be digested, and thus clarified, and differs from the **septic tank** in that it provides for a separation of the sedimentation and digestion process It is much better adapted for the digestion of large amounts of sewage than is the septic tank, due to the excessive size required of the latter, whose action is, comparatively, much slower The Imhoff tank is divided into two compartments, the upper being the settling, and the lower the digesting compartment The gases of digestion are separated from the settling solids, and the time required for treating of sewage is only one-half of that of the plain septic tank (F T M)

IMIDES. Amines and Amides.

IMINO-COMPOUNDS Imino-compounds are organic compounds containing the imino-group (<NH), e g, dimethylamine ($(CH_3)_2NH$), dibenzamide ($(C_6H_5CO)_2NH$), succinimide  , pyrrole ($(CH)_4NH$), uric acid  .

(R K S)

IMMUNE. One who is protected against a specific disease, either by having had the disease previously, having natural immunity, or by artificial means, as by **inoculation.** (R S M.)

IMMUNITY. The power of the body to resist or overcome a specific disease. the state of being **immune.**

Natural immunity is immunity developed by an individual without having the disease or inoculations against it Congenital immunity is immunity that is present at birth Acquired immunity is immunity that is acquired during life Active immunity is immunity produced by the activity of the body tissue after· (1) Recovery from a specific disease; (2) Cumulative exposures to infection without actually having suffered a noticeable attack of the disease; (3) Treatment with a vaccine; (4) Inocula-

tion with attenuated or weakened organisms causing the disease, (5) Injection of toxin—see **Diphtheria**; and (6) Injection of bacterial products (R S M)

IMPACT. Impact is the action of two bodies in collision, whereby the velocity of one or both bodies is changed In the case of direct impact, the velocity of the moving bodies is in the direction of the normal (perpendicular) to the bodies at the point of contact Otherwise the impact is oblique The impact is central when the centers of gravity of the two bodies lie on the line of impact (normal to the bodies at the point of contact) The momentum of a body is its mass multiplied by its velocity A law of impact is that the sum of the momentums of the two masses before and after impact is the same, provided the bodies are perfectly elastic, and no energy is absorbed in permanent plastic deformation

The impact coefficient (coefficient of restitution) is the ratio between the differences of velocities of the two bodies after impact to the same differences before impact This coefficient would be unity for impact of perfectly elastic bodies, and zero for fully inelastic bodies To find the energy lost in an imperfect impact (one in which the impact coefficient is some number less than one), the masses of the two bodies, M_1 and M_2, may be substituted into the following formula This formula has in it also the differences of velocity of the bodies after collision Let f be the impact coefficient

$$\text{Energy lost} = \frac{M_1M_2(1-f^2)(v_1-v_2)^2}{2(M_1+M_2)}.$$

(F T M)

IMPALA, PALA Mammalia, Artiodactyla *Aepyceros* Moderately large African **antelopes** of several species They have long slender horns, slightly spiraled and ringed through most of their length (A W L)

IMPEDANCE **Alternating Currents.**

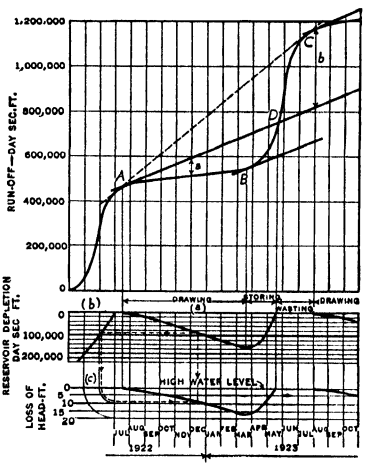
IMPELLER The impeller is the rotating member of a **centrifugal pump.** It has backwardly curved vanes mounted on a hub attached to the pump shaft When these vanes are cased with disks on either side, they are known as shrouded impellers The water is admitted to the pump in such a way that it comes in contact with the impeller first near the central or hub portion The impeller rotates in its cases with close clearances, and the water is constrained to remain in the impeller, which, by virtue of its rotation and the action of centrifugal force, drives the water from the periphery at high velocity (F T M)

IMPETIGO. An inflammatory skin disease characterized by the appearance of many small pustular lesions on the body *Impetigo contagiosa* is a contagious skin disease, usually of childhood, the **pustules** being caused by *streptococci* (R S M)

IMPLICIT FUNCTION If a **function** is defined by a relation between the **variables** given by an **equation** which must be solved in order to express one variable in terms of the other, the function so defined is called an implicit function (L L S)

IMPOTENCY. Loss of ability to produce children on the part of the male It is an adult disease of previously normal males resulting from degeneration of the tissue in the **testicle** which produces the sperm cells The most frequent cause is **gonorrhea.** The libido may be decreased but is usually present (R S M)

IMPOUNDING RESERVOIR. When the required flow of water from a reservoir or from a stream is larger than the minimum rate of flow of that stream in a dry season, a reservoir of the impounding type is needed. Ordinarily, storage is relied upon to a greater or lesser extent to regulate flows. For a study of storage conditions the mass curve is indispensable The mass curve can best be explained by reference to the accompanying figure The point of origin of the mass curve is a month when the reservoir is known to be full, as after spring floods. The ordinates of the curve represent the total



Mass curve and its derivatives.

flow, or mass of water, from the date of origin. River gaging records have mass expressed in acre-feet but, for the purpose of the mass curve, acre-feet are converted into "day-second-feet" so that the slope of a straight line drawn on it will represent a rate of flow in second-feet A day-second-foot is the volume of water equivalent to a flow of one cu ft per sec for one day. One day-second-foot = 1 98 acre-feet The line AD represents a uniform flow of 1000 second feet Its ordinate is $1000 \times 30 = 30{,}000$ day-second-feet per month The mass curve of the non-uniform stream flow is $ABDC$ If lines parallel to AD are drawn tangent to the mass curve, the significance of the points of tangency A, B, C is that, on their dates, the stream flow was equal to the steady flow represented by the slope of AD. At A and C the stream flow passes from greater than to less than the required regulated flow, while at B it changes from less than to greater than the required flow. Having passed A and C the stream discharge becomes less than the required regulated flow, and the difference is made up by drawing on the storage in the reservoir At the end of November, 1922, the reservoir would have supplied the number of day-second-feet indicated by the ordinate a Passing B the stream flow has increased and is now in excess of the flow requirements, consequently the storage is regained, and regained completely at D From D to C there is wastage over the crest gates amounting to a maximum as indicated by the ordinate b The slope of the line AC is the maximum regulated flow that could be realized without wastage over the crest gates or ultimate depletion of the reservoir. (F T M)

IMPROPER INTEGRALS AND INFINITE INTEGRALS. If $f(x)$ is continuous for $x \geqq a$ and if the **definite integral** $\int_a^t f(x)dx$ **approaches a limit as** $t \to \infty$, we denote this limit by $\int_a^\infty f(x)dx$ and call it an infinite integral

$$\int_a^\infty f(x)dx = \lim_{t\to\infty} \int_a^t f(x)dx$$

The infinite integral is then called convergent

We define $\int_{-\infty}^{a} f(x)dx$ in a similar way

The infinite integral $\int_{-\infty}^{+\infty} f(x)dx$ is defined by:

$$\int_{-\infty}^{+\infty} f(x)dx = \int_{-\infty}^{a} f(x)dx + \int_{a}^{\infty} f(x)dx$$

If $f(x) \to \infty$ as $x \to a$, the integral $\int_a^b f(x)dx$ is defined by

$$\int_a^b f(x)dx = \lim_{\delta \to 0} \int_{a+\delta}^{b} f(x)dx,$$

this is called an improper integral, and it is said to be convergent

Similarly, if $f(x) \to \infty$ as $x \to b$, we define

$$\int_a^b f(x)dx = \lim_{\delta \to 0} \int_a^{b-\delta} f(x)dx$$

If $f(x) \to \infty$ as $x \to c$, where c is between a and b, we define

$$\int_a^b f(x)dx = \lim_{\delta \to 0} \int_a^{c-\delta} f(x)dx + \lim_{\delta' \to 0} \int_{c+\delta'}^{b} f(x)dx$$

These improper integrals are also called convergent (L L S)

IMPULSE. See **Momentum.**

INBREEDING. The mating of closely related animals As practiced in stock breeding brothers and sisters are often mated, or parents and their offspring In most human societies the mating of individuals more closely related than first cousins is not approved, and even cousin marriages are regarded as close inbreeding

Inbreeding is popularly regarded as a weakening process but this is not entirely true Closely related individuals are more likely to have a similar complex of hereditary potentialities than those from different lines of descent, hence hereditary characters which may be masked in them have a better opportunity of appearing in their offspring according to the processes of Mendelian **heredity.** These characters may, however, be either desirable or undesirable In either case if the character in question can be concealed by some other it may appear more often in an inbred line (A W L)

INCISOR. A sharp-edged cutting tooth The incisors are located at the front of the jaws of **mammals,** between the canines (A W L)

INCLINATION. Inclination is that **element** of the **orbit** of a celestial object which indicates the angle between the plane containing the orbit of the object in question, and some reference plane In the case of orbits of members of the solar system the reference plane is the ecliptic, while in orbits of **binary stars** inclination refers to the angle between the plane of the orbit of the stars and the plane perpendicular to the line of sight (W K G)

INCLINED PLANE. See **Machines.**

INCLUSION. This term is used chiefly to connote a fragment of a foreign rock or mineral in an igneous rock It may also be used to refer to gas or liquid enclosed in a mineral crystal (E C E S)

INCONSISTENT SYSTEMS OF LINEAR ALGEBRAIC EQUATIONS. See **Systems of Linear Algebraic Equations.**

INCUBATION PERIOD. That period that elapses between exposure to an infectious disease and the signs of active infection or clinical manifestations of the disease (R S M)

INDAZOLE. See **Pyrrole and Related Compounds.**

INDEFINITE INTEGRAL. Let $f(x)$ denote a given **function** of x, a function $F(x)$ which has $f(x)$ for its **derivative** (or $f(x)dx$ for its **differential**), is called an integral of $f(x)$ (or of $f(x)dx$)

If $f(x)$ is **continuous** and has an integral $F(x)$ in the interval (a,b), then every integral of $f(x)$ in (a,b) is of the form $F(x) + C$

Hence, if $F(x)$ be any particular integral of $f(x)$, the general integral of $f(x)$ is $F(x) + C$, where C is an **arbitrary constant.** A general integral is also called an indefinite integral The constant C is called the constant of integration

The symbol for the general integral or indefinite integral of $f(x)$ is

$$\int f(x)dx$$

To integrate $f(x)$ is to express $\int f(x)dx$ in terms of known functions We may interpret the symbol $\int$ as a symbol for this operation of integration and call $f(x)$ the integrand

By definition

$$\frac{d}{dx}\int f(x)dx = f(x), \text{ or } d\int f(v)dx = f(x)dx$$

Hence, integration is the **inverse operation** of **differentiation,** that is, it is the operation which differentiation undoes

No general process of integration exists The process depends ultimately on recognizing a function as a derivative of a known function It consists, therefore, of reversing differentiation rules (L L S)

INDEPENDENT VARIABLE See **Functions.**

INDETERMINATE EQUATIONS. An indeterminate equation is an **equation** with more than one unknown or **variable.** Indeterminate equations are sometimes called Diophantine equations, after the Greek mathematician Diophantus, who studied them

An indeterminate equation in two variables is frequently studied to determine positive integral values of the variables which satisfy it, similarly for more unknowns (L L S)

INDETERMINATE FORMS In various mathematical investigations, when limiting processes are applied to certain types of expressions involving special combinations of **functions,** an indeterminate form arises, which is one having no meaning in itself To assign useful meanings to these forms, methods (which belong mostly to the **Calculus**) have been devised, as follows

The form 0/0

If the fraction $f(x)/\phi(x)$ takes the form 0/0 when $x = a$, it is often possible to discover a factor common to $f(x)$ and $\phi(x)$ which vanishes when $x = a$, and after the removal of this factor, to find $\lim_{x \to a} f(x)/\phi(x)$ directly

A more general method is If $f(a) = 0$ and $\phi(a) = 0$, and if $\lim_{x \to a} \frac{f'(x)}{\phi'(x)}$ exists, then

$$\lim_{x \to a} \frac{f(x)}{\phi(x)} = \lim_{x \to a} \frac{f'(x)}{\phi'(x)}.$$

If $f'(a) = 0$ and $\phi'(a) = 0$, but if $\lim_{x \to a} \frac{f''(x)}{\phi''(x)}$ exists, then

$$\lim_{x \to a} \frac{f(x)}{\phi(x)} = \lim_{x \to a} \frac{f''(x)}{\phi''(x)},$$

and similarly for higher derivatives

The form ∞/∞:

If the fraction $f(x)/\phi(x)$ takes the form ∞/∞ when $x \to a$, but if $\lim_{x \to a} \frac{f'(x)}{\phi'(x)}$ exists, then

$$\lim_{x \to a} \frac{f(x)}{\phi(x)} = \lim_{x \to a} \frac{f'(x)}{\phi'(x)};$$

and similarly with higher derivatives.

The forms $0 \cdot \infty$ and $\infty - \infty$:

These forms can frequently be reduced to the form $0/0$ or ∞/∞ and treated as in the preceding.

The forms 1^∞, 0^0, ∞^0:

A function of the type $[f(x)]^{\phi x}$ may take one of these forms. If we put $u = [f(x)]^{\phi x}$, take logarithms and get $\log u = \phi(x) \log f(x)$, which will then take the form $0 \cdot \infty$, which can be evaluated by the preceding methods. (L.L.S.)

INDETERMINATE STRUCTURE. A statically indeterminate structure is one which cannot be solved by the equations for static equilibrium. These equations state that the components of the forces acting on a body, taken in any two directions, must be equal to zero and that the sum of the moments of these same forces, taken around any moment center, must equal zero. If the axial stresses in the members of a structure are changed by altering the length of one of the members a very small amount the structure is classified as indeterminate.

When there are more **reactions** than equations for static equilibrium the structure is externally, indeterminate. After these reactions have been calculated the stresses in the members of the structure become statically determinate unless internally indeterminate, that is, contains redundant members (See **Redundancy**).

In general, statically indeterminate structures can be analyzed by methods such as the energy theory or the deflection theory although some are so complicated that the analyst must resort to experimental methods. The analysis of any indeterminate structure requires a knowledge of the size, shape and elastic properties of the individual members.

Examples of indeterminate structures are triangular frameworks containing redundant members, rigid frames having **loads** transmitted by the rigidity of the joints, fixed on two hinged **arches,** suspension **bridges** with stiffening **trusses,** building frames under the action of **lateral** forces, beams with built-in end supports, beams fixed at one end and simply supported at the other end and beams continuous over a number of supports. In each case some members or supports can be removed and the structure will still be stable under very light loads. See **Least Work.** (C.W.C., F.T.M.)

INDEX OF REFRACTION. Refractive Index.

INDEX OF ROOT OF NUMBER. Roots of Numbers.

INDICATED HORSEPOWER. The horsepower developed in the cylinder of any **piston** and **cylinder engine** is called indicated horsepower because it can be measured by the "indicator" mechanism. This power is the result of a gas or vapor pressure pushing against a piston, and is larger than the crank shaft horsepower by the amount of friction and windage losses of the engine.

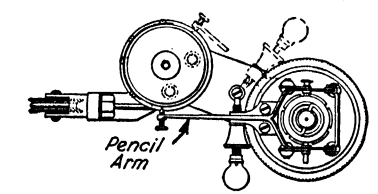
If, during a certain power stroke in a cylinder, P is the average effective pressure acting against each unit of piston area, the piston will receive and pass on to the piston rod a push of $P \times A$ pounds. In the above, A is the piston area. When the piston moves through a stroke measured as L feet, the work represented by the motion of the push of PA pounds is PAL. In the ordinary double-acting steam engine, the number of these power strokes per minute is double the number of revolutions per minute, since there is an action of steam against the piston on both the out and in stroke. Thus in one minute there are $2PLAN$ foot pounds of work done in the cylinder. The number of foot pounds per minute in a horsepower being 33,000, the above explains the origin of the common indicated horsepower formula,

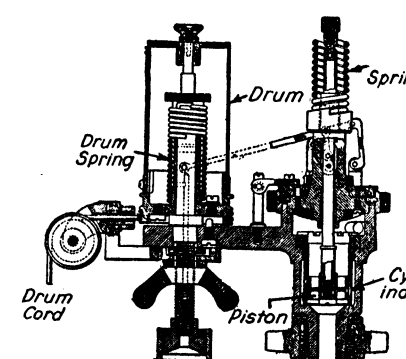
$$IHP = \frac{2\ PLAN}{33{,}000}.$$

The actual use of this formula requires knowing the bore and stroke of the engine from which A and L are determined, the operating speed in revolutions per minute, and the mean effective pressure P. This mean effective pressure can be obtained experimentally with the use of the indicator, which is an autographic device by means of which an engine draws its cycle on a PV plane. The average height of the figure so drawn is the mean effective pressure. (F.T.M.)

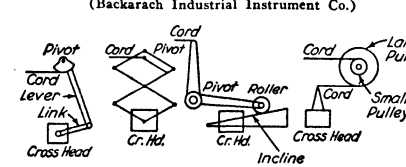
INDICATOR. Chemical indicators are discussed in the article on **Reactions Involving Recombinations of Ions.**

In engineering the indicator is an **engine** instrument the purpose of which is to give an autographic record of the pressure-volume relationship of the working medium within the cylinder as the engine goes through its **cycle** of operations. The cross-section of a **steam engine** indicator is shown in the accompanying drawing. The record is traced on a paper of oblong shape about $3'' \times 6''$, which is wound around and fastened to the drum. The lower portion of the drum is a pulley around which is wound a cord. The end of the





Sectional view of Maihak standard indicator. (Backarach Industrial Instrument Co.)



Indicator reducing motion.

cord is made fast to the drum, and the other end is attached either directly to the crosshead or through a **reducing mechanism.** The rotation of the drum under the influence of a pull on the cord is always opposed by a coil spring In action, the cord transmits to the drum an oscillatory motion which is synchronized with the motion of the piston in the cylinder This places the paper wound around the drum in a position (with respect to a fixed pencil point) which is proportional to the stroke or to the volume of piston displacement at any instant The other element of the indicator, the pressure element, consists of a piston moving in a cylinder and opposed by a calibrated spring The indicator cylinder is connected to the engine cylinder by short interconnecting piping through which the instantaneous pressures in the cylinder are transmitted to the indicator piston The latter rises against the spring pressure until the point of equilibrium is reached The position of the piston in the indicator cylinder is proportional to the pressure in the engine cylinder This position is transferred to the record as a corresponding vertical motion of the pencil arm At the extremity of this arm, the pencil writes on the drum It draws a record which, by virtue of the features pointed out above, is a diagram of the cycle of pressure vs the volume in the engine cylinder (F T M)

INDICOLITE. Tourmaline.

INDIGESTION. Impairment of **digestion** and the symptoms resulting therefrom The term is a loose one and the condition is present in a good many diseases or conditions The symptoms complained of vary, but usually include discomfort and feeling of fullness in the abdomen, belching, sour eructations, heartburn or even a dull pain in the upper abdomen (R S M)

INDIGO. Indigofera tinctoria. Leguminoseae The indigo-yielding plant is a shrub four to six feet tall, growing wild in southern Asia It has **pinnately** compound leaves, which are downy beneath, and bears reddish-yellow flowers

For thousands of years the plant has been grown in India, where it was first discovered to yield a dye which would give cotton or woolen cloth a deep blue color of great permanence Curiously enough, no indication of this color is found in the plants They contain, however, a glucosidal (See **Carbohydrates**) substance which can be extracted from the shoots with water, and which yields indigo blue This substance is insoluble in water Before it can be used to color cloth, the dyestuff must be dissolved in lime-water (or any **alkaline** solution), and some fermenting substance, such as molasses Then a new compound, indigo white, is formed When the cloth to be dyed is soaked in this solution and then exposed to the air to dry, it soon acquires the deep blue color characteristic of indigo (For the chemistry of Indigo, see **Pyrrole and Related Compounds** See also **Dyes**)

The development of synthetic indigo has caused the use of the natural product to decline considerably (R M W)

INDIUM. Symbol In Atomic number 49 Atomic weight 114 76 Density 7 28 Hardness 1 2 Melting point 155° C Boiling point· 1450° C.

Indium is a silver-white metal, softer than **lead,** malleable, ductile and crystalline· stable in dry air· on heating in air burns with a blue flame to form oxide does not decompose water at 100° C , dissolves in **hydrochloric, sulfuric or nitric acids** but not in **sodium** hydroxide, combines with **chlorine** and with **sulfur.** Discovered by Reich and Richter in 1863 by means of spectroscope

Indium occurs in very small **amount** in **zinc blende, tungsten,** tin and **iron** ores of certain localities The recovery of indium from zinc **flue** dust (sometimes, 1 part in per thousand) is effected by treating with a slight deficiency of hydrochloric acid and allowing to stand The residue is subjected to a series of treatments until finally pure indium sulfate is obtained, a solution of which when electrolyzed yields compact indium metal

Chlorides Indium monochloride (InCl), dark red crystals, indium dichloride ($InCl_2$), colorless crystals, indium trichloride ($InCl_3$), white crystals Volatile indium salts, such as the chlorides, color the bunsen flame blue violet, which accounts for the derivation of the name indium (indigo blue)

Hydroxide Indium hydroxide ($In(OH)_3$), white, gelatinous precipitate by sodium hydroxide with indium salt solutions, soluble in excess sodium hydroxide, but reprecipitated on boiling

Oxides Indium monoxide (InO), black, pyrophoric powder, by heating indium sesquioxide in hydrogen at 300° C , indium sesquioxide (In_2O_3), light yellow powder, by burning indium in air, or by ignition of indium nitrate below 850° C , above 850° C trindium tetroxide (In_3O_4) is formed (R K S)

INDOLE. Pyrrole and Related Compounds.

INDRI. Mammalia, Primates A **lemur,** *Indris brevicaudatus,* of Madagascar with a slender body, disproportionately large arms and legs, and a small head resembling that of a dog (A W L)

INDUCED DRAG. This is the air drag on an **airfoil,** induced by the creation of a lift When an airfoil is in an attitude of zero lift, the drag is entirely profile drag, but as real lifts are obtained by rotation of the airfoil to some positive **angle of attack,** an induced drag enters to supplement and increase the profile drag This induced drag is the result of a downward deflection of an air stream passing an airfoil, or by the downward momentum given to air as an airfoil passes through it The magnitude of an induced drag depends upon the plan form of the airfoil Airfoils of high **aspect ratio** have low induced drags Induced drag can be a very large fraction of the total drag of an airfoil, consequently, high aspect ratio airfoils are used on aircraft in which considerable attention is focused on aerodynamic efficiency Unfortunately high aspect ratio is associated with structural difficulties in the construction and bracing in the sustention surfaces of an airplane, so that it is not possible to use aspect ratios as great as would be desirable for the reduction of induced drag Theoretically the coefficient of induced drag is the same,

$$\frac{(\text{lift coefficient})^2}{\pi \times \text{aspect ratio}}$$

for any wing profile, but actually different profiles have drag coefficients which vary somewhat from the above theoretical magnitude (F T M)

INDUCED RADIOACTIVITY. Artificial Disintegration of Elements.

INDUCTANCE. The inductance of a circuit (such as a coil) is the rate of increase in magnetic linkage with the current If we have a coil of several turns, carrying a steady current, certain magnetic flux will, as a result, be linked with the coil, depending upon the size and shape of the coil, the number of turns, and the material occupying the surrounding space If the current is now slightly increased, the resulting increase in flux may or may not be proportional to the change in current, if not, we shall have to consider a very small increase in each The "linkage" is the product of the flux through the coil by the number of turns. Since magnetic flux is ordinarily expressed in lines or maxwells (See **Magnetic Field**), the linkage may be expressed in maxwell-turns The inductance unit called the henry corresponds to a rate of linkage increase of 10^8 maxwell-turns per ampere of current. This is a

rather large unit, hence the millihenry is commonly used

Since an increase of 10^8 maxwell-turns per second induces 1 volt of electromotive force in the circuit, a coil may be said to have 1 henry of inductance if an increase of 1 ampere per second results in the self-induction of 1 volt, this is an alternative definition of the henry

Mutual inductance may be explained in the same way and expressed in the same units, except that the current in one circuit causes a flux linkage, or induces an electromotive force, in another, neighboring or coupled circuit An **induction coil** or a **transformer** involves this kind of inductance, as well as the self-inductance of each circuit A coil arranged to have its inductance adjustable and provided with a scale to indicate its inductance in millihenrys is called an inductometer (L D W)

INDUCTION COIL. A device for obtaining a high, intermittent voltage from a source of low, steady voltage, such as a battery This is accomplished by electromagnetic induction A coil of relatively few turns, called the primary, and provided with a soft iron core, is connected in series with the battery and with some form of interrupter which renders the current intermittent The rapid variations of magnetic flux thus produced give rise to correspondingly high electromotive forces in the secondary, a coil of many turns of fine wire wound on the same core and thus effectively coupled with the primary The secondary electromotive force of course reverses with each make and break of the primary circuit The performance is improved by placing a **condenser** across the terminals of the interrupter This takes up the surge of current that would otherwise cause destructive sparking at the interrupter gap, while the discharge of the condenser causes a higher peak electromotive force in the secondary The change of flux during the charging and discharging of the condenser while the interrupter is open is much more rapid than that while the primary circuit is closed This gives a partially unidirectional character to the secondary voltage and makes the induction coil suitable for operating Geissler and small x-ray tubes The largest use of the induction coil at present is for ignition in the operation of internal combustion engines, where it is commonly called a spark coil (L D W)

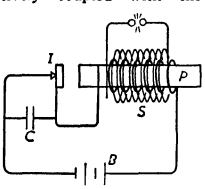


Diagram of an induction coil, showing battery B, interrupter I, and condenser C

INDUCTION, MATHEMATICAL. The method of mathematical induction is a general method of proof of theorems in which a positive integral variable is involved It consists of two main parts (1) direct verification of the theorem for the smallest admissible value of the positive integer involved, (2) the algebraic proof that if the theorem is true for any value of the integer, it is true for the next greater value In conclusion, the theorem is proved by combining the above two parts (L L S)

INDUCTION MOTOR. Electric Motors.

INDUCTIVE LOAD. An electrical load consisting of resistance and inductance, that is to say, of coils, solenoids, windings, etc, is said to be inductive since the induction in such windings delays the current to the point where variations of current in an alternating current circuit lag a certain degree behind variations of voltage See **Alternating Currents.** (F.T.M)

INDUCTOMETER. Inductance.

INDURATION. The state of increased resistance or hardness in any tissue or organ This may be an indication of inflammation, abscess or tumor formation (R S M)

INDUSIUM. Ferns.

INEQUALITIES. The notation $a < b$ means a is less than b, and the notation $a > b$ means a is greater than b. The notation $a \leqq b$ means a is either less than or equal to b; similarly for $a \geqq b$

The rules for operating with inequalities are expressed by

if $a < b$, and $b < c$, then $a < c$,
if $a < b$, then $a + c < b + c$,
if $a < b$ and $c > 0$, then $a\ c < b\ c$

If the sense of an inequality is the same for all values of the symbols for which its members are defined, the inequality is called an absolute or unconditional inequality

If the sense of an inequality holds only for certain values of the symbols involved, but is reversed or destroyed for other values of the symbols, the inequality is called a conditional inequality

The sense of an inequality is not changed if both members are increased or decreased by the same number

The sense of an inequality is not changed if both members are multiplied, or divided, by the same positive number The sense of an inequality is reversed if both members are multiplied, or divided, by the same negative number (L L S)

INERT GASES. These are the elements which are found in the first group of the periodic table and consist of **helium, argon, neon, krypton, xenon** and **radon.** (R K S)

INERTIA. Inertia is one of the few properties manifested by all kinds of matter While its name infers inaction (no doubt from the fact that bodies do not set themselves into motion), inertia is an actual opposition to any alteration of motion That is, the acceleration of a body in any sense, either as to speed or direction of motion, requires the application of force proportional to the mass of the body and to the amount of acceleration The reaction to this force, acting always through the **center of mass,** is a measure of the inertia of the body

It is interesting to speculate as to wherein the inertia of a body resides Is it inherent in the body itself, or does it in some way concern also its physical environment? The discovery of electromagnetic mass and electromagnetic inertia, and the identification of the latter as a property of the **electromagnetic field** surrounding a moving charge, suggests that the ordinary inertia of neutral masses may be similarly traceable to some reaction in the neighboring space And when we consider that all matter is, in the last analysis, probably composed of electricity, the idea that inertia may actually be an electromagnetic reaction appears not unreasonable (See **Moment of Inertia.**) (F T M)

INFANTILE PARALYSIS. Poliomyelitis.

INFINITE GEOMETRIC PROGRESSION. Geometric Progressions.

INFINITE SEQUENCES. An infinite sequence is an endless set of elements such that we can establish a one-to-one correspondence between these elements and the natural numbers 1, 2, 3, . . , n, . . An infinite sequence may be represented in general by $u_1, u_2, u_3, \ldots, u_n, \ldots$, or more briefly by $\{u_n\}$

A sequence $\{u_n\}$ is called convergent when it has a limit, that is, if a number u exists such that for any arbitrary number $\epsilon > 0$ there exists a number N such

that $|u - u_n| < \epsilon$ for every $n > N$, then the sequence $\{u_n\}$ is convergent and has the limit u We write $u = \lim_{n \to \infty} u_n$

If a sequence is not convergent, it is frequently called divergent (L L S)

INFINITE SERIES. Let $u_1, u_2, u_3, \ldots, u_n,$ be an infinite sequence, form the partial sums $s_1 = u_1$, $s_2 = u_1 + u_2$, $s_3 = u_1 + u_2 + u_3$, , $s_n = u_1 + u_2 + \cdots + u_n$, The infinite sequence $s_1, s_2, s_3,$, $s_n,$. is called the infinite series whose terms are $u_1, u_2,$, $u_n,$, it is denoted by

$$u_1 + u_2 + u_3 + \cdots + u_n + \cdots, \text{ or by } \Sigma\, u_n, \text{ or } \sum_{n=1}^{\infty} u_n$$

If the infinite sequence $\{s_n\}$ converges and has a limit S, then the infinite series Σu_n is said to converge and to have the sum S, otherwise the series is usually said to be divergent

The general principle of convergence for series is A necessary and sufficient condition for the convergence of a series Σu_n is that, for any $\epsilon > 0$, an index N exists such that for every $n > N$ and for every value of p, we have

$$|u_{n+1} + u_{n+2} + \cdots + u_{n+p}| < \epsilon$$

A necessary condition for convergence of the series Σu_n is $\lim_{n \to \infty} u_n = 0$, this condition is not sufficient for convergency

If $\Sigma |u_n|$ is convergent, so also is Σu_n In this case Σu_n is called absolutely convergent If Σu_n is convergent but $\Sigma |u_n|$ is not convergent, then Σu_n is called conditionally convergent

Many tests of convergence and divergence of series are known We can give only a few of the most useful of these here

Comparison test If a positive term series Σc_n is known to be convergent, and if Σa_n is a positive term series to be tested and if $a_n \leqq c_n$ for all values of n (or at least for all values of n beyond a certain point), then Σa_n is convergent If Σd_n is a positive term series known to be divergent, and if $a_n \geqq d_n$ for all values of n (or for all values of n beyond a certain point), then Σa_n is divergent

Ratio test If Σa_n is a positive term series to be tested, and if $\frac{a_{n+1}}{a_n} < r < 1$ for all values of n (or for all values of n beyond a certain point), then Σa_n is convergent, if $\frac{a_{n+1}}{a_n} \geqq 1$ for all values of n (or all beyond a certain point), then Σa_n is divergent

Also, if $\lim_{n \to \infty} \frac{a_{n+1}}{a_n} = l$ and $l < 1$, then Σa_n is convergent, and if $l > 1$, then Σa_n is divergent, but if $l = 1$, there is no test

Radical test If Σa_n is a positive term series to be tested, and if $\sqrt[n]{a_n} < r < 1$ for all values of n (or for all beyond a certain point), then Σa_n is convergent, and if $\sqrt[n]{a_n} \geqq 1$ for all n (or for all beyond a certain point), then Σa_n is divergent

Also, if $\lim_{n \to \infty} \sqrt[n]{a_n} = l'$, then Σa_n is convergent if $l' < 1$, and is divergent if $l' > 1$, but if $l' = 1$ there is no test

Integral test If $f(v)$ is a positive monotonic decreasing function which approaches 0 as $x \to \infty$, then the series $\Sigma f(n)$ is convergent or divergent according as the definite integral $\int_1^{\infty} f(x)dx$ is convergent or divergent (that is, according as $\lim_{\lambda \to \infty} \int_1^{\lambda} f(v)dx$ exists (finite) or not)

Alternating series test If a series Σu_n has its terms alternately positive and negative, and steadily decreasing, so that each term is numerically less than the preceding, and if $u_n \to 0$ as $n \to \infty$, then Σu_n is convergent

In this case, the error involved in taking the sum of the first n terms as an approximation to the sum of the series is less in absolute value than the absolute value of the $(n+1)^{st}$ term

To add or subtract two series Σu_n and Σv_n is to form the series $\Sigma(u_n \pm v_n)$ If the given series are convergent with sums U and V, then the series $\Sigma(u_n \pm v_n)$ obtained by adding or subtracting them is convergent and has the sum $U \pm V$

The (Cauchy) product of two series Σu_n and Σv_n is defined as the series Σw_n, where $w_n = u_1 v_n + u_2 v_{n-1} + \cdots + u_n v_1$

If Σu_n and Σv_n are both absolutely convergent, then the product series Σw_n is absolutely convergent, and if their sums are U and V, then the sum W of the product series is $W = U\,V$ (Cauchy's theorem)

If Σu_n and Σv_n are convergent with sums U and V, and if at least one of them is absolutely convergent, then the product series Σw_n is convergent and its sum is $W = U\,V$ (Mertens' theorem)

If Σu_n and Σv_n are convergent with sums U and V, and if the product series Σw_n is convergent with sum W, then $W = U\,V$ (Abel's theorem)

If two series are only conditionally convergent, their product series may be convergent or may be divergent (L L S)

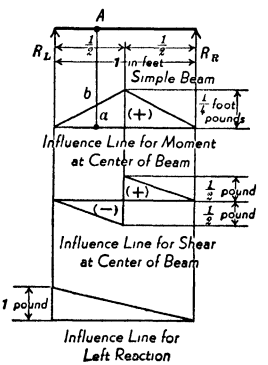
INFINITESIMALS. Limits.

INFLAMMATION. The response of the tissues of the body to infection or irritation It is characterized by redness, heat, swelling, and pain (R S M)

INFLECTION, POINT OF. Concavity and Convexity of Plane Curves.

INFLORESCENCE. Flower.

INFLUENCE LINE. An influence line is a graphical way of representing the effect of a certain variable circumstance upon a set of conditions In particular, the influence line as applied in structural engineering represents the influence of a single moving unit concentrated load upon the shear, bending moment, reaction, or any other function of a structure such as a beam, **truss**, or **bridge** The influence line is plotted in reference to a base or zero line Positive or tensile effects are represented above the line and negative or compressive effects below The ordinate of the influence line is the ratio of the effect to the concentrated load producing it If the load is in pounds or tons the effect is in pounds or tons It is very useful for locating the position of the load which will produce maximum effect For instance, the influence line for **bending moment** at the center of the beam shown above indicates that the maximum moment for this point will occur when the moving load which may be taken as unity is directly over the point Any other ordinate such as ab represents the bending moment at the center due to a load of unity at point A The maximum moment at the center of this beam due to a uniform load of w pounds



per linear foot, covering the entire length, may be computed by multiplying the area of the influence line by w.

$$\text{Area} = \frac{l}{4} \times l \times \frac{1}{2} = \frac{l^2}{8}$$

$$\text{Maximum moment at center} = \frac{wl^2}{8}$$

The results obtained from influence lines may also be found by analytical methods but the graphical solution is usually much more efficient from the standpoint of time This is particularly true when computing the stresses in the members of a large bridge due to its own dead weight and moving loads (C W C, F T M)

INFLUENZA. A highly contagious disease which usually occurs in **epidemic** or **pandemic** form, spreading with great rapidity

The disease in itself would rarely be serious, but for the fact that in severe form it predisposes to a particularly fatal secondary infection of the lungs, or other complications

The last great epidemic was 1918–20 Previous epidemics occurred in 1889–92, 1847–48, 1836–37, 1830–33, 1780–82, 1729–32

The disease is believed to be transmitted by a filterable **virus** The other organisms found are probably secondary invaders after the disease has established itself The principal symptoms are sudden onset with fever, marked prostration, severe aching pains in back and limbs, blood-shot eyes, headache and progressive inflammation of the respiratory mucous membranes The disease is self-limited (R S M)

INFRARED RADIATION. That range of radiation which extends from the limit of the visible red to the ultrashort **Hertzian radiation**, and therefore comprises wave lengths from approximately 0 00077 millimeter to 0 4 millimeter or longer This radiation is observed and measured by means of very sensitive thermal detectors such as the **bolometer**, the **radiomicrometer**, and different types of **radiometer**, while its **spectrum** is studied by the "spectrobolometer," and its **spectral energy distribution** by the "spectroradiometer" Much of the region may also be photographed, as is the visible spectrum, but special plates are necessary Pictures may even be taken by infrared radiation in total darkness Also, since these longer waves penetrate haze with less absorption, landscapes obscured by haze may be photographed by using an infrared filter with suitable plates Glass and water are nearly opaque to infrared radiation, while rock salt is relatively transparent to it (See **Thermal Radiation**).

A convenient laboratory source of infrared radiation is the "silica pencil," a heated rod of silicon dioxide When thermal radiation is allowed to fall on quartz reflectors, narrow bands of infrared **residual radiation** may be isolated for special study The spectra of elements exhibit lines in the infrared (See **Atomic Spectra**), for example, hydrogen gives the Paschen series, the Brackett series, and the Pfund series The wave-number formulae for these are, respectively,

$$w = R\left[\frac{1}{3^2} - \frac{1}{(n+3)^2}\right],$$

$$w = R\left[\frac{1}{4^2} - \frac{1}{(n+4)^2}\right],$$

$$w = R\left[\frac{1}{5^2} - \frac{1}{(n+5)^2}\right],$$

in which R is the **Rydberg constant** for hydrogen The rotation and vibration bands of **molecular spectra** are also in the infrared region. (L D W)

INFUNDIBULUM. A funnel-shaped cavity or organ. The alveolar sacs of the lungs from which the minute air chambers (alveoli) open are called infundibula and the end of the mammalian oviduct nearest to the ovary bears this name A small outgrowth of the ventral wall of the embryonic brain from which the pars nervosa of the posterior lobe of the pituitary gland develops is also named the infundibulum (A.W L)

INFUSION. (1) The injection of a saline or sugar solution into a vein This is used when, for any reason, the normal amount of fluid or nourishment cannot be given by mouth, in toxic states and in dehydrated conditions The usual quantity is about a quart, but when given slowly by the continuous drip method, several quarts may be given in twenty-four hours It is the only means by which nourishment can be supplied to the body when food cannot be taken in the normal manner (2) The product obtained by steeping a **drug** for the extraction of its medicinal principles (R S M)

INFUSORIA. A subdivision of the phylum **Protozoa**, no longer included by some taxonomists but used by others in place of the subphylum **Ciliophora** or the class **Ciliata** (A W L)

INFUSORIAL EARTH. Diatomaceous earth **Diatoms.**

INGESTION. The reception of food into the body The simplest type of ingestion is found in some of the one-celled animals, whose **protoplasm** merely flows around the food particle and engulfs it In all groups some means of bringing food to the body or of catching it or cutting it from the parent plant or animal occur It must then be taken into the body for digestion by an engulfing action of single cells like that of one-celled animals, by ciliary action, or by a muscular process of swallowing, all of which are forms of ingestion (A W L)

INIA Dolphin.

INITIAL CONDENSATION. The ordinary **steam engine** is double acting and has at each end of the **cylinder** a port which serves both for the admission and exhaust of steam The use of one port both for admission and exhaust causes a loss known as initial condensation This term refers to the condensation of some amount of the incoming steam on the walls of the port and cylinder head The reason for this condensation is to be found in the cooling of the same surfaces by the outflow of the exhaust steam Thus the ports have a cycle of heating and cooling which is in unison with the engine cycle Unfortunately, the heat given up by the port during the cooling cycle is released to steam which is on its way out of the cylinder Thus any initial condensation, though it may be re-evaporated, is an entire loss in so far as availability of the heat for work is concerned This is no minor loss, in fact, it is one of the major sources of thermal loss of the dual flow steam engine The uniflow engine, which represents the most significant advance in steam engine practice in recent years, derives its advantage chiefly from the elimination of this loss Steam flows from the ports towards the center of the cylinder in the uniflow engine The cool exhaust steam does not backflow through the entrance ports It escapes through ports located in the center of the cylinder, uncovered by the piston at the end of its stroke This one-way flow prevents cooling of the admission ports, and is the essential difference between the uniflow and conventional engine The Corliss engine, with its valves in the end of the cylinder, but having separate exhaust and admission valves, has much less initial condensation than the single-ported engine. (F.T.M.)

INJECTION. This term is commonly used to designate the act of placing or forcing a fluid, **drug**, **serum**, or **vaccine** into a vein, tissue (such as a muscle), or a portion of the body (such as the rectum) A hypodermic injection is one that is made with a syringe and needle into the tissues beneath the skin An intramuscular injection is similar to a hypodermic injection, except that a longer needle is used so that the material

injected may be introduced in the muscle. This is used for drugs that are slightly painful, and also because faster and more thorough absorption is obtained An intravenous injection is one in which the drug is introduced directly into the blood stream by inserting a needle into a vein The most rapid absorption is obtained in this way

The term injection is also used to designate the substance that is being injected Again, injection is used in another sense to denote the state of being congested, inflamed, or reddened, as in beginning **inflammation** of a part of the body (R S M)

INJECTION GNEISS. A **gneiss** whose banding or foliation is wholly or partly due to interlaminar injection of **granitic** magma into already **metamorphosed** and foliated rocks. (R M F)

INK. Inks are aqueous solutions containing organic ferrous compounds, as, for example, the tannate They are used for writing (See **Tannins**, and **Iron.**) (R K S)

INK SAC. A glandular sac found in the **squids** and related species (**cephalopod** mollusks) which secretes a dark fluid The duct of the gland opens into the intestine near the anus When the animal is aroused the ink is discharged into the mantle cavity and thence through the siphon into the surrounding water The ink of the **cuttlefish** is the source of the pigment, sepia (A W L)

INORGANIC CHEMISTRY. **Chemistry.**

INSECTA. The insects, a class of the phylum **Arthropoda** This is by far the largest taxonomic division of the animal kingdom, including approximately three and one-half times as many species as there are of all other animals About 450,000 species of insects have been described

Insects are characterized by the hard exoskeleton and jointed appendages of the phylum Among other arthropods they are distinguished by several characteristics 1 The body is divided into head, **thorax**, and abdomen 2 Both compound and simple eyes may be present 3 They have one pair of antennae 4 The thorax bears a maximum of three pairs of legs 5 Wings are found in the adults of many species. Two pairs occur in most orders 6 The abdomen is usually without jointed appendages although a few primitive forms bear modified derivatives of these structures 7 Respiration is accomplished by means of tracheae, which are air tubes opening from the exterior and branching among the tissues 8. Metamorphosis is complex in some orders although lacking in the most primitive forms

The immense numbers of insects indicate remarkable biological success They have invaded all possible habitats save the ocean, here only one form, *Halobates*, a genus of marine water striders, is known On land and in fresh water insects are found in almost every imaginable habitat They eat plants, animals, and dead organic matter of all kinds and many are parasitic They walk, run, jump, fly, swim, and burrow Moreover, their small size permits them to live in very limited habitats, hence the plant feeders include species which are confined to flowers, leaves, stems, fruits, or roots and parasites are not limited to larger animals but find adequate hosts in other insects, even insect eggs are attacked by parasitic insects Predacious species are, of course, confined to smaller prey such as other insects and the small members of other groups. This extreme diversity makes it impossible for human beings to avoid experience with insects The blood-sucking mosquitoes and flies and the scavenger clothes moths and beetles force themselves upon us

The contacts of insects and man are often of great economic importance, both beneficial and harmful. Among useful insects the honey-bee and silkworm are the outstanding examples, but among harmful species it is more difficult to select, for many species have caused appreciable losses in various fields of human activity In agriculture the plant-feeding species such as the Colorado potato beetle and the **codling moth**, the **gipsy moth** and the **Japanese beetle** are important pests, and the **bot flies** have at times been serious parasites of domestic animals Man suffers direct injury from many parasites such as the lice (**louse**), **fleas**, **black flies**, and **mosquitoes**, and in the tropics from the **chigger**, bot flies and other species, but the most serious damage done by insects in his life is through their role as carriers of disease Malaria and yellow fever are transmitted by mosquitoes, typhus by the body louse, and bubonic plague by fleas.

The classification of insects is necessarily complex and it is impossible for any individual to have detailed knowledge of more than limited subdivisions of the class. Two subclasses, **Apterygota** and **Pterygota**, are commonly recognized The former includes only primitive wingless insects, the latter the winged species and those which are secondarily wingless In these subclasses from nineteen to thirty-three orders are recognized by various authorities The following tabulation summarizes a classification which is widely used

Subclass **Apterygota**
- Order **Protura.** Rare and primitive insects of very small size
- Order **Thysanura** The **silverfish** or fish moth and allied species
- Order **Collembola.** The spring tails

Subclass **Pterygota.**
- Order **Orthoptera. Grasshoppers, crickets, cockroaches, katydids, mantises, walking-sticks** and their allies
- Order **Isoptera.** The white ants or **termites.**
- Order **Plecoptera.** The **stone flies.**
- Order **Ephemerida. May flies,** locally called shad flies, salmon flies, **June bugs** and Canadian soldiers
- Order **Odonata. Dragon flies** and **damsel flies**
- Order **Zoraptera.** Rare insects without a common name
- Order **Corrodentia.** The **book lice** and psocids
- Order **Mallophaga. Bird lice** or biting lice
- Order **Anoplura.** True or sucking lice
- Order **Embiidina.** Rare insects with no common name
- Order **Thysanoptera.** The **thrips.**
- Order **Hemiptera** The true **bugs.**
- Order **Homoptera. Cicadas, leaf hoppers, plant lice, scale** insects, etc
- Order **Dermaptera Earwigs.**
- Order **Coleoptera.** The **beetles**
- Order **Strepsiptera.** The stylopids
- Order **Neuroptera Lacewings, dobson flies, hellgrammites, ant lions, alder flies,** and others
- Order **Mecoptera.** The **scorpion flies.**
- Order **Trichoptera.** The **caddis flies,**
- Order **Lepidoptera. Butterflies, skippers,** and **moths**
- Order **Hymenoptera. Saw flies, ants, bees, wasps,** any many parasitic forms
- Order **Suctoria.** The **fleas.**
- Order **Diptera.** The two-winged flies, including true **flies, mosquitoes, midges, gnats,** and others.

(A W L)

INSECTIVORA. An order of mammals made up of small animals, mostly of nocturnal habits, which live on insects and other small invertebrates and in a few cases on vegetation **Moles, shrews, hedgehogs** and related species. (A W L)

INSECTIVOROUS PLANTS. These are plants which are able to obtain a part of their **nitrogen** supply from the bodies of small insects and other animals which are trapped by the plants in various ways They are also frequently called carnivorous plants. All of them

are green and capable of living without this animal nitrogen, but many seem to thrive better if they have it. They are plants which grow in marshy or boggy places, where the supply of nitrogen available may be very slight. Some of them are water plants.

Insectivorous plants may be divided into three distinct groups, distinguished by the manner in which the plant captures the insects In one group, the insects are attracted to the plant's leaves by a glandular secretion which is sticky and holds them fast In some species in this group, the glandular hairs fold inward over the prey to hold it firmly and to aid in digesting it The most common plants of this group are the sundews, species of the genus *Drosera* They are small bog plants of fairly common occurrence In some species the leaves are linear, in others round and long-petioled In all, the upper surface of the leaf is covered with long tentacle-like hairs with swollen tips This tip secretes a copious quantity of a colorless sticky substance which glistens in the sunlight and attracts many small insects. When the insect alights on the leaf or on one of the hairs, it stimulates the latter to fold inward, gradually carrying the insect towards the center of the leaf The stimulus is transmitted to other nearby hairs, which fold in likewise, until the insect is carried to the leaf center and pressed firmly against the surface A digestive enzyme is there secreted, which acts on the proteins of the animal body, changing them to a soluble form which can be absorbed by the leaf When digestion is completed, the glandular hairs unfold, and the leaf is ready for another victim

Another common plant of this group is the Butterwort, *Pinguicola vulgaris* In this plant the surface of the leaf is shiny with the sticky secretion from the glands, while the edges of the leaf are rolled inward Insects attracted by the sticky surface are gradually caught under the enrolled margin and there digested Other plants in this group are tall herbs or low shrubby plants, in them no movement of the glands occurs, the prey being held by the sticky secretions alone

The second group of insectivorous plants comprises all those in which the leaf is variously modified to form a pitcher in which the prey is entrapped Plants of this group are often very striking objects They occur in widely scattered regions In the eastern part of North America are found species of the genus *Sarracenia*, which are commonly called pitcher-plants They are found in open marshes where plenty of light will reach them The leaves occur in basal rosettes, and are green, often deeply mottled with red Each leaf has the form of an open pitcher with a distinct lip or flange at the top, and a green wing down one side of the pitcher Around the mouth of the pitcher, on the inner side, are numerous glands which secrete a fluid which attracts insects Lining the inside of the pitcher are numerous stiff pointed teeth or bristles which project sharply downward, so that it is easy for the insect to crawl down into the pitcher, but practically impossible to crawl up The lower part of the pitcher is usually full of water, into which the unfortunate insect eventually falls and is drowned Either due to the action of bacteria or that of secretions from glands in the surface of the leaf, the proteins of the animal body become assimilable by the leaf, which thus obtains nitrogenous matter. In California is found *Darlingtonia californica*, the leaves of which are even more remarkable The same pitcher-like structure occurs, but the opening of the latter is covered by the overgrowing of the upper part of the leaf, which ends in a brightly colored flap. In the arching part of the pitcher which covers the opening there is a clear translucent space, against which insects persistently move until exhausted, then fall into the pitcher below. Even more remarkable pitchers are found in the leaves of the genus *Nepenthes*, which is native in the East Indies, Malaya, and Madagascar. These plants are herbs or shrubby plants which grow in bogs. At first they have leaves like other plants, but soon very much modified leaves appear and aid the plant in climbing upward to a position having a favorable light supply. The mature leaves of these plants are remarkable objects In each there is a flat green blade which is prolonged at its tip into a long slender stem-like structure which often tightly twines about any supporting object Beyond this portion of the leaf the pitcher is found In size the pitcher varies according to species, from a small object an inch or so long, to bodies capable of holding a quart or more of liquid. The rim of the pitcher is rolled inward and provided with an abundance of glands which secrete a substance attractive to insects. The lower part of the inner surface of the pitcher is slippery, offering no foothold to insects seeking to escape Often the pitcher is rather brightly colored Beyond the pitcher the leaf is again prolonged into a slender stalk which ends in an expanded flap which frequently stands over the opening of the pitcher Because of their curious habit many species of *Nepenthes* are cultivated as hot-house plants

Other species of pitcher plants are found in South America and in Australia.

The third group of insectivorous plants is composed of those plants which capture their prey by some sort of movable trap In this group are found Venus' fly-trap, the Bladderworts, and Aldrovanda

Venus' fly-trap, *Dionaea muscipula*, is a small plant found in the Carolinas The leaves form a basal rosette close to the ground Each leaf has a broad blade-like petiole which abruptly narrows at its tip and bears a remarkable blade. The latter is formed of two halves which are joined by a movable hinge down the center. The edges of each half are fringed by long stiff bristles, while on the upper surface of each are borne three long slender trigger hairs which are sensitive to contact with any solid object Each trigger hair is jointed at its base The upper surface of the blade is abundantly supplied with small glands When any insect alights on the leaf and comes in contact with one of the trigger hairs, a stimulus is given which causes the two halves of the blade to fold together with the bristles around their edges interlocking and so trapping the insect securely Once caught the insect is slowly digested by the leaf

Aldrovanda vesiculosa is a rootless plant found in quiet waters in Europe and Asia Its leaves are stalked, and have a hinged blade with trigger hairs, and digestive glands very similar to those of Venus' fly-trap Small aquatic animals are trapped in the leaves of this plant

The Bladderworts belong in the genus *Utricularia*, which contains some 200 species, widely distributed in tropical and temperate regions One of the commonest species, *Utricularia vulgaris*, occurs in ponds and slow streams in both Europe and North America This plant never has any roots, even when it first develops from the seeds. The leaves of the plant are finely dissected and bear small bladders which give the plant its name The bladders have a narrow opening which is surrounded by a group of radiating hairs which form a funnel-like approach to the opening This opening is provided with a "trap-door." The inside of the bladder bears many four-parted hairs Should a small aquatic creature chance to venture into the funnel of hairs and touch certain sensitive hairs, the bladder suddenly expands, creating a current of water which sweeps the unfortunate creature into the bladder The "trap-door" closes behind him and he is held prisoner until he dies Other species of bladderworts have ordinary undissected leaves In the tropics certain species are found only in the waters contained in the pitchers formed by the wide leaves of certain members of the Pineapple family (R M W)

INSEMINATION. The introduction of the seminal fluid, bearing the reproductive cells of the male, into the genital passages of the female **Copulation. Mating.** (A W L)

INSOLATION. One of the processes of weathering. Extreme diurnal (daily) changes in temperature such as occur on high plateaus, and especially high deserts, causing relatively rapid expansion and contraction of the rocks so that they crack and disintegrate Differences in temperature between day and night have been registered as high as 120° F Insolation is only effective on bare rock faces, as a slight blanket of soil or debris serves to protect the rock from relatively rapid heating and chilling (R M F)

INSTANTANEOUS CENTER. The instantaneous center is the imaginary point about which a body having general motion may be considered to be rotating for the instant The instantaneous center is not necessarily on the body, in fact, it can be, in the case of rectilinear motion, infinitely distant. (See **Centrode**) (F T M)

INSTAR. A single period of growth of an arthropod larva, ending with a moult or **ecdysis** The term is applied chiefly to insects In this group normal growth is completed in a fixed number of instars, the last one terminating with pupation Under abnormal conditions, however, the **larva** may grow slowly and moult more than the usual number of times It is evident from such cases that the length of instars and their number are conditioned by more factors than growth of the animal to a size which demands a larger integument (A W L)

INSTRUMENT. The term instrument describes a wide range of subjects, but from a technical standpoint, an instrument is a tool or mechanism for scientific and professional service As far as tools are concerned, instrument might be taken to designate such tools as are delicately, accurately, and scientifically constructed, and whose use requires above average dexterity and technique

Nearly every technical field exhibits a great number of specialized scientific mechanisms which might be called, with reason, instruments Obviously, the scope of mechanisms included under so general a heading is too extensive for detailing here. However, a great many measuring devices, meters, gages, and the like, in their construction, will satisfy the definition of instrument given above A great many meters and gages are called instruments, although in some cases there could be some reasonable doubt as to whether they could rightfully be so designated For further details, see **Meters, Gages, Electrical Instruments.** (F T M)

INSULIN. Insulin is the active principle or **hormone** secreted by certain cells of the **pancreas** which enables the body to utilize **carbohydrates** When **diabetes** is present there is a deficiency of this hormone and it is necessary that this substance be given by hypodermic injection The hormone is extracted from the pancreas of slaughter-house animals It is standardized in units—one unit of insulin will enable a diabetic to utilize 1 5 to 2 grams of sugar In diabetes it reduces the elevated blood sugar to normal so that sugar no longer appears in the **urine**, enabling the patient to eat a liberal diet, and relieving him of all symptoms of diabetes When insulin is necessary in diabetes it is usually continued through life At times when the disease appears in later life it may be discontinued after the diabetes is brought under control In young girls when menstruation begins less insulin is required In all subjects when infection develops the dose of insulin must be increased

An overdose of insulin produces an "insulin reaction" characterized by perspiration, tremor, visual disturbances, convulsions, and coma The same symptoms may appear if a meal is omitted after taking the injection of insulin The symptoms can be immediately relieved by eating sugar in any form, or if necessary, injecting **glucose** into a vein This insulin reaction or "shock" as it is sometimes called, is now used therapeutically in certain forms of insanity as **dementia praecox** Some promising results have been obtained

Insulin is also used in other conditions, as in wasting diseases, to enable the body to use more sugar and thereby help the patient to put on more weight

There is a recent insulin preparation—ptomaine insulin—which is absorbed more slowly, enabling the patient to carry through the entire day on one injection of insulin (R S M)

INTEGRAL EQUATIONS. An integral equation may be described in a general way as an equation in which an unknown function appears under a **definite integral**

A linear integral equation of the first kind is an equation of the form

$$\int_a^b K(x, t)u(t)dt = f(x),$$

where $u(t)$ is an unknown function to be found, $K(x, t)$ and $f(x)$ are known functions, and the limits a and b are known The function $K(x, t)$ is called the kernel of the equation

A linear integral equation of the second kind (or Fredholm integral equation) is an equation of the form

$$u(x) = f(x) + \int_a^b K(x, t)u(t)dt,$$

where $u(t)$ is an unknown function to be found, $K(x, t)$ and $f(x)$ are known functions, and a and b are given The function $K(x, t)$ is called the kernel of the equation

If $f(x) \equiv 0$, the resulting equation

$$u(x) = \int_a^b K(x, t)u(t)dt$$

is called a homogeneous linear integral equation of the second kind

The equation

$$u(x) = f(x) + \int_a^x K(x, t)u(t)dt$$

is called Volterra's linear integral equation of the second kind

Non-linear integral equations have also been investigated

Three types of solutions of linear integral equations of the second kind have been developed

(1) The first method, which may be called the method of successive substitutions, is due to Neumann, Liouville, and Volterra It gives the unknown function $u(x)$ in the equation

$$u(x) = f(x) + \lambda \int_a^b K(x, t)u(t)dt$$

as a power series in λ, whose coefficients are functions of x, this series has in general a finite radius of convergence

(2) The second method, due to Fredholm, gives $u(x)$ as a ratio of two power series in λ, each series converging for all values of λ In the numerator the coefficients of the powers of λ are functions of x, while the denominator is independent of x The solution is obtained by considering the integral equation as the limiting form of a system of n linear algebraic equations in n variables as n becomes infinite

(3) The third method, which was developed by Hilbert and Schmidt, gives the unknown function $u(x)$ in terms of a set of so-called fundamental functions These functions are in the ordinary case the solutions of the corresponding homogeneous equation

$$u(x) = \lambda \int_a^b K(x\ t)u(t)dt$$

This equation is in general satisfied only by $u(x) \equiv 0$, but there exists a sequence of numbers $\lambda_1, \lambda_2, \ldots, \lambda_n, \ldots$, called characteristic constants (or fundamental numbers) for each of which the equation has a finite solu-

tion. $u_1(x)$, $u_2(x)$, . . . , $u_n(x)$, . . . These functions are the fundamental functions The solution of the given integral equation is then obtained in the form

$$u(x) = \sum_{n=1}^{\infty} a_n u_n(x),$$

where the a_n are arbitrary constants (L L S)

INTEGRAL FUNCTION. An integral function is a **function** (of a real or complex variable) defined by a **power series** which converges for all finite values of the variable, this includes **polynomial functions** as special cases An integral function may also be defined as a function of a complex variable which is **analytic** at all finite points of the complex plane Simple examples of integral functions (besides the polynomials) are the **exponential function**, and the sine and cosine (**trigonometric**) **functions** (L L S)

INTEGRAPH. An integraph is an instrument which draws the integral curve of a given curve mechanically, from it areas may be read off as ordinates (L L S)

INTEGRATING METERS. The ordinary electric service meter measures the total of electric energy used over a period of time It is in principle much like a **wattmeter**, except that the movable coil is replaced by a motor armature rotating against a magnetic damping arrangement The speed of revolution is proportional to the torque, which, in turn, is proportional to the product of current and electromotive force The total revolution of the armature is recorded on dials by pointers suitably geared to the armature shaft Since angle = revolution speed × time, the reading of the dial is proportional to current × electromotive force × time, that is, to amperes × volts × hours or watt-hours The dial may thus be graduated directly in watt-hours or in convenient multiples or sub-multiples thereof (See **Power** and **Watt**) (L D W)

INTEGRATING PHOTOMETERS. The usual types of **photometer** give the luminous intensity of a source as viewed from one direction only If the lamp under examination is turned around its vertical axis and the measurement thus obtained from various horizontal directions averaged, the result is the mean horizontal candle power Usually a still more significant quantity is the mean spherical candle power, that is, the average luminous intensity from all directions To obtain such averages, some type of integrating photometer is used

One plan is to reflect the light emitted in various directions toward one spot by means of a system of mirrors appropriately placed, and to measure the resulting illumination at that point The most common device at present, however, is the "sphere" or "globe" photometer This has a large hollow globe painted white inside with barium sulfate paint The lamp is mounted at any convenient point inside, and the resulting diffuse illumination of a translucent screen covering an opening in one side is measured by a photometer (The screen must be protected from the direct rays of the lamp) It was shown by Sumptner (1892) that under these conditions, the illumination on the screen is proportional to the mean spherical candle power and is independent of the orientation or the position of the lamp Comparison may thus be made with a standard lamp of known spherical candle power by the substitution method A photovoltaic cell may be substituted for the translucent screen and the readings thus made electrically. (See **Illuminometer**) (L.D W)

INTEGRATION. Indefinite Integral, also Definite Integral.

INTEGRATION AS A PROCESS OF SUMMATION. Definite Integral.

INTEGRATION, TECHNIQUE OF. Standard integrals

$$\int u^n\,du = \frac{u^{n+1}}{n+1} + C \quad (n \neq -1),$$

$$\int \frac{du}{u} = \log_e u + C, \quad \int e^u\,du = e^u + C,$$

$$\int \sin u\,du = -\cos u + C, \quad \int \cos u\,du = \sin u + C,$$

$$\int \sec^2 u\,du = \tan u + C, \quad \int \csc^2 u\,du = -\cot u + C$$

$$\int \sec u \tan u\,du = \sec u + C, \quad \int \csc u \cot u\,du = -\csc u + C$$

$$\int \tan u\,du = -\log \cos u + C = \log \sec u + C,$$

$$\int \cot u\,du = \log \sin u + C,$$

$$\int \sec u\,du = \log (\sec u + \tan u) + C,$$

$$\int \csc u\,du = \log (\csc u - \cot u) + C,$$

$$\int \frac{du}{u^2 + a^2} = \frac{1}{a} \tan^{-1} \frac{u}{a} + C,$$

$$\int \frac{du}{u^2 - a^2} = \frac{1}{2a} \log \frac{u - a}{u + a} + C,$$

$$\int \frac{du}{a^2 - u^2} = \frac{1}{a} \tanh^{-1} \frac{u}{a} + C,$$

$$\int \frac{du}{\sqrt{a^2 - u^2}} = \sin^{-1} \frac{u}{a} + C,$$

$$\int \frac{du}{\sqrt{u^2 \pm a^2}} = \log (u + \sqrt{u^2 \pm a^2}) + C,$$

$$\int \frac{du}{\sqrt{u^2 + a^2}} = \sinh^{-1} \frac{u}{a} + C,$$

$$\int \frac{du}{\sqrt{u^2 - a^2}} = \cosh^{-1} \frac{u}{a} + C,$$

$$\int \frac{du}{u\sqrt{u^2 - a^2}} = \frac{1}{a} \sec^{-1} \frac{u}{a} + C.$$

Integration by substitution

An integral $\int f(x)dx$ may often be reduced to a standard form by expressing x as a function of another variable t If $x = \phi(t)$, the substitution $x = \phi'(t)$, $dx = \phi'(t)dt$ will transform $\int f(x)dx$ into an equivalent integral in t

Integration by parts

This is based on the formula

$$\int u dv = uv - \int v\,du$$

Integration of rational fractions

When the function to be integrated has the form of a rational fraction, it should be decomposed into a sum of **partial fractions**, each of these partial fractions can then be integrated separately by standard forms

Trigonometric forms

(1) Type $\int \sin^m x \cos^n x\,dx$, where either m or n is an odd integer

Suppose n is an odd integer Write the integral $\int \sin^m x \cos^{n-1} x (\cos x\,dx)$, by use of $\cos^2 x = 1 - \sin^2 x$, we can express $\cos^{n-1} x$ rationally in terms of powers of $\sin x$ since $n - 1$ is an even integer, and since $\cos x\,dx = d \sin x$ we obtain an expression in powers of

$\sin x$ each multiplied by $d \sin x$, so that they can each be integrated by the power law

$$\int u^n \, du = \frac{u^{n+1}}{n+1} + C$$

(2) Type $\int \left.\begin{matrix}\sin\\ \cos\end{matrix}\right\} mx \cdot \left.\begin{matrix}\sin\\ \cos\end{matrix}\right\} nx \, dx$

To evaluate $\int \sin mx \cos nx \, dx$, we use the trigonometric identity $\sin mx \cos nx = \frac{1}{2}[\sin (m+n)x + \sin (m-n)x]$ To evaluate $\int \sin mx \sin nx \, dx$, we use the identity $\sin mx \sin nx = \frac{1}{2}[\cos (m-n)x - \cos (m+n)x]$ To evaluate $\int \cos mx \cos nx \, dx$, we use the identity $\cos mx \cos nx = \frac{1}{2}[\cos (m+n)x + \cos (m-n)x]$

(3) Type $\int \sin^m x \cos^n x \, dx$, where m and n are both even integers

Transform the integrand function into an integrable form in terms of sines and cosines of multiples of x by use of the trigonometric identities

$$\sin^2 x = \tfrac{1}{2}(1 - \cos 2x), \qquad \cos^2 x = \tfrac{1}{2}(1 + \cos 2x),$$
$$\sin x \cos x = \tfrac{1}{2} \sin 2x.$$

(4) Type $\int \tan^n x \, dx$ or $\cot^n x \, dx$, where n is any integer

These forms may be reduced to standard forms by use of $\tan^2 x = \sec^2 x - 1$ or $\cot^2 x = \csc^2 x - 1$, and $\sec^2 x \, dx = d(\tan x)$ and $\csc^2 x \, dx = -d(\cot x)$

(5) Type $\int \tan^m x \sec^n x \, dx$ or $\int \cot^m x \csc^n x \, dx$, where n is an even integer

In this case we use the relations $\tan^2 x = \sec^2 x - 1$, $\sec^2 x = 1 + \tan^2 x$, $d \tan x = \sec^2 x$, and similar forms in terms of $\cot x$ and $\csc x$, and reduce to use of the power law

$$\int u^n \, du = \frac{u^{n+1}}{n+1} + C.$$

Integration of linear radical forms·

If the integrand contains a linear radical $\sqrt[n]{ax+b}$, the substitution $a + bx = z^n$ will reduce it to a rational form

Integration by trigonometric substitutions

Expressions involving $\sqrt{a^2 - x^2}$ or $\sqrt{x^2 \pm a^2}$ are often most easily integrated by aid of one of the following substitutions

when $\sqrt{a^2 - x^2}$ occurs, put $x = a \sin\theta$, $\sqrt{a^2 - x^2} = a\cos\theta$,
when $\sqrt{x^2 + a^2}$ occurs, put $x = a \tan\theta$, $\sqrt{x^2 + a^2} = a \sec\theta$,
when $\sqrt{x^2 - a^2}$ occurs, put $x = a \sec\theta$, $\sqrt{x^2 - a^2} = a \tan\theta$.

Integrals with quadratic radicals

If the integrand contains $\sqrt{x^2 + ax + b}$, substitute $\sqrt{x^2 + ax + b} = z - x$, and we obtain a rational integrand in terms of z

If the integrand contains $\sqrt{-x^2 + ax + b}$, substitute $\sqrt{-x^2 + ax + b} = (\alpha - x)z$ or $(\beta + x)z$, where $\alpha - x$ and $\beta + x$ are the factors of $-x^2 + ax + b$, the integrand becomes rational in z

An integral in which the integrand is a rational function of $\sin x$ and $\cos x$ is transformed into one having a rational algebraic integrand by the substitution $\tan \frac{1}{2}x = z$, then

$$x = 2\tan^{-1} z, \; dx = \frac{2dz}{1+z^2}, \; \sin x = \frac{2z}{1+z^2}, \; \cos x = \frac{1-z^2}{1+z^2}.$$

Tables of integrals are published, giving more or less extensive classified lists of integrals (L L S)

INTEGUMENT, INTEGUMENTARY SYSTEM. For the use of this term in botany, see **Seed.** The body of every multicellular animal is covered with a layer of tissue adapted to meet the external conditions that prevail in the normal environment of the species. This covering is the integument and together with all of the specialized structures derived from the cellular layers it constitutes the integumentary system.

The general functions of the integumentary system are protection against mechanical damage and desiccation, the transmission of materials which must pass into or out of the body, the conservation of heat, and the reception of stimuli Among the invertebrates such rigid supporting structures as the animal may possess are often developed in the integument, so that it becomes a **skeletal system** or exoskeleton as well as a covering for the body

The integument is always at least partly ectodermal in origin In the simpler animals such as the **coelenterates** it is an epithelial layer containing cells specialized for the reception of stimuli, defensive cells, and simple cells bearing contractile basal processes It bears **cilia** in some of the flatworms, in the **rotifers** and **bryozoans,** and in some of the mollusks (**Mollusca**), and so aids in bringing food to the animal and in locomotion In parasitic flatworms it degenerates into a **syncytium** and produces a non-cellular **cuticle,** and in roundworms, segmented **worms,** and **arthropods** it also secretes an external cuticle although it remains cellular It gives rise to the **setae** of the segmented worms and arthropods and to the external portions of sensory organs, and contains glands of various kinds In the arthropods the cuticula is highly developed as an exoskeleton The integument also lays down the hard deposits of **corals** and secretes the shells of **brachiopods** and mollusks

The integument of **vertebrates** is a **skin** composed of two layers, an inner corium or dermis derived from mesoderm and an outer cuticle or epidermis which is ectodermal It produces various hard structures including the scales of fishes, scales of reptiles, birds and mammals, feathers, hair, horns, claws, hoofs, and nails In addition it contains glands of various kinds, such as the mucus glands of fishes and amphibians and sweat glands of mammals and forms parts of the sensory organs (A W L)

INTERCONNECTION. Each year witnesses interconnections and mergers which are slowly uniting the power and light companies of the United States into one vast interconnected network of transmission lines The justification for interconnection can be presented on a financial basis, but the ability to render intersystem assistance during local trouble and in that way to prevent interruption of service to the customer should be the basic reason for interconnection, even though no definite financial expression may be attached to it Of more tangible value is the use of the more efficient plants as base load stations Off-peak power may be exchanged on some prearranged basis when the load peaks on one system do not occur simultaneously with those on another This has the effect of delaying, for a time, the purchase of new equipment to care for increasing peaks Also, it renders economical the installation of additional capacity beyond that justified by the gain in the individual system, that is, a new station or unit causes temporary surplus capacity and consequent annual charges for idle equipment which may be reduced by adjacent systems installing their new equipment alternately A decrease in the total of emergency standby capacity is possible when two or more systems operate interconnected Systems predominantly hydroelectric, but with steam standby, realize the maximum economy in interconnected operation because of the diversity of stream flow in different localities

Interconnection relieves the necessity of splitting up the plant capacity into a number of small units for the sake of uninterrupted service.

A superpower system is a vast interconnected system which has for its basis the maximum exploitable water power of the country, relying on excess flows at one point to counteract low water at another, and having

steam plants suitably located to care for deficiencies in water power While it would be possible to transmit over great distances, actually transfers of energy between groups constituting the superpower system would rarely occur over distances greater than two hundred miles. (F T.M)

INTERFERENCE. For a general technical definition of interference, it may be said that interference is the action of a body or process which tends to oppose, become entangled with, or offer physical impediment to another body or process The more common cases of interference will be discussed below

Gear tooth interference is encountered in certain designs. The standard Brown and Sharp involute tooth system, having an angle of obliquity of 14½°, has interference between the face and flank of mating gear teeth, if the involute pinion engaging a gear has fewer than 32 teeth In this interference, the tip of a tooth tends to occupy the same space as the flank of its mate, with consequent under cutting of the flank or rounding of the tip This can be overcome by modifying the tooth profiles, either by purposely under cutting the flanks or rounding the tips, or by using the unequal addendum system, in which the addendum of the driving pinion is made long, while that of the driven gear is made short. (See **Gear Teeth**)

Inductive interference arises sometimes in telephone circuits In telephone systems, where speech strong and audible must be received, it is essential that the currents in the lines connecting receiver and transmitter be not unduly altered or distorted Yet inductive interference from many sources possesses the power so to affect telephonic communication, and an important phase of communication engineering is the neutralizing or removing of inductive interference. The interference may arise from natural sources, including lightning, aurora borealis, or from artificial transmission lines, railway feeders, etc With the growth of electric power networks, power line interference became quite serious, and it was found necessary to co-ordinate the activities of electric light and telephone companies in an endeavor to control inductive interference This problem has been fairly well overcome by the use of many devices such as the transposition of lines, special transformer connections, cut-outs, and grounded sheaths See **Telephony.**

The term interference is applied to certain mechanical fits Here interference is negative tolerance, and is allowable on certain press fits and shrink fits

Interference is familiar in radio The superheterodyne radio receiver is susceptible to certain types of interference, which are described as image frequency interference, station interference, and interference from harmonics

Interference between wave trains is very important, throughout many phases of physical science When two wave trains of similar character traverse the same point in space simultaneously, in such a way that their displacements affect each other, the resultant effect, corresponding to the algebraic sum of the separate displacements, is called interference For this to be observable, the wave trains must have some degree of "coherence," that is, their vibrations must be related in character. Then when the waves are in the same phase, they will augment each other; when in opposite phase, they tend to neutralize each other

There are two general types of wave interference: that exhibited by wave trains of different frequency, and that by wave trains of the same frequency The former is well illustrated by the **beats** produced by similar tones of different pitch, the latter by the interference fringes observed in an **interferometer** or in **Young's experiment,** or by **Newton's rings.** When a wave train is reflected normally so as to return along the same path, as sound waves echoed by a flat wall, the waves traveling in opposite directions interfere and alternately augment and neutralize each other, thus producing "stationary waves" with alternate nodes and antinodes The curious phenomenon known as **Lippman fringes** exhibits this effect with light waves. Since the distribution of interference phenomena in space depends upon frequency, non-homogeneous wave trains are subject to **dispersion,** in the case of white light, this takes the form of spectral colors The "structural colors" exhibited by thin films and finely striated surfaces are produced in this way. (F T M, L D W)

INTERFEROMETERS. The term interferometer may be applied to any arrangement whereby a beam of light from a large, luminous area (as a sodium flame) is separated into two or more parts by partial reflections, the parts being subsequently reunited after traversing different optical paths The two components then produce **interference** The best known instrument is that of Michelson, shown diagrammatically in the accompanying figure The original beam a is separated at the surface AM of a glass plate, part of it $(1,1')$ going to a mirror M_1 and part $(2,2')$ going on through a second, exactly similar plate B to the mirror M_2. They reunite at AM and are observed together at E One of the mirrors, M_1, is mounted on a micrometer screw so that its distance from AM can be varied, the phase difference of the reunited beams thereupon passing through a series of cycles If M_1 or M_2 is not quite perpendicular to the beam reflected by it, the field at E is crossed by interference fringes, which move across the field as the mirror M_1 is moved Each complete cycle corresponds to a displacement of M_1 equal to a half-wave length The Fabry and Perot interferometer is somewhat simpler in design, but utilizes multiple reflection and produces very sharp fringes (high resolving power)

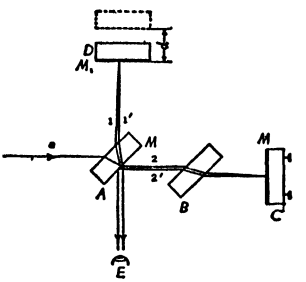


Diagram of Michelson interferometer.

Interferometers are used for precise measurements of wave length, for the measurement of very small distances and thicknesses by using known wave lengths, for the detailed study of the **hyperfine structure** of spectrum lines, for the precise determination of refractive indices, and, in astrophysics, for the measurement of **double-star** separations and the diameters of very large **stars.** (L D W)

INTERLOBATE MORAINE. If large glaciers and continental ice sheets advance irregularly so that their margins are lobate, when the margins retreat by melting the resulting **terminal moraines** of boulders, clay, and sand simulate the original interlobate shape of the glacier or glaciers, and therefore such moraines are called interlobate (R M F)

INTERMEDIATES. **Coal Tar Products and Intermediates.**

INTERNAL COMBUSTION ENGINE. The internal combustion engine is one in which **combustion** of a **fuel** takes place within the **cylinder,** and the products of combustion form the working medium during the

power stroke As it is a self-contained power supply unit, the internal combustion engine assumes a position of great importance in the power field, especially for that class of service where portability, light weight, and compactness are important Witness the majority of self-propelled vehicles powered by internal combustion engines The principal cycles of internal combustion engines in use at present are the **Otto** and **Diesel** cycles Other cycles are of some historical importance, but these two have supplanted the others in the course of time by possessing certain points of superiority such as economy, reliability, compactness, etc

An internal combustion engine consists primarily of a cylinder, almost always stationary, and a **piston**, generally single acting, which, together, form a combustion chamber of variable volume Both of these parts are constructed of metal, and as the temperatures attained during combustion are well above the ability of uncooled metals to withstand, the cylinder of an internal combustion engine must be adequately cooled by transferring through the cylinder wall a certain amount of the heat contained in the gases of combustion This is accomplished in a practical way by surrounding the cylinder with a **jacket** of cooling water, or by providing it with an extended outer surface of fins so that air can absorb enough heat to keep the metal cool The required motion is given to the piston by a crank and connecting rod mechanism which also serves to take from the piston the power developed by gas pressure

An engine operating with flaming gas in its cylinder would not last long with simple metal to metal contact of the moving parts, therefore a lubricating system, embodying oil as the lubricant, is an important feature of every internal combustion engine The most difficult job is that of lubricating the piston in the cylinder During a portion of the stroke, at least, the lubricated wall is exposed to incandescent gases which tend to burn off the film of lubricating oil The cooling system must be adequate to maintain the metal surfaces cool enough to save the lubricating film

The events of the cycle upon which an internal combustion engine works are controlled chiefly by the operation of **valves** located in ports leading to and from the cylinder Generally, an admission or inlet valve, and an exhaust valve, are provided in each cylinder The operation of these valves is derived mechanically from the crankshaft through the **valve gear** system

The combustion of fuel in an internal combustion engine is not a continuous affair, but a series of individual explosions, each one requiring a metered amount of fuel to be individually ignited For this reason, every internal combustion engine must incorporate an **ignition system**, whose function it is to supply in proper time the ignition temperature required for combustion The internal combustion engine is of a type tending to deliver its power cyclically, and in a fashion which would be very fluctuating unless balanced by the use of heavy **flywheel**, or by overlapping of power impulses through multi-cylindered arrangements It is usual, in fact, to build internal combustion engines with more than one cylinder so that the delivery of power will be more uniform, and flywheel proportions will not be excessive The supply of fuel to multi-cylindered engines from a common source, and the conduction of exhaust from them, leads to another service feature for the internal combustion engine, namely, the inlet and exhaust **manifolds**

The production of power by this type of engine represents a **thermodynamic** conversion of a portion of the heat energy developed into mechanical energy The heat energy enters the engine latently in the form of fuel Mechanical energy appears as power available at the crankshaft Unavailable or rejected heat is found in exhaust, cooling, and friction The conversion of the energy of the fuel into useful power takes place about as follows Air is brought into the cylinder and, either after, before, or during compression depending on the cycle, fuel is introduced into the air and mixed with it Upon ignition of this fuel, the heat developed raises the pressure of the products of combustion, or, at least, maintains the pressure during some motion of the piston. The fact that the piston has, against one face of it, a gas pressure greatly exceeding that on the other, inevitably results in the transmission of energy through the train of mechanism consisting of moving piston, wrist pin, connecting rod, and crankshaft During the motion of the piston, the gases of combustion expand and are cooled somewhat It has not been found economical to build an engine sufficiently bulky to expand the gases until they reach ordinary atmospheric temperature, and there is always considerable heat loss in the exhaust (In spite of the losses the internal combustion engine of the present is the most efficient prime mover that has been devised) (See **Diesel Engine, Otto Engine, Two-cycle, Four-cycle, Aeronautical Engine, Engine, Ignition System, Carburetion**) (F T M)

INTERNAL FRICTION. Viscosity.

INTERNAL PRESSURE. Adhesion and Cohesion.

INTERNAL SAC. An organ of larval **bryozoans** by which the animal attaches itself to a supporting surface before transforming into the adult (A W L.)

INTERNATIONAL DATE LINE. In accordance with the fundamental definition of civil **time** the date changes when the mean sun crosses the **meridian** at lower culmination, i e, at midnight It would be possible for a traveler to travel around the earth on a sufficiently high parallel of **latitude** in twenty-four hours Say such an observer starts out at one o'clock in the afternoon, i e, with the sun about one hour west of his meridian, and travels westward at just the proper rate to maintain the sun in that position For such a traveler the date would not change and he would return to his starting point on the same date, as he would reckon it, as that on which he set forth on his journey If the traveler had taken one hundred days to complete his journey instead of only one, he would still return to his starting point a day earlier, on his own reckoning, than the date of those who had remained at home To avoid confusion of this sort the so-called international date line has been established

This date line is approximately 180° west of Greenwich in **longitude** but is adjusted so that, so far as is possible, the Pacific insular possessions of the different countries shall carry the same date as the home nations, and also so that the line shall not cross any land Ships crossing the date line from east to west skip one day That is, if it is Monday when the ship arrives at the line from the east it immediately becomes the same hour on Tuesday after crossing the line and the day so dropped is omitted from the log book On crossing the line from west to east a day is repeated (W K G)

INTERNATIONAL TEMPERATURE SCALE. Thermometry.

INTERPOLATION. Interpolation is a process by which an appropriate value is placed between tabulated values of a function

Simple interpolation, by first differences, is based on a principle of proportional parts when the variable (or argument) changes by a small amount, the change in the tabulated function is very nearly proportional to the change in the variable

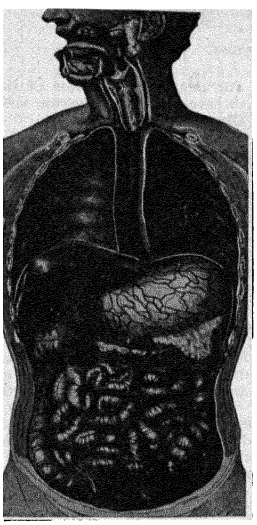
For more accurate work, interpolation by second and higher differences is needed, and more complicated interpolation formulas are then used (L L S)

INTERRAY. A division of the body of a starfish (**Asteroidea**) between the axes of two rays or arms, or a corresponding division of the sea urchins which lack radiating arms but have radii indicated in the structure of the compact body (A W L)

INTERSTITIAL CELL. 1. Small undifferentiated **cells** in the outer layer of polyps such as *Hydra* which develop into the **cnidoblasts** and reproductive cells. 2. Cells between the reproductive structures of the ovaries and testes of vertebrates. They have been interpreted as glands of internal secretion but the point is disputed. (A.W.L.)

INTERTENTACULAR ORGAN. A temporary duct leading from the **coelom** to the exterior within the tentacle bearing ridge (**lophophore**) of **bryozoans**. **Germ cells** escape through it. (A.W.L.)

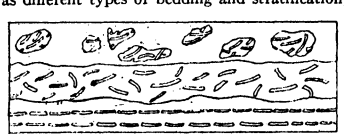
INTESTINAL OBSTRUCTION. This serious condition which is compatible with life for only a short period is one of the grave surgical emergencies. In the acute form, unless surgical relief is very prompt, death soon follows. The causes of this condition are many. Any mechanical condition that blocks the intestine, such as a cancerous growth shutting off the intestinal canal, a band or adhesion constricting the intestine, twists in the intestine, infections in the peritoneal cavity or of the intestines themselves, such as tuberculosis, syphilis, etc., can produce this condition. A loop of intestine that becomes caught in a **hernial** opening is a frequent cause of this catastrophe. Other forms of intestinal obstruction are of the paralytic type, that is, the toxins of a general **peritonitis** cause the intestines to dilate because of paralysis of the intestinal musculature. Treatment in acute intestinal obstruction is always prompt surgery. (R.S.M.)



Gastro-intestinal tract. Heart and lungs have been removed.

INTESTINE. Digestive system.

INTRAFORMATIONAL. This term is used by **stratigraphers** to denote textures and structures developed in **sedimentary rocks** at the time of the deposition of the sediments and thus previous to their consolidation through **lithification**. While normal structures, such as different types of bedding and stratification, may



Intraformational conglomerates, in cross-section. (Field, *Outline*, Barnes & Noble.)

be considered as intraformational, the term is usually confined to such phenomena as mud-cracks (desiccation fractures), raindrop imprints, and intraformational or "edgewise" conglomerates whose "pebbles" or **phenoplasts** were formed from mud while it was still plastic. (R.M.F.)

INTROMITTENT ORGAN. A protuberance or protrusible organ of the male for the introduction of the seminal fluid into the genital passages of the female in the act of **copulation**. (A.W.L.)

INTROVERT. In zoology, a portion of the body which can be thrust out or retracted by a process of involution. Applied to the proboscis of sipunculids (**Annelida**) and sometimes to the eversible portion of the body of the **bryozoans**. (A.W.L.)

INTRUSIVE ROCK. Igneous rock.

INTUBATION. The insertion of a tube into the **larynx** through the throat to permit breathing when the larynx becomes closed through swelling such as occurs in severe laryngeal diphtheria. This procedure was formerly used extensively, but since the widespread use of **diphtheria** immunization and antitoxin there is less occasion for it at present. It was first introduced by Dr. Joseph O'Dyer of New York City in 1885. (R.S.M.)

INTUSSUSCEPTION. For the use of this term in zoology, see **Growth**. In medicine, it refers to the telescoping of one section of the intestine into the part below. This causes **intestinal obstruction**. This condition may occur in either the small or large intestine and is generally caused by the pulling up of a section over a zone of marked spasm just above. Other causes are polyps, cancer, and foreign bodies; it occurs most often in infants and children. Death results from this condition unless surgery is promptly resorted to. The clinical picture of this condition is striking. The onset is sudden and marked by severe pain and vomiting occurring in paroxysms. Collapse and shock soon follow with pallor, feeble pulse and subnormal temperature. Without surgery **peritonitis** develops, temperature rapidly rises, and death soon occurs. Bloody stools are almost a constant accompaniment of this disease, with diarrhea in which only blood and mucus are passed. The mortality rises in direct proportion to the time lost before operation. (R.S.M.)

INULIN. Carbohydrates.

INVAR. Alloys.

INVARIANTS AND COVARIANTS. An invariant of a **quantic** is a **function** of the coefficients of the quantic which is transformed into the same function of the new coefficients, multiplied by a power of the modulus of the transformation, when the variables of the quantic are subjected to a **linear transformation**.

A covariant of a quantic is a function of both coefficients and variables of the quantic which retains its form, multiplied by a power of the modulus of the transformation, when the variables of the quantic are subjected to a linear transformation. (L.L.S.)

INVERSE FUNCTIONS. If $y = f(x)$ is a given **function** of x, then x regarded as a function of y is called the inverse function of the given function.

Examples of pairs of inverse functions are: the square of a variable and the square root function, the **exponential function** and the **logarithmic function**, the **trigonometric functions** and the **inverse trigonometric functions**. (L.L.S.)

INVERSE HYPERBOLIC FUNCTIONS. Hyperbolic Functions.

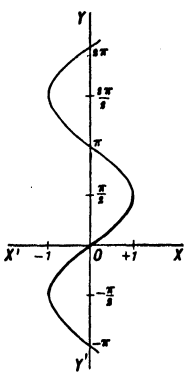
INVERSE OPERATIONS. Two operations are said to be inverse operations when each one counteracts the effect of the other.

Inverse operations occur in many places in mathematics. In elementary algebra, the operations of **addi-**

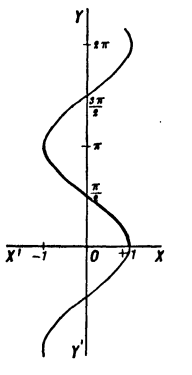
tion and **subtraction**, the operations of **multiplication** and **division**, the operations of **evolution** and **involution**, the operations of **evolution** and taking **logarithms** are examples of inverse operations. In calculus, the fundamental operations of **differentiation** and **integration** are inverse operations. (L.L.S.)

INVERSE TRIGONOMETRIC FUNCTIONS. The function inverse to the sine function is defined as follows: if $y = \sin x$, then x is the angle whose sine is y, denoted by $x = \sin^{-1} y$ or $x = \text{arc sin } y$; similar notation is used for the other inverse trigonometric functions.

If $y = \sin x$, there are infinitely many angles x (all coterminal) satisfying this relation, hence $x = \text{arc sin } y$ is an infinitely many-valued function, and similarly for the other inverse trigonometric functions.



$y = \text{arc sin } x$
Figure 1.

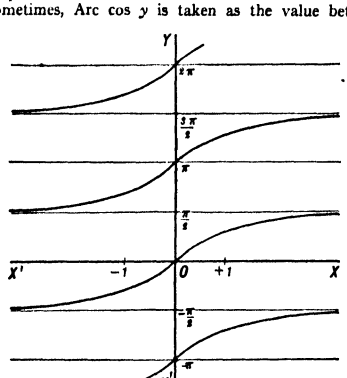


$y = \text{arc cos } x$
Figure 2.

The principal value of the inverse sine, arc sin y, is the value which lies between $+90°$ and $-90°$ (or $+\frac{\pi}{2}$ and $-\frac{\pi}{2}$). It is often denoted by Arc sin y or $\text{Sin}^{-1} y$.

Usage is not uniform in regard to the definition of principal values.

Sometimes, Arc cos y is taken as the value between $0°$ and $180°$ (or 0 and π); sometimes Arc tan y is taken as the value between $+\frac{\pi}{2}$ and $-\frac{\pi}{2}$



$y = \text{arctan } x$
Figure 3.

General values of inverse trigonometric functions are given by:

$$\text{arc sin } x = n\pi + (-1)^n \alpha, \text{ where } \alpha = \text{Arc sin } x,$$
$$\text{arc cos } x = 2n\pi \pm \alpha, \quad \text{where } \alpha = \text{Arc cos } x,$$
$$\text{arc tan } x = n\pi + \alpha, \quad \text{where } \alpha = \text{Arc tan } x,$$

where n is any positive or negative integer or 0.

The graphs of the inverse trigonometric functions are shown in Figures 1–3. (L.L.S.)

INVERSIONS. Determinants.

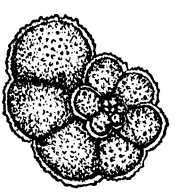
INVERT. Aqueduct.

INVERTASE. Enzymes.

INVERTEBRATA. All animals except those of the phylum **Chordata** which have an internal skeleton with a vertebral column. **Classification.** (A.W.L.)

INVERTEBRATE PALEONTOLOGY. The study, description, and geologic use of invertebrate **fossils** in relation to paleo-biological and **stratigraphic** problems. The science of invertebrate paleontology is primarily founded upon invertebrate zoology. Since thousands of invertebrate fossils, ranging in age from the **Cambrian** to the **Pleistocene**, have been figured and described, it is not possible to list them all in a general science encyclopedia. Also there is no single reference work in existence which covers the entire subject. For detailed information the student must consult special bibliographies which list the references in a large number of special papers and monographs. The following condensed classification of the invertebrates serves as an outline of the more significant facts relating to invertebrate paleontology.

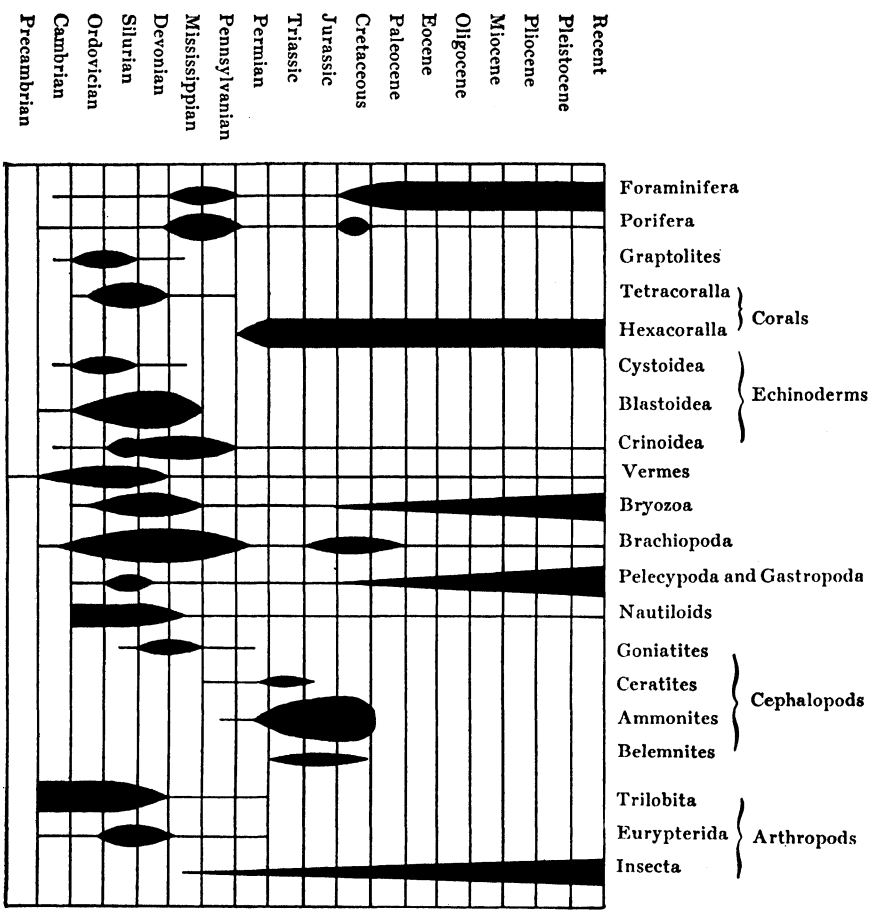
I. Protozoa. Single-celled animals. While most of the protozoa are naked, a particular marine group called the foraminifera (a term derived from words meaning a hole and to bear) form shells which occur as fossils from the Cambrian to the present. Foraminifera are an important constituent of chalk. Due to the large number of distinctive and rapidly evolving species foraminifera are useful index fossils, especially in the **Mesozoic** and **Cenozoic** periods.


Cretaceous foraminifers, greatly enlarged. (LeConte, *Elements of Geology*, Appleton-Century Co.)

An Eocene foraminifer, *Nummulites*. (LeConte, *Elements of Geology*, Appleton-Century Co.)

II. Porifera or Sponges. The name porifera is derived from words meaning a pore and to bear. Fossil sponges occur from the Cambrian to the Pleistocene. Except for a few species they are not particularly valuable index fossils. A particularly interesting genus is *Hydnoceras*, a delicate glass sponge which has left its imprint in the fine-grained muds of **Devonian** Age.

III. Graptolites. This term is derived from words meaning written and stoned, because the fossils look like pencil marks on slate. Graptolites were colonial marine

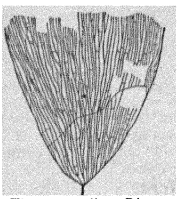


GEOLOGIC RANGE OF THE INVERTEBRATES

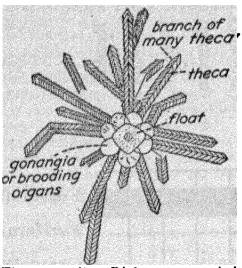
NOTE: The "lifelines" are swelled during the periods in which there were the greatest number of genera and species, or when the particular class of organisms is most important as "index fossils."

Field, *Laboratory Manual*, Princeton University Press.

animals with chitinous skeletons. Their stratigraphic range is from the **Ordovician** to the **Silurian**, inclusive. Because the graptolites evolved rapidly and have a world-wide distribution they are excellent index fossils.



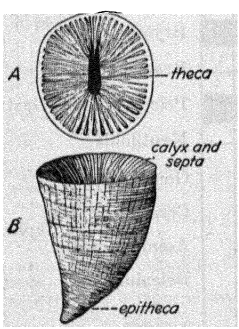
The graptolite *Dictyonema*. The theca are microscopic and like those shown on *Diplograptus*. Dendroid type of benthonic or anchored graptolite. (Field, *Geology Manual*, Part II. Princeton University Press.)



The graptolite *Diplograptus pristis*. Floating type of graptolite. Only single stipes are usually found fossil. (Field, *Geology Manual*, Part II, Princeton University Press.)

The accompanying sketches illustrate two of the principal types of Graptolites.

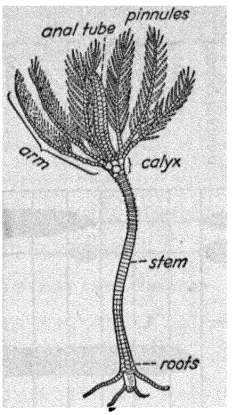
IV. **Corals.** The geologic record of fossil **corals** is from the Ordovician to the present day. Important reef builders in the tropical waters of the present oceans and seas. The earliest forms are both colonial and single. The accompanying illustration is that of a single or rugose coral of Ordovician age. Corals are important and useful index fossils in the strata of certain geologic periods.



Single, rugose or cup coral. A, Top view. B, Complete coral skeleton. (Corallite). (Field, *Geology Manual*, Part II, Princeton Univ. Press.)

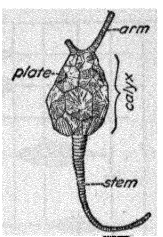
V. Vermes, or **Worms.** Worm trails and worm tubes are found in the sedimentary strata of all ages from the pre-Cambrian to the present. Not particularly useful as index fossils, except in the early Silurian. The jaws and teeth of worms, called conodonts, are useful index fossils.

VI. **Echinoderms.** The term is derived from words meaning hedge hog and skin, because certain types of **echinoderms** have sharp barbed spurs. Echinoderms are aquatic, marine animals with radial symmetry. The test or skeleton is composed of plates of **calcium** carbonate, with or without a chitinous covering (when living), and usually in the shape of a cup or "calyx" with or without "arms." **Some** forms are attached to the sea bottom by means of "stems" and "roots"; others are floating or free swimming. The echinoderms are subdivided into the following characteristic groups. (1) Cystoids (Cystids). Stratigraphic range from the Cambrian to the **Mississippian.** (2) Blastoids. Stratigraphic range from the Cambrian to the Mississippian. An important and frequently beautiful preserved genus is *Pentramites*. (3) **Crinoids,** or sea lilies. Stratigraphic range Cambrian to present. (4) **Asteroids,** or starfishes. (5) **Echinoids,** sea urchins, from which the echinoderms take their name. (6) **Holothouroids,** or sea cucumbers.



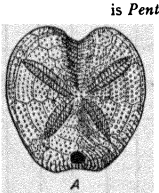
Crinoid

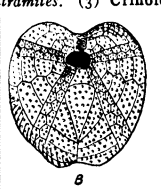
(Field, *Geology Manual*, Part II, Princeton University Press.)



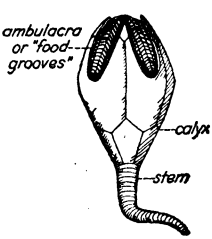
Cystid

(Field, *Geology Manual*, Part II, Princeton University Press.)





"Sea Urchin," Echinoid. A, Dorsal view. B, Ventral view. (Field, *Geology Manual*, Part II, Princeton University Press.)

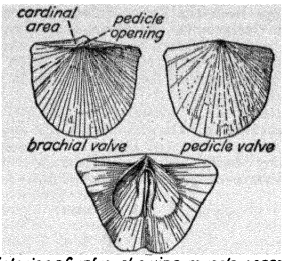


Blastoid. An anchored echinoderm without free "arms." (Field, *Geology Manual*, Part II, Princeton University Press.)

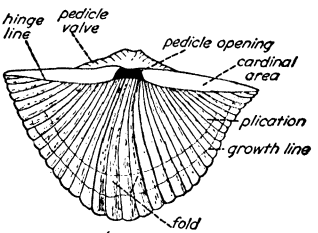
VII. **Molluscoidea**, meaning the form of a mollusk. A group of diverse forms of aquatic, and usually marine, animals with chitinous calcareous skeletons. Free swimming only in the young stages. The two principal subdivisions are the **bryozoa** (moss-like animals) and the **brachiopoda** (arm-footed), which are bivalves. The bryozoans are aquatic, colonial, and usually marine, ani-

Bryozoans. A, Portion of modern colony seen from above (×15); C, an individual expanded; D, fossil form. A-C after Verrill and Smith; D, from Ulrich. (Shimer's *Introduction to the Study of Fossils*, The Macmillan Company.)

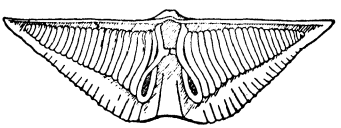
mals whose skeletons look something like small colonial corals. Important index fossils from the Ordovician to the present. Important reef builders, especially in the **Paleozoic**. The skeleton of the brachiopod is composed of two parts or valves which are formed of either "horn" or calcium carbonate. The brachiopod skeletons are principally distinguished from the pelecypods (clams, etc.) by a different type of bilateral symmetry.



Rafinesquina. A calcareous brachiopod having no interior skeleton. (Field, *Geology Manual*, Part II, Princeton University Press.)

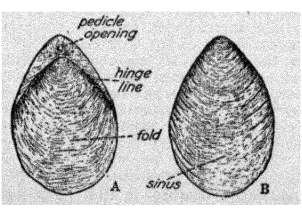


Front view of spirifer, showing full view of brachial valve. (Field, *Geology Manual*, Part II, Princeton University Press.)

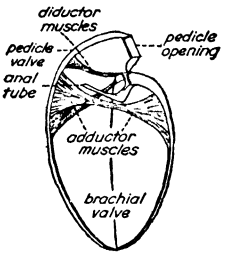


Interior of brachial valve of spirifer showing brachidia, or spires. (Field, *Geology Manual*, Part II, Princeton University Press.)

The higher forms have internal skeletons. Brachiopods are excellent index fossils, especially in the Paleozoic, where they share their importance with the graptolites and the trilolites. The accompanying figures illustrate some of the principal types of brachiopods.

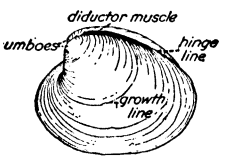


Brachiopod. "Lamp Shell." A, Front view. B, Rear view (Pedicle valve). (Field, *Geology Manual*, Part II, Princeton University Press.)

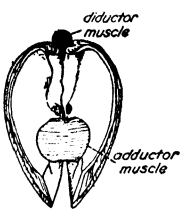


Cross-section of brachiopod (lamp shell) showing musculature. (Field, *Geology Manual*, Part II, Princeton University Press.)

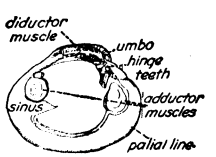
VIII. **Mollusca**, meaning soft-bodied animals. This class includes the following diverse forms. (1) **Pelecypoda**, meaning axe-footed. Bivalves whose shells are formed of calcium carbonate with a "horny" covering. No interior skeleton, even in the higher types. The skeleton is distinguished from that of the brachiopods by a different type of bilateral symmetry. A few species, such as the oyster, have no symmetry. All pelecypods are aquatic, but may be either fresh water or marine. Most species are attached to the bottom in the adult stage, but a few are free swimming. Pelecypods are not particularly good index fossils except at certain horizons in the Mesozoic and Cenozoic.



Quahog, modern pelecypod. (Field, *Geology Manual*, Part II, Princeton University Press.)



Cross-section, normal to hinge line, of pelecypod, showing musculature. (Field, *Geology Manual*, Part II, Princeton University Press.)

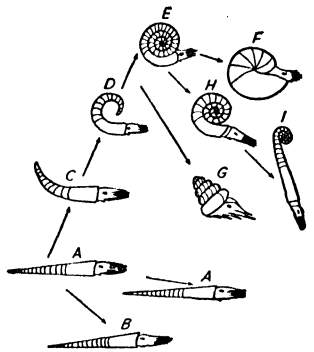


Interior view of left valve of pelecypod. Showing muscle scars. (Field, *Geology Manual*, Part II, Princeton University Press.)

IX. **Gastropoda**, or snails, meaning stomach-footed. Mollusca with single unchambered shells composed of calcium carbonate. All shapes and types of ornamentation, frequently well preserved. Gastropods are only important as index fossils in the **Canadian**, and at certain horizons in the Mesozoic and Cenozoic.

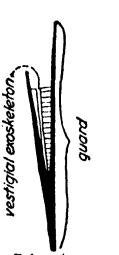
X. **Cephalopoda.** Meaning head-footed. Existing forms are **nautilus**, **cuttle-fish**, **octopus**, etc. Shells composed either of calcium carbonate or horn, and either external or internal in relation to the living animal. The shell differs from that of the gastropods because the interior is divided into a number of compartments by means of platforms or septa, the animal living only in the outer compartment. The cephalopods are naturally divisible into the following groups, which, because of their anatomical and stratigraphical history, make the

cephalopods one of the best known paleontological examples of **Adaptive Evolution.** The forms with external shells are (1) Nautiloids. Straight to coiled forms

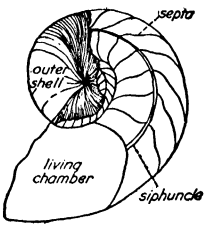


Adaptative Evolution of the Nautiloids. (After Dunbar, *Organic Adaptation to Environment,* Yale University Press.) A, Straight form, poor swimmers; B, first adaptation to bottom habitat, straight, slightly flattened form; C, slightly coiled; D, partly coiled; E, fully coiled; F, coiled and involuted; G, second adaptation to bottom habitat. Coiled and twisted; H-I, decadent (gerontic) stages. Partly uncoiled. NOTE: The ammonoids also passed through a somewhat similar adaptive evolution.

with smooth septa. Important as index fossils from the Cambrian to the Devonian, inclusive. (2) Goniates. Coiled forms with septa wrinkled into saddles and lobes.

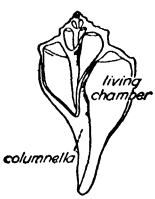


Belemnite.

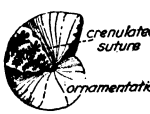


Nautilus, with outer shell broken away to show septa and siphuncle.

Goniatite, showing sutures with simple saddles and lobes.



"Conch Shell." Gastropod, cut away to show interior whorls.

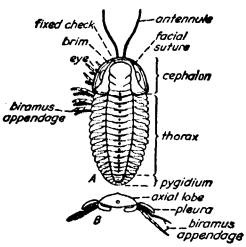


Ammonite with exterior of shell broken away to show dendritic form of sutures.

(Field, *Geology Manual,* Part II, Princeton University Press.)

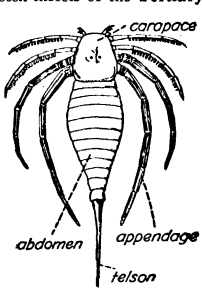
Range from the Silurian to the Permian. Important index fossils in the Devonian. (3) Ceratites. Similar to the goniatites except that the saddles are smooth and the lobes are wrinkled or crenulated. Range from the Devonian to the **Jurassic. Important index fossils in the Triassic.** (4) Ammonites. Similar to the ceratites except that both the saddles and lobes are highly crenulated. Range from the Upper **Pennsylvanian** to the close of the **Cretaceous.** Important index fossils. The forms with interior skeletons are divided into the **squids, cuttle-fishes,** and belemnites. Only the latter are important as fossils, ranging from the Triassic to the Cretaceous, inclusive.

XI. **Arthropoda.** Meaning joint-footed. Transversely segmented animals with mouth and anus at opposite ends of an elongated body that is composed of the following fairly well-defined regions, "head" or cephalon, thorax or pleura and pygidium. A few or



Trilobite. A, dorsal view; B, cross-section of thorax. (Field, *Outline,* Barnes & Noble.)

most of the segments bear paired appendages. Arthropods range from the Cambrian to the present, and are both fresh water and marine. The four most important subdivisions of this group, from the paleontological point of view, are the Trilobites, Ostracods, and Eurypterids. The first insects appear as fossils in the Carboniferous and several of the ancestral types of the older order appear in the Permian. The fossil insects of the **Tertiary** are particularly interesting as they prove that social life in the insect world began as long ago as the **Oligocene.** From the Paleontological point of view however the trilobites are the most interesting. (1) Trilobites. Extinct group of arthropods, or transversely segmented invertebrates with mouth and anus at the opposite ends of an elongated body which is made up of a variable number of segments each of which bears a pair of appendages. The term trilobite means "three-lobed" referring to the bilateral symmetry. The major anatomical features of the external skeleton are shown in the accompanying figure. Although one of the highest orders of the invertebrates, trilobites occur among the oldest known fossils of the Cambrian period, becoming extinct at the close of the Paleozoic Era. Trilobites are important as index fossils, especially in the Cambrian, Ordovician, Silurian and Devonian periods, and are of great aid to the geologist in helping to determine the relative ages of the oldest fossiliferous formations of the **geologic time-scale.** (2) Eurypterids, meaning head-winged. Extinct marine or estuarine scorpion-like arthropods, related to the horse-shoe crab. Body elongated, with appendages attached to the head region only. Eurypterids also differ from the trilobites in that the former always have a regular number of appendages. The Eurypterids range from the Cambrian to the **Per-**



Eurypterid. (Schubert, *Textbook of Geology,* John Wiley & Sons.)

mian, and are important index fossils in certain horizons of the Silurian and Devonian (R M F)

INVOLUTION. The operation of extracting a **root of a number** is sometimes called involution It is one of the **inverse operations to evolution** (raising to positive integral powers) (L L S)

INYOITE. Colemanite.

IODIC ACID AND IODATES Iodic acid (HIO_3) is a white soluble solid Upon heating to 110° C forms iodic anhydride, **iodine** pentoxide (I_2O_5) A solution of iodic acid can be concentrated by evaporation up to 70% HIO_3. Iodic acid is an oxidizing agent in hot solution, smoothly converting **sulfur** to **sulfuric acid, phosphorus** to **phosphoric acid, carbon** to **carbon dioxide, silicon** to silicic acid

Prepared by reaction (1) of iodine and **chloric acid** (25% $HClO_3$), (2) of iodine and **nitric acid** ("fuming") —the yield is low, but the product, upon evaporation, is pure, (3) of iodine and excess **chlorine** in water

Potassium iodate is formed (1) by electrolysis of potassium iodide solution, with stirring, heated, and over some hours, (2) by reaction of iodine and potassium chlorate solution, (3) by allowing potassium **hypoiodite** solution to stand a few hours at ordinary temperatures

Metallic iodates are solids, moderately soluble in water, except that silver, lead, barium, thallous iodates are insoluble Potassium hydrogen iodate ($KH(IO_3)_2$) recalls potassium hydrogen fluoride (KHF_2), an acid salt Iodates, when heated, evolve oxygen and leave the iodide (or oxide) as residue

Test Upon addition of hydriodic acid (or iodide plus dilute sulfuric acid), iodate liberates iodic acid, which reacts with hydiodic acid to form iodine. (R K S)

IODIDE. Iodine.

IODINE. Symbol I Atomic number 53 Atomic weight 126 92 Density 4 94 Melting point 113 5° C. Boiling point 184 4° C

SELECTED REPRESENTATIVE ORGANIC COMPOUNDS OF IODINE

	Name	Formula	Melting Point	Boiling Point
1	Methyl iodide	CH_3I		45
2	Ethyl iodide	C_2H_5I		72
3	Normal-propyl iodide (1-iodopropane)	C_3H_7 CH_2I		102
4	Iso-Propyl iodide (2-iodopropane)	CH_3 CHI CH_3		89
5	Vinyl iodide (iodoethylene)	CH_2 CHI		56
6	Allyl iodide	CH_2 CH CH_2I		101
7	Benzyl iodide	C_6H_5 CH_2I	24	93 (10 mm)
8	Glycol iodohydrin (Ethylene iodohydrin)	CH_2I CH_2OH		85 (25 mm)
9	(Mono)iodoacetic acid	CH_2I $COOH$	82	
10	Alpha-iodopropionic acid	CH_3 CHI $COOH$	45	105 (0 3 mm)
11	Beta-iodopropionic acid	CH_2I CH_2 $COOH$	82	
12	Acetyl iodide	CH_3 COI		108
13.	Benzoyl iodide	C_6H_5 COI		135 (25 mm)
14	Cyanogen iodide	CN I	146 (sealed tube)	
15	Iodofurane	C_4H_3O $I(2)$		
16	Iodobenzene (phenyl iodide)	C_6H_5I		189
17	Ortho-iodotoluene (1,2-)	$C_6H_4(I)(2)(CH_3)(1)$		211
18	Meta-iodotoluene (1,3-)	$C_6H_4(I)(3)(CH_3)(1)$		204
19	Para-iodotoluene (1,4-)	$C_6H_4(I)(4)(CH_3)(1)$	35	211
20	Alpha-iodonaphthalene	$C_{10}H_7$ $I(1)$		305
21	Beta-iodonaphthalene	$C_{10}H_7$ $I(2)$	54	309
22	Ortho-iodophenol (1,2-)	$C_6H_4(I)(2)(OH)(1)$	40	186 (160 mm)
23	Meta-iodophenol (1,3-)	$C_6H_4(I)(3)(OH)(1)$	40	decom
24	Para-iodophenol (1,4-)	$C_6H_4(I)(4)(OH)(1)$	93	decom.
25	Ortho-iodoaniline (1,2-)	$C_6H_4(I)(2)(NH_2)(1)$	60	
26	Meta-iodoaniline (1,3-)	$C_6H_4(I)(3)(NH_2)(1)$	33	
27	Para-iodoaniline (1,4-)	$C_6H_4(I)(4)(NH_2)(1)$	67	
28	Ortho-iodonitrobenzene (1,2-)	$C_6H_4(I)(2)(NO_2)(1)$	53	
29	Meta-iodonitrobenzene (1,3-)	$C_6H_4(I)(3)(NO_2)(1)$	37	
30	Para-iodonitrobenzene (1,4-)	$C_6H_4(I)(4)(NO_2)(1)$	171	
31.	Ortho-iodobenzoic acid (1,2-)	$C_6H_4(I)(2)(COOH)(1)$	162	
32	Meta-iodobenzoic acid (1,3-)	$C_6H_4(I)(3)(COOH)(2)$	187	
33.	Para-iodobenzoic acid (1,4-)	$C_6H_4(I)(3)(COOH)(3)$	269	
34	Iodoso benzene	C_6H_5IO	210 (expl)	
35.	Iodoxy benzene	$C_6H_5IO_2$	236 (expl)	
36	Methylene iodide	CH_2I_2		180
37	Ethylene iodide (1,2-Diiodoethane)	CH_2I CH_2I	81	
38	Ethylidene iodide (1,1-Diiodoethane)	CH_3 CHI_2		178
39.	Diiodoacetic acid	CHI_2 $COOH$	110	
40.	Ortho-diiodobenzene (1,2-)	$C_6H_4I_2(1,2)$	27	286
41.	Meta-diiodobenzene (1,3-)	$C_6H_4I_2(1,3)$	40	285
42	Para-diiodobenzene (1,4-)	$C_6H_4I_2(1,4)$	129	285
43.	Diphenyl iodonium iodide	$(C_6H_5)_2I$ I	182	
44.	Iodoform	CHI_3	119 (subl)	
45	Methyl iodoform (1,1,1-triiodoethane)	CH_3 CI_3	93 (decom)	
46	Benzotriiodide (Phenyl iodoform)	C_6H_5 CI_3		
47	Triiodoacetic acid	CI_3 $COOH$	150 (decom)	
48.	Carbon tetraiodide	CI_4	decom	
49	Tetraiodoethylene	CI_2 CI_2	190	
50	Hexaiodoethane (ε)	$CI_3 \cdot CI_3$		
51.	Hexaiodobenzene	C_6I_6	340 (decom)	

(R K S)

Iodine is a violet to black solid, of characteristic odor, color of vapor violet, easily purified by **sublimation,** insoluble in water, soluble in alcohols, ether, **carbon disulfide, carbon tetrachloride.** Discovered by Courtois in 1812 Used (1) in **photography,** (2) in certain chemicals and **dyes,** (3) as an antiseptic solution in ethyl alcohol (3% to 7%), (4) as a reagent for testing starch, and in estimating such substances as **sulfites** (5) In medicine, various salts of iodine are given internally in the treatment of such diseases as arteriosclerosis, hypertension, syphilis, actinomycosis, emphysema, chronic bronchitis, some forms of arthritis, and in certain thyroid disorders When overdosage occurs, or when an idiosyncrasy is present in the patient, acne and other skin disorders may result

Iodine occurs in the ashes of sea plants, e g , kelp, especially California and Bay of Biscay, in the petroleum oil well brines of California, and in small percentages in sodium nitrate of Chile, which source for a long time furnished the world's supply

Iodine is soluble (1) in carbon disulfide, in chloroform, and in carbon tetrachloride, yielding a violet solution, and upon evaporation leaves a residue of iodine crystals, (2) in ether, in ethyl alcohol, and in potassium iodide solution, yielding a brown solution Iodine reacts (1) with **sodium** thiosulfate solution to form dithionate, (2) with **sulfurous acid** to form **sulfuric acid,** (3) with **hydrosulfuric acid** to form **sulfur,** (4) with starch to form a dark blue solid

Acids hydriodic acid (HI), hypoiodous acid (HOI), iodic acid (HIO_3), periodic acid (H_5IO_6 or HIO_4) See each acid

Bromide iodine bromide (IBr)

Chlorides. iodine chloride (ICl), iodine trichloride (ICl_3)

Fluorides iodine pentafluoride (IF_5)

Hydride hydrogen iodide (HI), colorless gas when pure (frequently contains free iodine as violet to brown gas), melting point -51° C , boiling point -35° C , very soluble in water, yielding **hydriodic acid** Formed by reaction of red phosphorus, iodine, and water under the proper conditions

Hypoiodite See **Hypoiodous acid.**

Iodate See **Iodic acid**

Iodides **sodium** iodide (NaI), **potassium** iodide (KI), **ammonium** iodide (NH_4I) are soluble iodides, **silver** iodide (AgI), **mercurous** iodide (HgI), **mercuric** iodide (HgI_2), **lead** iodide (PbI_2) are insoluble iodides, **nitrogen** iodide ($N_2H_3I_3$) (See **Hydriodic acid.**)

Oxides iodine dioxide (IO_2 or I_2O_4), pale yellow solid, formed by grinding iodine and cold fuming **nitric acid;** iodine pentoxide (I_2O_5), white solid, decomposes upon heating to 300° C into iodine and oxygen, formed by heating iodic acid to 170° C Reactive with, and used to detect **carbon monoxide,** with accompanying formation of iodine and carbon dioxide

Periodate See **Periodic acid.**

Organic Iodo-Compounds

Hydrocarbons are generally without reaction with iodine or hypoiodous acid, except under special conditions, but olefins react readily with hydrogen iodide by addition, to form, for example, ethyl iodide (CH_3CH_2I) from **ethylene.**

Oxygen-function compounds, **e g , ethyl alcohol, acetaldehyde, acetic acid,** react with **phosphorus** iodide to form corresponding oxygen-function iodides, e g , ethyl iodide (C_2H_5I), ethylidene diiodide (CH_3CHI_2), acetyl iodide (CH_3COI)

Iodoform is made by reaction of **acetone** or **ethyl alcohol** with sodium **hypoiodite.**

Use is made of the diazo-reaction (See **Azo and Related Compounds**) to introduce iodine into benzenoid compounds Iodine-substituted carboxylic acids are made by heating the selected chloro or bromo acid, with potassium iodide, e g , monochloroacetic acid yields monoiodoacetic acid (potassium chloride are formed) Many of the iodo-compounds are used as reagents or as intermediate compounds in organic chemistry When paraffin iodo-compounds are treated with sodium hydroxide dissolved in alcohol, hydrogen iodide is removed, e g , ethyl iodide (CH_3CH_2I) yields ethylene ($CH_2 \cdot CH_2$).

IODINE NUMBER. Esters.

IODOFORM. A yellow crystalline powder (for its chemical properties, see **Iodine**) insoluble in water with a very penetrating and disagreeable odor It is antiseptic in action, but only when in direct contact with raw surfaces. It is used in infected cavities and abscesses which are packed with gauze saturated with the powder In certain susceptible subjects toxic symptoms may result if too much is used (K S M)

IOLITE. Cordierite.

ION Reactions Involving Recombinations of Ions; and **Ionized Gases.**

ION COUNTER. Counting Tube.

IONIC THEORY. Reactions Involving Recombination of Ions.

IONIUM. Symbol Io A radioactive element of the uranium-radium series See **Radioactive Changes**

IONIZATION CHAMBER. The term applies to a variety of enclosures used in the study of **ionized gases** or of ionizing agencies The essential features are a closed vessel containing a gas at normal or altered pressure, and furnished with two electrodes kept at different potentials These may be in the form of parallel plates or of coaxial cylinders, or one of them may be the vessel itself with the other inside and insulated from it When the gas between the electrodes is ionized by any means, as by **x-rays** or **radioactive** emission, the ions move to the electrodes of opposite sign, thus creating an ionization current which may be measured by a **galvanometer** or an **electrometer.** If, when ions are being produced at a fixed rate, the potential difference between the electrodes is gradually increased, a point is reached at which further increase of voltage causes no increase in current, because the ions are removed as fast as they are formed This limiting current is called the saturation current, and its value may be used as a measure of the rate of ionization and hence of the intensity of the ionizing radiation. (See also **Counting tube**) (L D W)

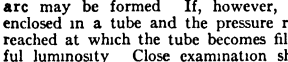
IONIZATION CONSTANT Reactions Involving Recombination of Ions; Amines.

IONIZED GASES Various agencies, such as fast-moving **electrons, alpha particles,** various forms of **radiation,** and high temperature, are capable of dislodging electrons from **atoms** or **molecules** of a gas and thereby leaving them positively charged Some of the dislodged electrons may attach themselves to other molecules and render them negatively charged In some cases two or more electrons may be removed from the same molecule, or a molecule with a double positive charge may unite with a singly charged negative molecule, forming a singly charged complex, etc Such charged atoms, molecules or molecular groups are called ions and their production from neutral molecules is called ionization The complete separation of an electron from a molecule or an atom requires a definite amount of energy This may be expressed in ergs, but is more commonly given in **electron-volts** ($1\ 59 \times 10^{-12}$ erg), its value being the "ionizing potential" A less amount of energy may excite the atom or molecule to emit radiation, but will not ionize it

If an ionized gas is left to itself, the ions soon recombine and become neutral But if it is subjected to an electric field, as in an **ionization chamber,** the ions pass to the electrodes, such a migration being an "ionization current" Such currents, commonly called electric dis-

charges, are attended by diverse phenomena and vary widely in character from the silent glow discharge to the **lightning** stroke

At ordinary pressures, discharges may be classified into four types (1) If the voltage between two electrodes in open air is gradually increased, the electrodes become surrounded with a luminosity This "glow" or "corona" gives way, at the negative electrode first, to (2), a "brush," composed of hairlike branches (3) Finally the disruptive **spark** passes (4) Under other conditions an **arc** may be formed If, however, the electrodes are enclosed in a tube and the pressure reduced, a point is reached at which the tube becomes filled with a beautiful luminosity Close examination shows this to have structure. Very close to and surrounding the cathode is a thin, luminous layer *c*, the cathode glow (see figure), and outside this, the Crookes dark space *C* Next, extending toward the anode, is the short negative glow *n*, then the Faraday dark space *F* From this to the anode extends the long positive column *p*, with its regular, transverse striations As the pressure is further reduced, the cathode dark space enlarges and the other features dwindle toward the electrodes until they finally disappear at about 0 001 millimeter pressure From this point on, the **cathode rays** are the predominant feature (See also **Anode Rays, Canal Rays, Cloud Chamber, Cosmic Rays, Counting Tube, Crookes Tube, Electrodeless Discharge, Geissler Tube, Vacuum Tube.**) (L D W)



IONIZING POTENTIAL. Ionized Gases.

IONOSPHERE. A layer of ionized air high above the earth's surface, the existence of which was surmised by Heaviside and verified later by Kennelly It is also called the Kennelly-Heaviside layer Its importance in the transmission of radio signals is now well recognized Waves from a transmitting station *T*, proceeding obliquely upward and encountering this layer, are deflected (reflected or refracted) downward, so that a distant receiving station *R* receives waves from *T* both by the direct path along the surface and over the longer route *via* the ionosphere Were it not for this layer, much more of the energy emitted from the transmitter would escape into space

The height of the ionosphere has been ascertained by measuring the time interval between an emitted signal and its "echo," and appears to vary from 100 to 400 miles There is reason to believe that the ionization is produced largely by sunlight, especially by the absorbed ultraviolet radiation The ionosphere generally recedes at night, sometimes apparently to the region outside the earth's shadow, and approaches the earth during the daylight hours

Interference between waves directly received and those taking the ionosphere route gives rise to the troublesome phenomenon of radio "fading" (L D W)

IPECAC. (Ipecacuanha) the root of *Cephaeles ipecacuanha* from Brazil (See **Madder Family**) It is an irritant and promotes secretion, especially of the skin and respiratory tract It is used as an expectorant in respiratory infections In larger doses it is an **emetic.** It is also used for the cure of **amoebic dysentery.** (R S M)

IRIDIUM. Symbol Ir Atomic number 77 Atomic weight 193 1 Density 22 42 Hardness 6 0–6 5 Melting point 2350° C

Compact iridium is a white, very hard metal, and is not attacked by acids Discovered by Tennant in 1804. Iridium metal is used chiefly as an alloy with **platinum,** which latter metal is thereby hardened Standard measures and weights are made of such an alloy (10% Ir), also pen points, and parts of scientific apparatus and surgical tools.

Iridium occurs native with platinum, and with **osmium** as osmiridium (50%–75% Ir) When osmium is present it is removed as volatile osmium tetroxide, and the residue is converted into soluble chlorides by chlorine From the resulting solution ammonium iridium chloride ($(NH_4)_2IrCl_6$) is precipitated, and then ignited and fused to obtain iridium metal

Chloroiridate Ammonium chloroiridate ($(NH_4)_2IrCl_6$) is insoluble in alcohol

Hydroxide Iridium hydroxide ($Ir(OH)_4$), dark blue precipitate, by excess of **sodium** hydroxide solution, and boiling (R K S)

IRIS. The pigmented structure in front of the lens of the **eye.** It is contracted and expanded by muscular action so that the opening in its center, known as the pupil, varies in size according to the brightness of the light By this means the quantity of light that reaches the sensitive retina is regulated An iris occurs in **molluscan** and **vertebrate** eyes In the **insect** eye a group of iris cells shut out light except from the direction of the lenticular cornea Also a plant (A W L)

IRON. Symbol Fe (ferrum) Atomic number: 26 Atomic weight 55 84 Density 7 86 Hardness 4–5 (iron), 5–8 5 (steel) Melting point 1535° C Boiling point 3000° C (**Isotopes** page 238)

Iron is a silver-white metal, capable of taking a high polish, hard, ductile, malleable, can be welded when white hot, pure iron is attracted by a magnet but does not retain the **magnetism** (silicon steel is used for **electromagnets**) Discovery prehistoric

Iron is seldom encountered as a "chemically pure" metal, but usually as steel (ordinary, with **carbon** as the essential alloying element, special, with various elements), iron is the most largely used of the metals, and considerable scrap metal is recovered Steel is used in construction of machines and apparatus where workability is required, and definite resistance to corrosion is supplied by the metal The metal is at times protected (1) by depositing a layer of metal, e g , **tin, zinc, lead, copper, nickel, aluminum,** (2) by formation of a chemical surface layer, such as black oxide of **iron,** (3) by painting the surface

Iron occurs abundantly as oxide, **magnetite** (ferroferric oxide, triiron tetroxide, Fe_3O_4), black, **hematite** (ferric oxide, Fe_2O_3), red, **limonite** (hydrated ferric oxide) yellow to brown, as carbonate, **siderite** (ferrous carbonate, $FeCO_3$), colorless to pale brown, as sulfides, **pyrite** (iron disulfide, FeS_2), brass colored, **arsenopyrite** (iron sulfoarsenide, FeAsS), and as **aluminosilicates** in most rocks, evidenced by green coloration of ferrous, by yellow to red to brown of ferric, and by black of ferroferric The element iron is fourth in abundance of the elements of the earth's crust (5 1% of the solid crust) and is responsible for practically all of the coloration of ordinary rocks Native iron is rarely found except in **meteorites.** In the United States about 85% of the iron ore mined comes from the Lake Superior region of Minnesota and Michigan, and, in the south, Alabama is a producing state The ore is at present commercially usable when somewhat above 50% Fe content The industrial nations (Britain, France, Germany, Japan, the United States) are the great consumers of iron and steel The oxide is smelted in a **blast furnace** with **carbon** (coke) and **flux** (**limestone**) at a high temperature In operation, all products are withdrawn as liquid or gas, the heavier liquid iron settles beneath the lighter liquid **slag,** and each is drawn off separately The iron is cast into cast iron bars or treated immediately in a furnace for the removal of impurities, such as carbon, **silicon, sulfur, phosphorus,** then the desired additions, such as carbon, **manganese,** are made, and the resulting steel is fabricated

Four allotropic forms of iron are known, namely, (1) alpha-iron below 769° C, (2) beta-iron between

769° C and 906° C, (3) gamma-iron between 906° C and 1404° C, (4) delta-iron between 1404° C and 1535° C, the properties of iron are markedly affected by the addition of other elements, notably carbon, silicon, sulfur, phosphorus, manganese in steel, and **chromium, manganese, nickel, molybdenum, tungsten, vanadium** in special steels Iron is scarcely attacked in dry air, but is rapidly corroded in moist air at ordinary temperatures, forming iron rust, hydrated ferric oxide, burns when heated in air to form ferroferric oxide, reacts with steam at a red heat to form ferroferric oxide plus hydrogen gas, dissolves in **hydrochloric** or dilute **sulfuric acid**, forming ferrous salt solution and **hydrogen gas**, dissolves in hot concentrated sulfuric or in cold dilute **nitric acid**, forming ferric salt solution, no reaction (passive) with cold concentrated nitric, no reaction with alkalis, except hot solutions of high concentration

Acetate ferrous acetate "iron liquor" ($Fe(C_2H_3O_2)_2 \cdot xH_2O$), prepared as an industrial chemical—a black solution—by reaction of scrap iron and pyroligneous acid (See **actic acid**), and then evaporation Used as a mordant in dyeing, ferric acetate ($Fe(C_2H_3O_2)_3$), formed by the reaction of iron, and acetic acid and oxygen of the air, and then **crystallization**. Used in textile and leather dyeing, as a wood preservative, and in medicine, basic ferric acetate formed as a precipitate upon boiling ferric acetate solution

Bromides. ferrous bromide ($FeBr_2$), green solid, soluble, formed by reaction of iron and **hydrobromic acid**, and then evaporating out of contact with air, ferric bromide ($FeBr_3$ $6H_2O$), red solid, soluble, formed by reaction of ferrous bromide solution and **bromine**, and then evaporation, ferric bromide anhydrous ($FeBr_3$), red solid, formed by reaction of iron and dry bromine upon heating

Carbide· iron carbide, cementite (Fe_3C), black hard solid, melting point 1837° C, formed by reaction of iron and carbon at high temperature, an important component of steels

Carbonate ferrous carbonate ($FeCO_3$), white precipitate, when pure, but soon changes to green in air, then to black ferroferric hydroxide, and then to red ferric hydroxide, formed by reaction of soluble ferrous salt solution and **sodium** carbonate solution

Carbonyl iron tetracarbonyl ($Fe(CO)_4$), gas, formed by reaction of iron and **carbon monoxide** at 80° C, burns with a yellow flame, iron pentacarbonyl ($Fe(CO)_5$), yellow liquid, boiling point 103° C, formed by reaction of finely divided iron and carbon monoxide at ordinary temperatures, is decomposed by light

Chloride ferrous chloride ($FeCl_2$ $4H_2O$), greenish solid, soluble, formed by reaction of iron and **hydrochloric acid**, and then evaporation out of contact with air, ferric chloride ($FeCl_3$ $6H_2O$), reddish-yellow solid, soluble, formed by reaction of ferrous chloride solution and **chlorine**, and then evaporation, used in photography and as an oxidizing agent, ferric chloride anhydrous ($FeCl_3$), red solid, formed by reaction of iron and dry chlorine upon heating Used as a reagent in organic chemistry, ferroferric chloride ($FeCl_2$ $2FeCl_3$ $18H_2O$), yellow solid, soluble, ferric ammonium chloride ($FeCl_3$ NH_4Cl), orange solid, soluble

Citrate ferric citrate ($Fe(C_6H_5O_7)_3$ $3H_2O$), reddish-brown solid, soluble, formed by reaction of ferric hydroxide and **citric acid**, and then evaporation Used in preparing **blueprint** paper, ferric ammonium citrate, brown solid, soluble Used in preparing blue-print paper

Ferrate sodium ferrate (Na_2FeO_4), purple solution, formed (1) by fusing **sodium** nitrate and finely divided iron, and then extracting with water, (2) by reaction of ferric hydroxide suspension in concentrated **sodium** hydroxide and addition of **chlorine** in excess

Ferrites By fusion of ferrous oxide with the appropriate basic oxide, hydroxide or carbonate, e g, calcium ferrite ($Ca(FeO_2)_2$), barium ferrite ($Ba(FeO_2)_2$), magnesium ferrite ($Mg(FeO_2)_2$), ferrous ferrite ($Fe(FeO_2)_2$), sodium ferrite ($NaFeO_2$).

Ferricyanides: potassium ferricyanide, red prussiate of potash ($K_3Fe(CN)_6$), red crystals, soluble to reddish-brown solution, formed by reaction of potassium **ferrocyanide** solution and an oxidizing agent such as chlorine, and then crystallizing, ferrous ferricyanide, "Turnbull's blue" ($Fe_3(Fe(CN)_6)_2$) blue precipitate by reaction of ferrous salt solution and potassium **ferricyanide** solution, unattacked by acids, but blue color destroyed by alkalis Used as a pigment

Ferrocyanides sodium ferrocyanide, yellow prussiate of soda ($Na_4Fe(CN)_6$ $10H_2O$) and potassium ferrocyanide, yellow prussiate of potash ($K_4Fe(CN)_6$ $3H_2O$) are yellow solids, soluble, formed by treating "spent oxide" of coal gas works with **calcium** hydroxide to extract the ferrous cyanide as soluble calcium ferrocyanide, and converting, with **sodium** or **potassium** carbonate, into the respective ferrocyanide Used (1) in the preparation of other ferrocyanides (e g, ferric ferrocyanide), and of ferricyanides, (2) in blue print paper, (3) in tanning, ferric ferrocyanide, "Prussian blue" $Fe_4(Fe(CN)_6)_3$ blue precipitate formed by reaction of ferric salt solution and sodium ferrocyanide solution, unattacked by acids, but blue color destroyed by alkalis Used as a pigment.

Hydroxides ferrous hydroxide ($Fe(OH)_2$), white precipitate, when pure, but soon changes in air to ferroferric hydroxide and then to ferric hydroxide, formed by reaction of soluble ferrous salt solution and **sodium** or **ammonium** hydroxide solution, soluble in acids, insoluble in alkalis, ferroferric hydroxide ($Fe(OH)_2$ $2Fe(OH)_3$), black precipitate, soon changes in air to ferric hydroxide, formed by reaction of mixture of soluble ferrous and ferric salt solution and **sodium** or **ammonium** hydroxide solution, ferric hydroxide ($Fe(OH)_3$), reddish-brown gelatinous precipitate, formed by reaction of soluble ferric salt solution and sodium or ammonium hydroxide solution, soluble in acids, insoluble in alkalis

Iodide ferrous iodide (FeI_2 $4H_2O$), grayish-black solid, soluble, formed (1) in solution by reaction of soluble ferric salt solution and **potassium** iodide solution, with accompanying separation of iodine, (2) by reaction of **iron** and **iodine.**

Nitrate ferrous nitrate ($Fe(NO_3)_2$ $6H_2O$), greenish solid, soluble, unstable, formed (1) by reaction of ferrous hydroxide or carbonate and dilute **nitric acid**, (2) by **barium** nitrate and ferrous sulfate solutions, filtration, and then evaporation at low temperature out of contact with air, ferric nitrate ($Fe(NO_3)_3$), violet solid, soluble, formed by reaction of iron metal, or ferric oxide, and dilute nitric acid, and then crystallization Solution is colorless when freshly prepared in excess of nitric acid

Oxalate ferrous oxalate (FeC_2O_4 $2H_2O$), yellow precipitate, formed by reaction of soluble ferrous salt solution and **ammonium** oxalate solution, yields ferrous oxide on heating at 160° C out of contact with air, ferric oxalate ($Fe_2(C_2O_4)_3$), greenish solid, soluble, formed by reaction of ferric hydroxide and **oxalic acid**, and then crystallization, ferrous potassium oxalate ($Fe(C_2O_4)_2$ $K_2C_2O_4$ $2H_2O$), yellow solid, soluble, ferric potassium oxalate ($K_3Fe(C_2O_4)_3$ $3H_2O$), ferric ammonium oxalate ($(NH_4)_3$ $Fe(C_2O_4)_3$ $3H_2O$), green solid, soluble

Oxides ferrous oxide (FeO), black solid, insoluble, formed (1) by heating ferrous oxalate at 160° C out of contact with air, (2) by heating ferric oxide or ferroferric oxide and **hydrogen** gas at 300° C, (3) by heating iron metal and steam above 570° C, soluble in hydrochloric or dilute **sulfuric acid** to ferrous salt, ferroferric oxide, black oxide of iron, **magnetite**, "iron scale," (Fe_3O_4), black solid, insoluble, formed (1) by heating iron metal, ferrous or ferric oxide in air, (2) by heating iron and steam below 570° C, believed to be ferrous ferrite ($Fe(FeO_2)_2$), ferric oxide, red oxide of iron, **hematite** (Fe_2O_3), red solid, insoluble, formed by heating ferric hydroxide or nitrate to a high temperature The mineral is the important source of iron, and when pulverized is used as a paint pigment, various naturally occurring hydrated forms serve as brown or yellow pigments—umbers and siennas from **limonite.**

Perferrates sodium perferrate (Na_2FeO_4), formed (1) by fusing **sodium** peroxide and ferric hydroxide, (2) by heating finely divided iron, ferrous oxide, or ferric oxide in **sodium** nitrate to a red heat, barium perferrate ($BaFeO_4$) precipitate, formed by reaction of sodium perferrate solution and barium chloride solution

Sulfates ferrous sulfate, green vitriol, "copperas" ($FeSO_4 \cdot 7H_2O$), green solid, soluble, formed by reaction of iron and dilute **sulfuric acid** and then crystallizing Obtained as a by-product in the cleaning or "pickling" of steel Used widely (1) as a source of ferrous compounds, and of ferric compounds by easy oxidation, (2) as a disinfectant, water purifier, wood preservative, weed exterminator, (3) in the preparation of inks, pigments, medicines, (4) in the purification of coal gas, (5) in the textile and leather industries, ferrous ammonium sulfate, "Mohr's salt" ($FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$), green solid, soluble, more easily purified, more stable than ferrous sulfate, ferric sulfate ($Fe_2(SO_4)_3$), brownish solid, soluble, formed (1) by reaction of ferric hydroxide and sulfuric acid, and then evaporation, (2) by reaction of iron and hot concentrated sulfuric acid, (3) in solution by reaction of **chlorine** and ferrous sulfate in acid solutions Used (1) to prepare iron alum, (2) in water purification as basic ferric sulfate, ferric "persulfate" or "subsulfate," yellow solid, soluble, (3) in medicine, ferric ammonium sulfate "iron alum" ($Fe_2(SO_4)_3 \cdot (NH_4)_2SO_4 \cdot 24H_2O$), violet solid, soluble, more easily purified than ferric sulfate

Sulfides ferrous sulfide (FeS), black precipitate, formed by reaction of soluble ferrous salt solution and **sodium** or **ammonium** sulfide, soluble in acids, also formed by heating finely divided **iron** and **sulfur**, reacts with dilute **hydrochloric** or **sulfuric acid** to yield ferrous salt and hydrogen sulfide, iron disulfide, pyrite (FeS_2), brass colored mineral, when heated in air yields ferric oxide plus **sulfur dioxide** gas, ferric sulfide (Fe_2S_3), black precipitate, formed by reaction of soluble ferric salt solution and sodium or ammonium sulfide

Sulfite ferric sulfite ($Fe_2(SO_3)_3$), red solution, by reaction of soluble ferric salt solution and **sodium** hydrogen sulfite solution, is unstable, quickly forming ferrous sulfite and dithionate

Thiocyanate ferric thiocyanate ($Fe(CNS)_3$), red solution, by reaction of soluble ferric salt solution and ammonium **thiocyanate** solution Used as a delicate test for ferric (1 part ferric in solution in 1,500,000 parts of water may be detected), more soluble in ether than in water and easily concentrated in the ether layer by mixing

Ferrous salts are generally green, sometimes yellow to brown by slight oxidation, and in solution are generally green, but are quickly oxidized in part by air to ferric, brownish Ferrous is chemically related to zinc, cobaltous, nickelous, manganous, magnesium Ferroferric compounds are black Ferric salts are generally violet to brown, sometimes orange or greenish, and in solution generally red and on boiling yield red precipitate of basic salt or ferric hydroxide, ferric hydroxide, in various partially dehydrated forms in nature, is brown to yellow Ferric is chemically related to chromic, aluminum (R K S)

IRON AGE. Paleontology of man.

IRRADIATION (1) Exposure to **X-rays, radium,** or other forms of radioactivity, (2) exposure to ultraviolet rays to increase the **vitamin** A and D of a substance, (3) the spread of a nervous impulse beyond its normal conduction power (R S M)

IRRATIONAL EQUATIONS Radical Equations.

IRRATIONAL FUNCTION An irrational function is an **algebraic function** which is not a **rational function;** it therefore involves one or more root-extractions involving the variable (L L S)

IRRATIONAL NUMBERS. Number.

IRRATIONAL ROOTS OF POLYNOMIAL EQUATIONS. Polynomial Equations.

IRREGULAR VARIABLES. There are many **variable stars** which vary in brightness in such non-systematic manner as to be best designated as irregular variables In some cases their manner of variation and spectral class is so similar to that of the **long period variables** that they are classed as members of this class of stars by some authorities Notable among stars of this type are the bright stars α **Orionis** and α **Herculis,** both of which are **giant** red stars

There are certain groups of irregular variables which have enough characteristics in common that they may be considered as groups Such groups are usually designated by some typical star of the group The RV Tauri group resemble to some extent the **Cepheids** although their periods, of the order of magnitude of seventy-five days, is far too long to permit their inclusion in the true Cepheid class These stars are of G and K **spectral classes** and their light curves are characterized by shallow minima coming between two deep ones A few stars of the R Coronae Borealis type remain, often for several years, practically constant in brightness and then drop suddenly one or two magnitudes, returning to normal brightness after a few oscillations

The problem of the irregular variables is at present the subject of a great deal of research and observation, but to date there is no adequate explanation of their variability (W K G)

IRRITABILITY. A fundamental property of living matter which enables it to be stimulated by external factors Although the simplest forms of living things are capable of receiving stimuli from various environmental factors, such as light, mechanical contacts, and chemical compounds, the property is most highly developed in animals with a complex nervous system The **sense organs** of such animals show a high degree of specialization and diversification of this property (A W L)

IRROTATIONAL VECTOR. If the **curl** of a **vector function** of position vanishes everywhere in a certain region, the function is said to be an irrotational vector (or a lamellar vector) in this region

If a given vector function **v** is the **gradient** of a scalar function ϕ, the **v** is irrotational (I I S)

ISCHIOPODITE. Biramous appendage.

ISCHIUM. Skeletal system.

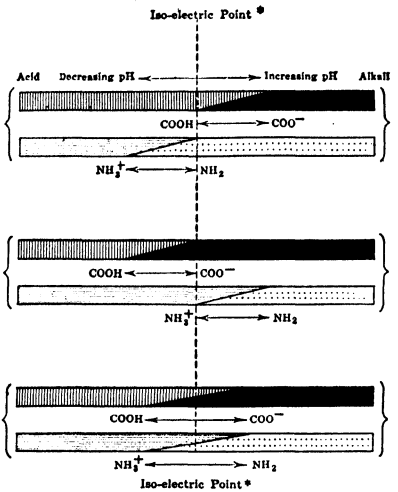
ISOCLINE Vertical duplication of formations by close folding, as illustrated in the accompanying diagram. (R M F)

ISOCYANATES. Cyanic Acid and Cyanates.

ISOCYANIDES. Hydrocyanic Acid and Cyanides.

Isoclinal folds

ISOELECTRIC POINT. In solutions of proteins and related compounds, the **hydrogen ion** concentration at which the dipolar **ions** are at a maximum is the isoelectric point At this point the solution shows minimum **conductivity, osmotic pressure,** and **viscosity** At this pH the protein shows the least swelling with water and does not undergo cataphoresis That is, the colloidal particles move toward neither electrode Proteins coagulate best and contain the least amount of inorganic matter at their isoelectric points (See also **Aminoacids, Polypeptides, and Proteins.**)



*The Iso-electric point is not the same for all proteins

Isoelectric point of proteins.

ISOELECTRIC POINTS

Substance	Isoelectric Point (pH)
Proteins:	
Glutenin	4.5
Gelatin	4.7
Egg albumin	4.8
Serum albumin	5.4
Edestin	5.7
Oxyhemoglobin	6.8
Gliadin	9.2
Clupeine	12.1
Dipeptides:	
Glycylglycine	5.5
Alanyl glycine	5.5
Leucyl glycine	5.7
Aminoacids:	
Glycine	6.6
Alanine	6.7
Leucine	6.5

(R.K.S.)

ISOGAMY. A type of sexual **reproduction** in which the male and female **germ cells** are similar in form. (A.W.L.)

ISOGEOTHERM. Depths of equal temperature in the earth. (R.M.P.)

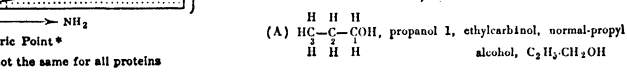
ISOLATION. A principle of organic **evolution.** Animals separated from the remainder of their kind are supposed to have a characteristic heritage which determines the nature of their descendants. This foundation may differ from that of the rest of the species and so may give rise in time to a different variety or species as a result of the isolation, independent of the adaptive value of the heritage.

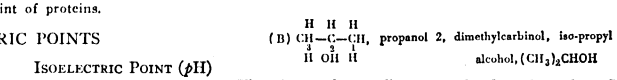
Isolation may be geographic or biological. The Galapagos Islands offer famous examples of geographic isolation. They are regarded as the remnants of a once continuous land mass and are now inhabited by distinct varieties of birds of several species. These varieties are characteristic of certain islands and do not pass from one to the other, hence they are interpreted as the descendants of birds which remained on the islands when they were first formed.

Biological isolation may be due to cytological incompatibility, physical differences or to time of reproductive activity. Some varieties of dogs, for example, are physically incapable of interbreeding although they belong to the same species. Time is a decisive factor in interbreeding among the insects, especially in species whose adult life is short. If some individuals emerge early and others late in the normal season, those of the two groups have little or no chance to interbreed. The result is that any distinctive characters of the two are likely to be perpetuated in different strains. (A.W.L.)

ISOLEUCINE. Aminoacids, Polypeptides, and Proteins.

ISOMERISM AND STEREOISOMERISM. Two substances are said to be isomeric when they possess the same ordinary molecular **formula** and different properties. A simple instance is that of C_3H_8O, which represents two propyl **alcohols,** one (A) of boiling point 98° C. and density 0.804, the other (B) of boiling point 82° C. and density 0.789. These two alcohols differ in other properties including their chemical behavior. It is believed that the difference is due to the arrangement of **atoms** in each **molecule,** thus:



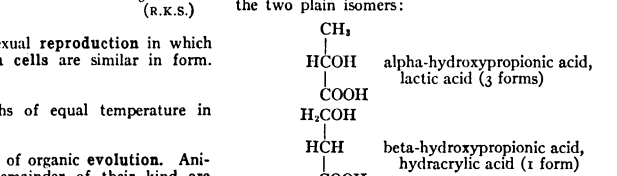


Therefore, the ordinary molecular formula, C_3H_8O, represents two different isomeric substances; $C_2H_5 \cdot CH_2OH$ and $(CH_3)_2CHOH$ are isomers; and the phenomenon displayed by these is known as isomerism.

The ordinary molecular formula, C_4H_{10}, corresponds to two butanes, namely, normal-butane, $CH_3CH_2CH_2CH_3$, (diethyl) of boiling point 0.6° C. and density 0.60, and iso-butane $(CH_3)_3CH$ (2-methyl propane, trimethyl methane) of boiling point — 10° C. and density 0.60.

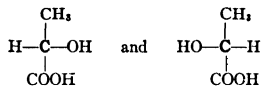
In any series of compounds, as alcohols and **hydrocarbons** above, the number of isomers increases rapidly with increase in the molecular formula, thus, there are four isomeric alcohols of C_4H_9OH, and eight of $C_5H_{11}OH$, and three isomeric hydrocarbons of C_5H_{12}, and five of C_6H_{14}.

Coming next to the hydroxyacids represented by the ordinary formula $C_3H_6O_3$, other forms are known than the two plain isomers:



Plain isomerism is not sufficient to account for these three known forms of **lactic acid.** The explanation that is accepted was offered by van't Hoff and LeBel, independently (1874). This explanation demands that the four valencies of the **carbon** atom be disposed equally in space. The carbon atom may be pictured as occupying the center of a regular tetrahedron. The four **valencies** are disposed from the carbon atom at the center towards the four corners of the tetrahedron. When *four different groups* are attached (at the corners of the tetrahedron) to the carbon atom (at the center of the tetrahedron) it is possible to arrange the resulting compound in *two*

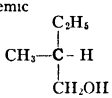
different ways. Upon projection these two forms appear thus·



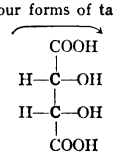
These are called space-isomers or stereoisomers, and the phenomenon displayed is known as stereoisomerism One of these forms rotates the plane of **polarized light** to the right (dextro-lactic acid, d-lactic acid or sarcolactic acid) and the other to the left (laevo-lactic acid or l-lactic acid) A mixture of the two forms in equal amounts is ordinary lactic acid (dextrolaevo-lactic acid, dl-lactic acid, racemic-lactic acid), from sour milk, which does not rotate the plane of polarized light These are the three forms of lactic acid, namely, dextro, laevo, and dextrolaevo or externally compensated From dl-lactic acid, the other two forms may be obtained in the following manner, (1) d-lactic acid, by treatment with the mold, *Penicillium glaucum*, whereby l-lactic acid is destroyed, (2) l-lactic acid, by treatment with an optically active base, **strychnine,** followed by fractional crystallization, and subsequent treatment with an acid

These two methods are of general application to racemic or externally compensated stereoisomers, the first, **biochemical,** in which one-half of the racemic substance is destroyed by the organism used, and the second, resolution, which can be applied in the case of acidic or basic stereoisomers A third method, involving plain **crystallization,** is described below (Pasteur's separation of tartrates)

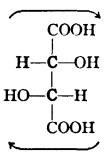
The simplest alcohol displaying stereoisomerism is amyl **alcohol,** which is known in the three forms dextro, laevo, dextrolaevo or racemic



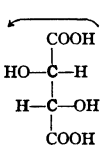
The carbon atom, to which are attached the four different groups to produce stereoisomerism or optical isomerism, is known as asymmetric, and, when it is desired to identify this carbon atom as such, it is written or printed more prominently than non-asymmetric carbon atoms, each of which has four different groups attached to it The projection formulas of the resulting four forms of **tartaric acids** are as follows



inactive or meso-tartaric acid (internally compensated, possesses a plane of symmetry, individual, optically inactive)



dextro-tartaric acid (arrangement of groups around each asymmetric carbon atom is cumulative, optically active, dextro-rotatory)

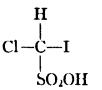


laevo-tartaric acid (arrangement of groups around each asymmetric carbon atom is cumulative, optically active, laevo-rotatory)

{d-tartaric acid / l-tartaric acid} Dextrolaevo-tartaric acid, racemic tartaric acid (externally compensated, optically inactive, can be resolved into d and l components)

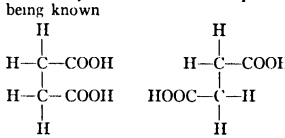
The two optically active tartaric acids differ when crystallized in the arrangement of the faces—one is the mirror image of the other Pasteur (1848), observing this difference, was able to separate the two optically active forms of ammonium sodium tartrate crystals from racemic tartaric acid

When stereoisomeric substances are synthesized using *inactive* materials, the product is optically inactive, since, it is believed, the chances of dextro and laevo forms being produced are equal Pope and Read (1914) prepared optically active forms of chloroiodomethanesulfonic acid



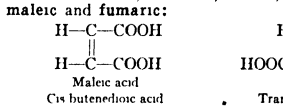
The sugars, $C_6H_{12}O_{16}$, have attracted much attention in this field (See **Carbohydrates**) Many substances in nature, especially notable are the alkaloids and glucosides, are optically active

Ethylene Stereoisomerism While it might appear that succinic acid, $C_4H_6O_4$, could demonstrate the phenomenon of stereoisomerism, the same has not been detected It is assumed that there is free rotation about the single bond joining the two central carbon atoms and the position finally assumed is one of equilibrium, one form only being known



(only one form of **succinic acid** known)

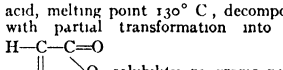
But in the case of olefin linkage between the central carbon atoms in an analogous compound, stereoisomerism is detected Thus, two acids, $C_4H_4O_4$, are known, namely, **maleic** and **fumaric:**



Maleic acid
Cis butenedioic acid
or
Cis 1,2-ethylenedicarboxylic acid

Fumaric acid
Trans butenedioic acid
or
Trans 1,2-ethenedicarboxylic acid

Each of these acids has distinctive properties Maleic acid, melting point 130° C, decomposes above 135° C, with partial transformation into maleic anhydride

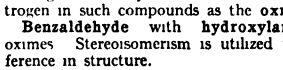


, solubility 79 grams per 100 grams water at 25° C, optically inactive, fumaric acid, melting point 287° C, boiling point 290° C, no anhydride, 0 7 gram per 100 grams water at 17° C, optically inactive

Oleic and elaidic acids display this type of isomerism

Carbon-Nitrogen (group $>C=N-$) Stereoisomerism Analogous to ethylene isomerism is that of carbon-nitrogen in such compounds as the **oximes.**

Benzaldehyde with **hydroxylamine** yields two oximes Stereoisomerism is utilized to explain the difference in structure.



Benzantialdoxime
Melting point 35°C
Optically inactive

Benzsynaldoxime
Melting point 128°C.
Optically inactive

Phenyl cyanide
Boiling point 191°C.
(For comparision)

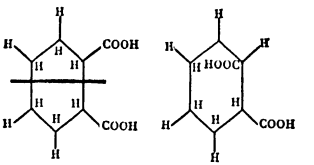
Benzsynaldoxime is transformed into benzantialdoxime by treatment with acids, and is more readily converted by

loss of water into phenyl cyanide (this is a debated point).

The **ketone** para-chlorobenzophenone with hydroxylamine yields two stereoisomeric oximes

$$H_4C_6—C(=HON)—C_6H_4Cl(4) \qquad H_4C_6—C(=NOH)—C_6H_4Cl(4)$$

Cyclic Cis-Trans Stereoisomerism in non-benzenoid compounds This phenomenon is illustrated by the two forms of hexahydroorthophthalic acid ($C_6H_{10}(COOH)_2$ (1,2)).



Cis Hexahydro 1,2 phthalic acid
Melting point 192 C.
Soluble in water
Plane of symmetry (the dotted line), therefore, optically in[active]

Trans-Hexahydro 1,2 phthalic acid
Melting point 221°C.
Soluble in water
No plane in symmetry, therefore two optically active forms

This type of isomerism is believed to explain the existence of two forms of glucose, namely, alpha and beta (not dextro and laevo, which is of the lactic acid and tartaric acid non-cyclic type) (See **Carbohydrates.**) (R K S)

ISOMETRIC SYSTEM. Crystallography.

ISOMORPHOUS The term applied to two or more minerals whose molecules can form intimate crystalline mixtures Such mixtures are called solid **solutions,** in which the physical properties vary with the chemical proportions The bulk of the silicate minerals are isomorphous, especially **albite** and **anorthite,** varying mixtures of which produce different species of **plagioclase feldspar** (R M F)

ISONITRILES. Amines and Amides.

ISOPHANE. A line plotted on a map through regions presenting uniform association of biological and climatic factors Isophanes of the United States curve upward from the southeast toward the northwest Phenomenidians crossing the isophanes at intervals in degrees of longitude corresponding to the spacing of the isophanes complete the division of the map into quadrangles In each quadrangle the same conditions prevail within certain limits of variation This system has been used for the computation of safe dates for sowing wheat to avoid the attack of the **Hessian fly** in various parts of the United States (A W L)

ISOPODA. Crustacea.

ISOPRENE. Hydrocarbons.

ISOPTERA. The white ants or termites. An order of insects of great economic importance and biological interest, made up of social species which eat wood and other vegetable matter Most termite species are tropical or subtropical but a few live in temperate regions

Termites have biting mouth parts and are moderate to small soft-bodied insects They live in dark nests and tunnels except when the winged sexual individuals emerge to leave the parent colony The bodies of these flying individuals are dark but the termites that remain in the nest are whitish with dark heads They do not resemble ants in form, hence their similar habits are probably responsible for the name white ant The temporary wings of termites are long and slender and the two pairs are similar in form In most species the veins near the anterior margin are strong and the rest are faintly marked The wings are shed after the swarming termites find a new nesting place

The termite colony contains workers, soldiers, and reproductive individuals of both sexes The workers are developed in subordinate castes in several species Soldiers have large heads and strong jaws The queen in some colonies becomes relatively enormous through the expansion of the abdomen as the eggs develop and is quite helpless The workers feed and groom her and carry away her eggs

It has been shown conclusively that termites depend on **protozoans** in the intestine for the digestion of the wood that they eat Very few animals can digest cellulose, which is the chief compound in wood, but the protozoans do so and the termites utilize the products developed by the protozoans This relationship is one of the finest examples of **symbiosis** among animals

Because of their wood-eating habits termites sometimes do great damage to buildings Their habit of building tunnels wherever they go and of remaining concealed in the wood where they work often results in their presence being unsuspected until the honeycombed timbers give way When they once enter buildings they are not restricted to wood but damage papers, books, clothing, carpets and many other things In regions where they are plentiful no timber in construction should be left in contact with the ground Even a small contact may be a point of entry Where timber must be exposed to attack it can be protected by impregnation with creosote, but the most effective type of construction demands masonry wherever contact with the ground must be made Even in such structures termites may traverse several feet of masonry, building tunnels as they go, and may work through small cracks into the wooden parts of the building Where termites have already entered, blocking their entrance and destroying the colony both inside the building and out with creosote or fumigants are usually effective methods of control Special equipment and methods are available commercially for this work (A W L)

ISOSTASY. A term proposed by C E Dutton in 1889 for the theory of **gravitational** balance between relatively broad, contiguous areas of different average altitudes or topographic relief The term is derived from the Greek meaning equal standing (balance), and has been applied particularly to the isostatic equilibrium of the major topographical features of the earth—continents and ocean basins Thus the continents are assumed to "stand high," relative to the ocean basins, because they are lighter (or less dense) material The condition of compensation, or no strain, is assumed to exist at some 60 miles below the surface of the earth, as at this depth all material must be non-rigid and capable of "flow" Thus the rigid blocks of the upper of the crust of the earth are postulated as floating on the subcrustal medium Since the surfaces of the continents are constantly being worn down by erosion, if it were not for isostasy, early in the geologic history of the earth all land areas would have been reduced to ocean level The theory of isostasy was originally proposed to explain major problems in structural geology, and has been amply justified by **geophysical** and **geodetic** surveys In the application of the theory there has been considerable disagreement between geophysicists and geologists as to the minimum areas of relief (topographic features) which may be subject to isostatic balance, especially in mountainous regions which are characterized by low angle **overthrusts** and consequent, horizontal translations of great thicknesses of the **lithosphere.** The general principle of isostasy has, however, been accepted by an increasing majority of geologists, geodesists, and geophysicists, and probably no other geophysical-geological theory is so firmly entrenched in geodetic, geophysical

and geological literature. The present outstanding exponent of Isostasy is William Bowie (R M F)

ISOTHERMAL. Having the same temperature.

ISOTHERMS. Contours of equal temperature as plotted on the surface of the earth. (R M F)

ISOTOPES. Chemical Composition.

ITABIRITE. A variety of **quartzite** rich in iron minerals. It is named from the type locality at Itabira, Brazil. (E.S.C S.)

ITACOLUMITE. This is a **sandstone** with a peculiar flexibility which is due to the interlocking of its constituent grains, permitting a limited amount of distortion without fracture The name is derived from *Itacolumi,* a mountain in Brazil. (E S C S)

ITERATED INTEGRALS. Double Integrals, and **Triple Integrals.**

IVORY. The dentine of teeth, a material similar to bone but harder and of different minute structure It is deposited outside of the layer of cells that produce it, in the form of small tubules extending toward the outside of the tooth

The chief sources of ivory for commercial purposes are the tusks of various animals. Elephants' tusks have only a little enamel at the tip and are solid ivory except where the pulp cavity invades the base. The tusks of walruses have also been an important source of ivory, although they are inferior to elephant ivory. The material is used extensively for carved ornaments. (A W.L.)

IZARD. Mammalia, Artiodactyla. **A name applied to the chamois in the Pyrenees. (A.W.L.)**

J

JABIRU. Aves, Ciconiiformes. The giant **storks** of South America, Africa, and Australia. (A W.L.)

JACAMAR. Aves, Piciformes. South American birds (**Aves**) related to the woodpeckers. (A.W.L.)

JACANA. Aves, Charadriiformes. Shore birds (**Aves**) of South America, Africa, and the Oriental region They have long legs and tail and very long toes. (A.W.L.)

JACARE. Caiman.

JACK. A jack is a portable device for lifting heavy loads through short distances by hand power Power is applied manually to a lever or bar The mechanism of the jack allows the operator to exert a great **mechanical advantage** and lift a weight many times that which would be possible unaided by the jack. The mechanical advantage is secured by a great reduction in motion, and consequently jacks are slow in action.

The requirement of being readily carried by hand from place to place necessarily limits the capacity which may be built into a jack. However, it is built to lift more than a few tons. The mechanical advantage of a jack may be secured by screw, lever, or hydraulic action. The screw jack has a threaded screw fitting to a nut which is a part of the base of the jack. The threaded portion is revolved by bars inserted in it, and is topped by a bearing plate, which presses against the load being lifted, and which rubs on the top of the jack as the latter is turned. In its usual form, the lever jack has a rack and pawl, the pawl being mounted on the end of a lever whose fulcrum point is very close to the pawl, thus giving a big mechanical advantage to any force exerted at the other end of the long lever The hydraulic jack, which is even more powerful than the other two types, has a very small piston which is actuated by hand, and which forces oil into a cylinder where it can act against a much larger piston. This larger piston is connected to the lifting portion of the jack, and the mechanical advantage which is, roughly, the ratio of the areas of the large and small pistons, may be made as large as wanted (F T M)

JACKAL. Mammalia, Carnivora An animal resembling the wolf and of similar habits The common jackal, *Canis aureus*, ranges from southeastern Europe to Ceylon and into northern Africa, and the remaining species are African. Jackals are predators and scavengers. They also eat some fruits and occasionally damage sugar cane. (A.W L.)

JACKDAW. Aves, Passeriformes. A small European **crow**, *Corvus monedula*, typically with a gray collar but also occurring in a wholly black form Another species of **daw** occurs in Asia and the name jackdaw is applied to the great-tailed **grackle** in the southwestern United States. (A.W.L.)

JACKET. A jacket is a covering whose function is associated with retention or extraction of heat from that which it covers. The **cylinder** of a **steam engine** is covered with a wooden jacket whose purpose is to prevent heat loss from the cylinder. The jackets of **internal combustion engines** remove the heat from the cylinder. While some internal combustion engines are air-cooled, the majority are water-cooled with water which is circulated in jackets which surround the cylinder head and sometimes extend the full length of the cylinder. These jackets may be cast on the cylinders when the latter are poured, or they may be made of thin sheet metal welded to the cylinder. The latter practice produces a lighter weight engine, but is much more expensive than the cast type water-jacketed cylinder. Small engines can have the water led into the jacket and conducted away from it by simple openings, but a more definitely controlled flow of cooling water is necessary for a large cylinder. In addition, other parts such as exhaust **manifolds**, and pistons, may be water-jacketed. About one-third of the heat of the fuel supplied to an internal combustion engine finds its way into the contents of the cooling jacket. (F T.M.)

JACK-IN-THE-PULPIT. Aroids.

JACOBIAN. A Jacobian is a type of mathematical expression, named after the great German mathematician Karl Gustav Jakob Jacobi (1804–1851).

Let F_1 and F_2 be two **functions** of u and v. The **determinant**

$$J = \begin{vmatrix} \frac{\partial F_1}{\partial u} & \frac{\partial F_1}{\partial v} \\ \frac{\partial F_2}{\partial u} & \frac{\partial F_2}{\partial v} \end{vmatrix} = \frac{\partial F_1}{\partial u}\frac{\partial F_2}{\partial v} - \frac{\partial F_1}{\partial v}\frac{\partial F_2}{\partial u}$$

is called the functional determinant or Jacobian of F_1 and F_2 with respect to u and v It is frequently denoted by $\frac{\partial(F_1, F_2)}{\partial(u, v)}$.

In general, if $F_1, F_2, \cdots, F_n$ are functions of $u_1, u_2, \cdots, u_n$, then the functional determinant or Jacobian of $F_1, F_2, \cdots, F_n$ with respect to $u_1, u_2, \cdots, u_n$ is defined to be the determinant

$$J = \begin{vmatrix} \frac{\partial F_1}{\partial u_1} & \frac{\partial F_1}{\partial u_2} \cdots \frac{\partial F_1}{\partial u_n} \\ \frac{\partial F_2}{\partial u_1} & \frac{\partial F_2}{\partial u_2} \cdots \frac{\partial F_2}{\partial u_n} \\ \cdots & \cdots \cdots \cdots \\ \frac{\partial F_n}{\partial u_1} & \frac{\partial F_n}{\partial u_2} \cdots \frac{\partial F_n}{\partial u_n} \end{vmatrix},$$

and is often denoted by $\frac{\partial(F_1, F_2, \cdots, F_n)}{\partial(u_1, u_2, \cdots, u_n)}$. (L.L.S.)

JADE. Jade is a general term for a compact green mineral substance much prized for ornamental purposes in China and Japan and to a less extent in the Western World. Jade is, properly speaking, either a compact **actinolite** called **nephrite**, a variety of **amphibole**, or jadeite, a **monoclinic pyroxene**. It is easily worked and many prehistoric implements have been found of this material in Mexico, Switzerland, France, Greece, and Egypt The word jade is derived from the Spanish *pietra di hijada*, kidney stone, because it was supposed to be beneficial to diseases of the kidneys Nephrite is derived from the Greek word for kidney, the allusion being the same as in the case of jade. (E.S.C.S.)

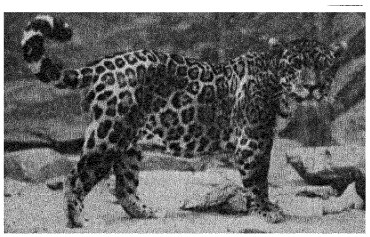
JADEITE. The mineral jadeite, essentially **sodium aluminum silicate**, $NaAl(SiO_3)_2$, is a monoclinic **pyroxene** usually appearing in crystalline masses, or may be granular, fibrous, or compact It has a prismatic **cleavage**; splintery **fracture**; hardness, 6 5–7, specific gravity, 3 3–3 5; luster, vitreous to pearly; color, various shades of green, bluish green, greenish white or almost white; translucent to opaque. The processes that have acted to form this mineral are little understood both because of the confusion that exists between jadeite and **nephrite**, and the fact that the localities are not well known.

Jadeite is found in Burma and China and has been reported from Mexico. It has probably resulted from the **metamorphism**, at great depths, of rocks rich in soda and aluminum, such as **nephelite syenites.** Its association in Burma with **serpentine** suggests its origin in more **basic igneous** rocks.

Jadeite is a tough and yet rather easily worked substance and has long been used for ornamental purposes. Evidence has been found in Europe, Mexico, Egypt, and elsewhere that it was used in prehistoric times for both ornaments and implements. The word jadeite has been formed by adding -ite to jade, the general term used for all green-colored tough compact stones that have been used as indicated above. (E.S.C.S.)

JAEGER. Aves, Charadriiformes. Birds closely related to the **gulls**, from which they differ in the elongate middle tail feathers. Four species nest in the Arctic regions and migrate into Europe, the southern United States, and even the southern hemisphere. One is Antarctic and one lives on the west coast of South America. Also called skuas. (A.W.L.)

JAGUAR. Mammalia, Carnivora. A large South American cat, *Felis onca*, found chiefly in the jungles



Jaguar. (Courtesy of *N. Y. Zool. Soc.*)

but also in open country. It is tan, marked with rings and dots of black, resembling the leopard. The jaguar is larger than the leopard and differs in details of structure and markings. (A.W.L.)

JAGUARONDI. Mammalia, Carnivora. A small **cat**, *Felis jaguarondi*, of uniform brownish or blackish color. It ranges from northern Mexico to Brazil and Paraguay. (A.W.L.)

JAPANESE BEETLE. Insecta, Coleoptera. A small bronze-green **beetle**, *Pompillia japonica*, about three-eighths of an inch long, related to the May beetles. It is native to Japan and was first noticed as a pest in the United States about 1916. From New Jersey, where it first appeared, it has now spread about five hundred miles westward. It attacks fruits, shrubs, forest and shade trees, and many crop plants, and the larvae damage the roots of grasses. The control of the pest is still a serious problem, since sprays strong enough to kill the beetles injure many plants and trees. In cultivated lands the working of the ground kills the grubs and strong sprays of **lead** arsenate (8 pounds per 100 gallons of water) are effective against the adults on some fruits, shade trees, and shrubs. (A.W.L.)

JARARACA. Reptilia, Sauria. A poisonous **snake**, *Lachesis jararaca*, which ranges from eastern Brazil to Ecuador and Peru. A **pit viper.** (A.W.L.)

JARGOON or JARGON. Zircon.

JAROSITE. The mineral jarosite is a **basic** hydrous sulfate of **potassium** and **iron** corresponding to the formula $K_2Fe_6(OH)_{12}(SO_4)_4$. It is formed in the outcrops of ore deposits during oxidation of **iron** sulfides. It is a **hexagonal** mineral with basal **cleavage**; is brittle, hardness 2.5–3.5; specific gravity 3.15–3.26; luster vitreous to dull; color, dark yellow to yellowish brown; shining yellow **streak**; translucent to opaque. Jarosite was originally reported from and named for Barranco Jaroso in the Sierra Almagrera, Spain. It has been found in Bohemia, France, the Island of Elba, Siberia and Bolivia. In the United States it is found in Arizona, Colorado, Texas, New Mexico, Utah, Nevada, and South Dakota. (E.S.C.S.)

JASMINE OIL. Volatile oils.

JASPER. This mineral normally occurs as a red **chalcedony**, the coloring matter being **hematite** or **limonite.** Other varieties of jasper are yellow, green, or dull blue. Jasper forms an important constituent of the hard iron ores of the **Lake Superior iron ranges.** (R.M.F.)

JASPILITE. A rock made up of alternating layers of **siliceous** material such as **quartz** or **chalcedony**, and red **jasper** or **hematite**. Jaspilites are often contorted and **brecciated** to a considerable degree, and are sometimes polished for ornamental use. (E.S.C.S.)

JAUNDICE (ICTERUS). A condition of the body in which the pigment of the bile stains the skin, mucous membranes, tissues, and body fluids. It is a symptom of many disorders and diseases of the body.

Jaundice may be divided into three types: (1) Obstructive jaundice. This form accounts for about 85% of all cases and is seen when there is any obstruction of the bile ducts leading from the liver to the duodenum. The obstruction may be caused by gall stones within the ducts, inflammation of the duct wall, shutting off the flow of bile by swelling (cholangitis), tumor formation within the walls or causing pressure from without, scar tissue formation, or kinking, or spasm of the bile ducts; (2) Non-obstructive jaundice. This is usually of splenic origin. (See **Hemolytic Jaundice**); (3) Toxic and Infectious jaundice. This occurs when the liver cells have been damaged by toxic substances, either chemical, bacterial, or spirochaetal in nature. It is seen in poison from chloroform, phosphorus, and arsenic compounds and may occur with syphilis or any of the acute infections or diseases. It is also seen in Weil's disease.

The symptoms and signs of jaundice are as follows: the whites of the eyes first show a yellow pigmentation and soon the entire body becames yellow. The urine varies from yellow to dark brown. The blood serum is bile-stained and in severe cases the clotting time of the blood is greatly prolonged so that bleeding is hard to control. In chronic cases there is marked and uncontrollable itching of the body. The cerebrospinal fluid is usually not colored. The stools, when there is complete absence of bile in the intestine, are clay-colored due to lack of bile pigment and the presence of undigested fat. With jaundice there is usually mental depression, headache, and drowsiness. In severe cases there may be stupor or coma.

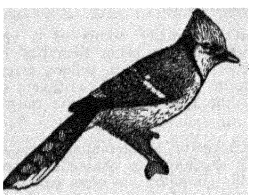
Other symptoms present depend on the condition of which the jaundice is a symptom. (R.S.M.)

JAW. The assemblage of bones before and behind or above and below the mouth of a **vertebrate**. The lower jaw is movably articulated with the skull to work against the upper jaw for biting and chewing and both bear teeth in most species.

The earliest vertebrate jaws, as exemplified by the **sharks**, consisted entirely of cartilage and were not rigidly attached to the brain case. With the acquisition of an outer covering layer of dermal bones the upper jaw was firmly attached to the cranium and the primitive jaw **cartilages** receded in importance, although they, or the replacement bone superseding them, still served as the jaw joint. In the evolution of the mam-

mals from the mammal-like reptiles a new jaw joint was formed, this time between dermal bones, and the old jaw joint became incorporated in the middle ear, where it still functions as the joint between the malleus and incus. (A.W.L.)

JAY. Aves, Passeriformes. Birds (**Aves**) of several species related to the magpies and crows. Most jays live in the northern hemisphere but a few species occur in the Oriental region and northern Africa. They are noisy birds, often brightly colored, and sometimes interesting in habits, but some are too destructive of the eggs and young of other species and too quarrelsome to be desirable.



Blue jay. *Cyanocitta cristata.* Blue above, with white bands on the wings. White below. A black band around the neck. Narrow black bars on wings and tail. A crest on the head.

The blue jay, *Cyanocitta cristata,* is the most widely known of the North American species. More than a dozen others occur in the western states, where the Oregon jay, *Perisoreus obscurus,* and the Canada jay or whiskey jack, *P. canadensis,* are friends of campers. These species visit camps and human habitations freely in search of food. (A.W.L.)

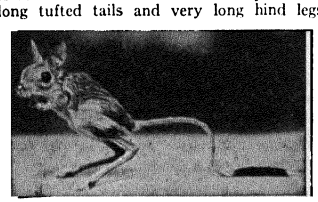
JEJUNUM. That portion of the small intestine that extends from the end of the **duodenum** to the beginning of the **ileum.** The jejunum is about eight feet long and continues into the ileum without any line of demarcation. It occupies the upper and left part of the abdomen lying below the stomach and spleen on the left side. Its coils are freely movable and are connected with the posterior abdominal wall by wide folds of membrane (**peritoneum**) called the mesentery, through which run the blood vessels and nerves supplying it. (R.S.M.)

JELLYFISH. Scyphozoa. Coelenterata. Medusa.

JENNET. Mammalia, Artiodactyla. The female **ass.**

JENNY HANIVER. A curiosity resembling a misshapen human figure, made by variously distorting and decorating a **ray.** Made in the past by New England fishermen and sometimes found among collections of curios. (A.W.L.)

JERBOA. Mammalia, Rodentia. Small jumping animals of Asia and northern Africa. They resemble mice with long tufted tails and very long hind legs. The



(Courtesy [illegible])

small fore legs are not used in locomotion. The Asiatic jerboas have five toes on the hind feet and the African three. The most common Asiatic species is also called the alagdaga, *Allactaga indica.* (A.W.L.)

JET. This term is used in geology and engineering. The geological material, jet, is not a mineral in the true sense of the word. It is a hard and compact variety of lignite, coal black in color. It can be easily polished and has been used for the manufacture of cheap ornaments. Jet is found in England, France, Spain, Germany, and the United States.

In engineering, a jet is a rapidly moving fluid stream spouting from a **nozzle** or **orifice.** A jet of water attains a theoretical velocity equal to $\sqrt{2gh}$ (g = **acceleration** due to gravity) when it issues from a nozzle under an effective **head** of h feet of water. The actual velocity is less than the theoretical, and the ratio between the two is expressed by the term known as the velocity coefficient. The path taken by a free jet of water discharged through a vertical orifice under a head of $h = \frac{v^2}{2g}$ in which v equals the velocity is parabolic in form, and follows closely the curve $x^2 = 4\ hy$. When the jet of water representing a flow of Q cubic feet per second is altered in momentum through a change in velocity, a dynamic force will be exerted upon the object which is causing the change. If this object is a turbine blade, the force is immediately set to work turning the turbine and producing useful work. The force required to deviate a jet of water is $\frac{62.4Q}{g}\Delta v$. Δv represents the change in velocity, and it may be a change in magnitude, a change in direction, or both.

A jet of steam is produced by the adiabatic **expansion** of steam from a higher to a lower pressure, with the conversion of heat energy into mechanical energy of the motion of the jet. The following equation is based on equating of the total energy of a pound of steam entering a nozzle to that leaving. While this is not strictly correct, it is nearly so, since the radiation and friction losses in steam nozzles are of a very low order of magnitude.

$$V_2^2 - V_1^2 = 224\sqrt{H}.$$

V_1 and V_2 are the steam velocities before and after the nozzle, feet per second. H is the adiabatic heat drop created by expansion of steam in the nozzle. While the density of a jet of steam is much less than that of water, large amounts of energy are obtainable from steam jets by virtue of the very high velocities which may be attained by steam, subjected to reasonable pressure drops. (E.S.C.S., F.T.M.)

JETTY. A jetty is a form of hydraulic works employed to control currents, sand bars, and shoals for the benefit of navigation. These are structures of rock, concrete, piling, or brushwork, made in the form of a long narrow dyke, and placed in accordance with the particular requirements of the installation which might be control of silt through maintenance of current, or control of waves or currents which might tend to produce sand bars. Sometimes jetties are in pairs, one on each side of the current, to confine and direct it, though single jetties are also useful in certain locations. The most famous jetties of the United States are those of the lower Mississippi, which serve to maintain the ship channel through the Mississippi Delta. (F.T.M.)

JEWFISH. Pisces, Teleostei. The giant **sea bass,** *Stereolepis gigas,* a game fish of the California coast which reaches a weight of five hundred pounds. The name is also applied to other fish. (A.W.L.)

JIG. Since the purpose of this article is to describe the apparatus for holding and guiding work, principally during machine operations, it can also be said to include a description of fixtures. As a matter of fact, there is no clear distinction between jigs and fixtures, and they are usually spoken of together descriptively. Operations on the **drill press** or drilling machine are frequently speeded up when a large number of duplicate pieces are to be drilled if a drilling guide is provided, so that measurements to center punch holes do not need to be made on each fresh piece. The drilling guide, and this is usually termed a jig, might, for example, consist

of a plate clamped or otherwise fastened atop the piece to be drilled. It contains holes slightly larger than the drill, properly spaced, and through which the drill can be lowered for the drilling operations without the necessity of individual hole measurements. Most machine tools are adaptable to the use of jigs in quantity production. Extreme accuracy may not be obtained with the use of drilling jigs, since the hole in the jig must naturally have some clearance to permit the drill to pass without binding. This establishes certain variations in hole location. However, the inaccuracies are not great, and are tolerable in many machining jobs. Jigs and fixtures may be employed very usefully in a wide variety of assembling operations where they are used to maintain work spacing and an alignment of parts during the assembly. They are especially valuable where assemblies are joined by gluing, nailing, or welding. (F.T.M.)

JIGGER. Chigger.

JIMSON WEED. Potato Family.

JOINT. In geology, a joint is a fracture in a rock with no apparent relative displacement as in the case of a **fault**. Fractures are exceedingly common in all types of rocks and are frequently arranged in definite relation to each other, such as to produce joint systems more or less constant over considerable areas. Depending on the supposed cause of a given joint system the fractures may be described as tension joints, or compressional joints. In **igneous rocks** a set of joints may be developed by contraction during their period of cooling and solidification within the earth's crust. Igneous rocks, after complete solidification, may later have sets of tension or compression joints superimposed on the first set by the relief of pressure, due to the **erosion** of the overlying formation, or to insolation or frost action after the removal of the overlying formations. Joints are of great importance in quarrying and all operations which require the removal of bed rock. Well-jointed rocks are relatively easily taken out and split into smaller blocks for various constructional purposes.

In mechanics, a joint is a mechanical union between two or more parts, or between different edges of the same piece. Among joints one may find static joints and moving joints, rigid joints and flexible joints, riveted, welded, bolted, and pinned joints, permanent and disconnecting joints. Riveted joints in plate steel can be either butt joints, using cover plates, or lap joints. By lap joint is meant an arrangement of overlapping plates which are drilled through and held together by one or

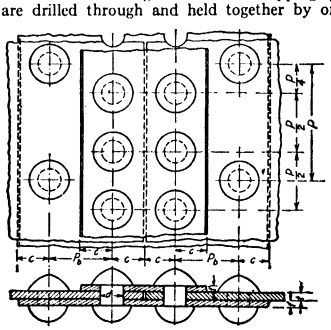


Figure 1. Double-riveted butt joint.

more rows of rivets. A defect of the lap joint is that when used for a pressure tank, the tensile forces in the two plates forming the joint are eccentric, and induce a bending stress. Butt joints are formed when the edges of the plates, being joined, butt against each other, and are connected by overlapping straps, which are pieces of the same material by which the butt edges are held together. Figure 1 shows a double riveted butt joint, in which the edges which are butted together are covered on each side by straps, and the connection is made by rivets which pass through all three plates. A joint of this type must have sufficient strength to prevent shearing of the rivets, and crushing of the plates or rivets, as well as protection against failure by tearing of the plate between rivet holes. The rivets must not be spaced so closely that the material between them could be injured by the punching operation, but they should be close enough to close the joint between the plates to prevent the entry of water. (See **Fastenings, Universal Joint, Coupling, Pipe Joint.**)

Figure 2. Deformation of lap joint.

In anatomy, a joint is a connection between rigid units of the **skeleton**. Joints are of two types, movable and fixed. The latter (synarthroses) provide for the formation of firm skeletal structures where more than one rigid part is involved, and movable joints (diarthroses) enable the separate divisions of the body and jointed appendages to act together as systems of levers, moved by muscles.

In the **arthropods** separate hard parts of the exoskeleton are known as sclerites. Since they are merely plates developed in a continuous tissue the flexible regions of the integument between them serve as connections. These joints are known as sutures and vary from well-marked and freely movable to completely obliterated unions. Where the principal sclerites of a segment unite along the sides of the body and between the sclerites of adjacent segments the unions are called conjunctivae. At the attachment of the segments of legs to each other and the articulation of legs and wings with the body the same principle prevails. The union of an appendage with the body is sometimes supplemented by small articular sclerites.

In the fixed joints of **vertebrates** the bones are united by tough **connective tissue**, including many white fibers which continue into the substance of the bone, or by a zone of cartilage (synchondrosis).

Movable joints of vertebrates develop in continuous tissue between the ends of the bones. The tissue splits to form a closed joint cavity filled with synovial fluid and surrounded by a connective tissue capsule. In this capsule a fibrous layer continues into the periosteum covering the bones. It is thickened in places to form the strong ligaments that bind the ends of the bones together. Folds or plates of fibrous tissue project into the cavity, forming articular disks and menisci, as in the knee joint. The entire cavity is lined with a looser layer of the capsule except at the ends of the bones, where articular cartilages are exposed to the **synovial fluid.** (R.M.F., F.T.M., A.W.L.)

JOINT EFFICIENCY. The efficiency of a riveted joint is the ratio of the strength of a given length of joint to the strength which the same length of solid plate would have. The efficiency of the joint should be computed after the joint has been designed. With steel rivets in steel plate, the efficiency may be made very high. For instance, it may be as high as 90% in double strap butt joints having sufficient rows of rivets. A single riveted lap joint would not have a joint efficiency much greater than 50%. (F.T.M.)

JOINTER. The jointer is a wood-working machine which is designed to cut a perfectly straight, smooth edge so that when two pieces of wood are so worked they may be jointed on those surfaces without a crack showing. The jointer resembles a **planer**, and may be used for light planer duty, though its use as such is necessarily attended by considerable danger of personal injury on the part of the operator, since the piece must

be held flat against the rotating blades by hand, whereas rollers perform this function in the planer. The jointer has a rotating arbor carrying three or four knife blades, and is driven at a speed of 3000 to 4000 revolutions per minute. It is equipped with a fence against which the work may be guided and tables to support the work so that it may be brought over the knives for a certain depth of cut, which is adjustable. (F.T.M.)

JOINTWORM. Insecta, Hymenoptera. Small **insects** whose larvae work in the stems of grains and grasses, sometimes causing swelling at the joints or the formation of growths. Their work may weaken the stem and cause it to break. (A.W.L.)

JOLY SCREEN. **Bench Photometers.**

JOULE. **C.G.S. System; Erg.**

JOULE'S LAW. The law commonly referred to by this name expresses the quantity of heat generated by a steady **electric current** as proportional to the **resistance** of the conductor in which the heat is generated, to the square of the current, and to the time of its duration: $H = KRI^2t$. If the resistance is in ohms, the current in amperes, the time in seconds, and the heat in calories, the constant K has the value $0.2388 \frac{\text{calories}}{\text{joule}}$. For example, an electric grill of 22 ohms resistance, operated at 110 volts, carries 5 amperes. In 10 minutes, therefore, the quantity of heat generated is $0.2388 \frac{\text{calories}}{\text{joule}} \times 22$ ohms $\times$ 25 amperes^2 $\times$ 600 seconds $=$ 78,800 calories; this amount would heat a gallon of water about 37 Fahrenheit degrees. In electric power distribution systems much energy is wasted through heating of conductors, which, because of the form of the above equation, is often called the "RI^2 loss."

Another, although less familiar, law due to Joule states that in an ideal or perfect gas (See **Kinetic Theory** and **Ideal Gas Law**), the "internal energy" does not change during any process such as compression or expansion unless there is a change in temperature. That this statement is not strictly true of actual gases was demonstrated by Joule himself (See **Joule-Thomson Effect**). (L.D.W.)

JOULE-THOMSON EFFECT. A result observed in the so-called "porous plug experiment," performed by Joule and Thomson (Lord Kelvin) in 1852. Some years earlier (1844) Joule had tried liberating a compressed gas into a vacuum. He sought for a possible cooling of the gas as a whole as the result of work against intermolecular forces, but found none.

This was probably because his thermometer was not sufficiently sensitive. With Kelvin he later arranged an apparatus to pump gas slowly and steadily through a plug of cotton, carefully insulated against thermal conduction. The gas, before entering the plug, was maintained at strictly constant pressure and temperature, the energy being furnished entirely by the pump and not at the expense of the internal energy of the gas. Hence, unless there were other energy transformations than that involved in working against the constant (atmospheric) pressure beyond the plug, the gas merely served as a means of conveying energy from the pump to the outer atmosphere and should not change temperature at all, even though it expanded during its passage through the plug.

But in most cases there was a slight fall of temperature, proportional to the pressure difference on the two sides of the plug; with hydrogen at ordinary temperatures there was a slight rise of temperature. The cooling is taken to mean that expansion of a gas usually involves work against intermolecular attraction. Why hydrogen shows the opposite effect is not quite clear; it may be due to an intermolecular repulsion. At higher temperatures, hydrogen behaves like other gases. The data obtained from these experiments have served to give the exact relation between the standard gas thermometer scale and the Kelvin thermodynamic scale. (See **Temperature Scales.**) (L.D.W.)

JULIAN DAY. In making calculations involving long intervals of time the use of the **calendar** date and hours, minutes, and seconds introduces both confusion and ambiguity. To avoid these difficulties astronomers have adopted a system of chronological reckoning using merely the mean solar day as a unit. According to a system first proposed in 1582, at the time of the adoption of the Gregorian Calendar, a date is expressed as the number of days elapsed since the beginning of an arbitrary "Julian Era," January 1, 4713 B.C. On this system of reckoning the use of hours, minutes, and seconds is eliminated by expressing the instant of occurrence of an event as a decimal part of a day, the day being assumed to begin when the mean sun is at upper culmination (mean noon) at Greenwich, England. On this system of reckoning an event which occurred at 2 hr. 43 m. 34.6 s. P.M., eastern standard time, on January 24, 1937, would be recorded as occurring at J. D. (Julian Day) 2,428,558.32193. The Nautical Almanacs of the various governments give tables for converting any date to the proper Julian day number. (W.K.G.)

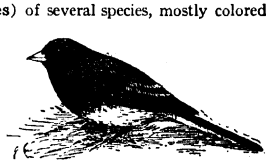
JUMPING HARE. Mammalia, Rodentia. A burrowing animal, *Pedetes caffer*, of the South African deserts. Its fore quarters are much like those of rabbits and the ears are long, but the tail is long and bushy like that of a squirrel and the hind legs are much larger in proportion than those of rabbits. It runs on the hind legs alone. (A.W.L.)

JUMPING MOUSE. Mammalia, Rodentia. Small mouse-like **rodents** with very large hind legs and long tail. They differ from the kangaroo mice in the absence of cheek pouches. Several genera, one Asiatic. Related to the jerboas of the Old World. (A.W.L.)

JUMPING PLANT LOUSE. Insecta, Homoptera. A small sucking **insect** which lives on plants. Family Chermidae. The numerous species include several of economic importance, among them the pear-tree psylla. Spraying with kerosene emulsion or nicotine sulfate is recommended as a check for this insect and the adults may be destroyed in winter by scraping off and burning the rough outer bark of the trees. The cylindrical galls on the leaves of hackberry trees are caused by another species. (A.W.L.)

JUMPING SHREW. Mammalia, Insectivora. Small African animals of several species, all with prolonged snouts and large hind legs. (A.W.L.)

JUNCO. Aves, Passeriformes. *Junco.* Small North American birds (**Aves**) of several species, mostly colored in shades of gray and white. They breed chiefly in colder regions and in higher altitudes, migrating to the valleys and to more southern latitudes although they thrive even in cold winters. (A.W.L.)



Junco. *Junco hyemalis.* Slate gray above and on the throat and breast. Belly white. Outer tail feathers white.

JUNE BUG. Insecta. A common name for the **May beetles,** large brown scarabaeid beetles whose larvae are the common white grubs of the garden. Applied along Lake Erie to the May flies. (A.W.L.)

JUNGLE FOWL. Aves, Galliformes. Wild game birds (**Aves**) of India and other parts of the Oriental region. One species, the red jungle fowl, is ancestral to

the domestic game cock and resembles it in color The jungle fowls are supposed also to be remotely ancestral to all domestic fowls (A.W L)

JUPITER. (c f tables of planetary data, page 865) Jupiter, the "giant planet," is the fifth of the major **planets** in order of distance from the sun Whether we consider bulk or mass, Jupiter is truly a giant planet, for it is larger than all of the other planets combined in both of these characteristics, having a volume more than 1300 times that of the earth and a mass nearly 317 times the earth

In spite of its great distance from the sun, the huge surface area and high **albedo** reflect a large amount of sunlight, with the result that the planet appears as one of the brightest objects in the night sky, being exceeded only by the **moon** and **Venus** In a telescope Jupiter is a most interesting object, showing a distinct flattening at the poles of rotation, and reddish bands parallel to the planet's **equator** With a large **telescope** and moderately high **magnifying power** a wealth of detail may be seen on the surface Most of these markings are only semipermanent and drift about over the surface to a considerable extent

The rotation period of the planet has been determined from these surface features and found to be the most rapid of all of the major planets, completing one rotation in slightly less than ten hours The rotation period varies with **latitude** on the planet, being the most rapid at the equator and diminishing toward the poles

The semipermanent character of the surface features, the variation in rotation period in different latitudes, the high reflecting power, and the low mean density (0 242 that of the earth) indicate that the planet probably has a relatively small solid core, surrounded by a very thick layer of **atmosphere** The characteristics of this atmosphere have been the subject of a large amount of research, particularly within the past decade The modern results all indicate that the atmosphere consists largely of ammonia and methane The temperature of the surface of the planet is too low to be accurately measured, but theoretical studies, based on the distance of the planet from the sun and its reflecting power, indicate that the temperature is in the vicinity of 133° K (—207° F) At temperatures of this value and under the calculated pressure of the atmosphere the ammonia gas would be in unstable condition and would be continually condensing and evaporating This leads to the conclusion that the semipermanent markings seen on Jupiter may well be clouds of droplets of ammonia

Jupiter has nine known **satellites,** the inner four of which are easily visible with a pair of field glasses The watching of the constantly changing apparent positions of these objects as they revolve about Jupiter forms an interesting program for those possessing moderate telescopic equipment These inner four satellites were probably the first celestial objects ever "discovered," having been found by Galileo shortly after he completed his first telescope and applied it to astronomical observations in 1610 In size and mass the so-called Galilean satellites are comparable with our own moon, the inner two having diameters very close to that of our own moon while the outer two are half as large again The planes of the orbits of these inner satellites are so nearly in the plane of the orbit of Jupiter that they pass within the shadow of the planet or cast a shadow on the surface of the planet at practically every revolution Observations of the times of **eclipse** or **occultation** of these Galilean satellites led to the first determination of the finite velocity of light The five outer satellites of Jupiter are too small and faint to be observed except with the largest telescopes, and even with such instruments the outer two can only be observed photographically Their motions are subject to tremendous **perturbations** by the inner satellites and the analysis of their motions forms a complicated problem in celestial mechanics which has never been completely solved The outer two satellites revolve about the planet in **retrograde** sense. (W K G)

JUPURA. **Kinkajou.**

JURARA. Reptilia, Testudinata The giant **tortoise,** *Podochemis expansa,* of the Amazon River basin (A.W L)

JURASSIC PERIOD. A major subdivision of the **Mesozoic Era** of the geologic time-scale Type locality, the Jura Mountains, Switzerland The formations of this system were first studied in the south of England by William Smith, the father of stratigraphy, and the period was named by A Brongniart in 1829 The Jurassic period began approximately 150,000,000 years ago and lasted for 40,000,000 years In North America the formations of this system are best exposed on the Pacific Coast, where they occur both in the Rocky Mountain and Pacific **geosynclines** No Jurassic strata are known to occur in eastern North America **Aeolian** "Red Beds" of Early and Middle Jurassic age occur in the western interior and are especially well exposed in the Colorado Plateau Marine Jurassic formations occur in the Arctic, also Africa, South America, Australia, New Zealand, Asia, the Himalayas, and Japan The principal economic products of Jurassic age are **gold** (Sierra Nevada), **coal,** and lithographic **limestone** from Solenhofen, Bavaria Plant life during this period was essentially like that of the Triassic Among the marine invertebrates the **pelecypods** and **cephalopods** are the most important fossils Sharks and the modern type of fishes were abundant The complete adaptive or radial evolution of the reptiles (Saurians) during this period is proved by the fossil skeletons of Ichthyosaurs (fish lizards), Plesiosaurs (marine lizards), Teleosaurus (ancestral crocodile), Pterosaurs (flying reptiles) (See **Fossil Reptiles**), and a number of terrestrial herbivorous and carnivorous **dinosaurs,** such as Diplodocus, Stegosaurus, Ceratosaurus, and Allosaurus Perhaps the most famous fossil of this or any other geologic period is Archaeopteryx, the "missing link" between the reptiles and the birds Severe crustal deformations occurred near the close of the Jurassic, especially in the Cordilleran region, with the birth of the Sierra Nevada and the Cascade Mountains These mountain-building movements, which typify the close of the Jurassic Period in North America, are referred to as the Sierra Nevada Revolution (R M F)

JUTE. Jute is a fiber obtained from *Corchorus capsularis* and *Corchorus olitorius* (Tiliaceae), largely grown in India The plants are woody, sparsely branched annuals growing ten to twelve feet in height, with ovate **leaves** and yellowish-white flowers In India the plant is grown mainly in the rich soil of river valleys, and cultivated by human labor Harvesting, also by hand, is done four or five months after planting The plants are pulled up, the roots and tops removed, and the stems tied in bunches and immersed in water for two or three weeks, during which time "retting" occurs, so that the fibers separate more or less easily from the remaining tissues The stalks, still in water, are then pounded with mallets, rinsed thoroughly, and wrung until the nonfibrous material is removed After this the fibers are hung up to dry The fibers are yellowish-white and lustrous, soft and without great strength It is the cheapest textile fiber in use today and is used in immense quantities, cotton alone outranking it The chief use is in the manufacture of burlap, from which are made sacks used in packing potatoes, sugar, grain, etc Burlap is also used as a backing for linoleum Cheap brown twine is often made from jute The principal drawbacks to an even wider use of jute are its brittle nature, lack of durability, and lack of resistance to moisture Nevertheless, about three-quarters of a billion pounds are used annually in the United States (R M W)

JUVENILE WATER. **Geyser.**

K

K SERIES. X-Ray Spectra.

KAGU. Aves, Gruiformes. A bird (**Aves**), *Rhinochetus jubatus*, of the island of New Caledonia, related to the sun bittern. It is about the size of a domestic fowl with longer legs and beak and a long drooping crest. (A.W.L.)

KAGUAN. Flying lemur.

KAKA. Parrot.

KAKAPO. Parrot.

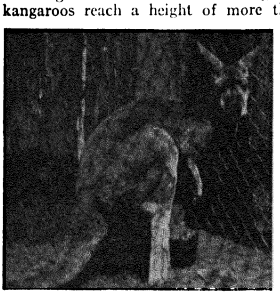
KAKAR. Muntjac.

KALIUM. Potassium.

KALONG. Mammalia, Chiroptera. The Malayan fox **bat**, *Pteropus*, largest of all bats, with a wing spread of five feet. (A.W.L.)

KAME. Irregularly shaped mounds and depressions associated with **terminal moraines**. A kame topography is usually the result of a rather mixed set of glacial conditions, including both stratified and unstratified **drift**, and frequent **kettle holes**. One peculiarity of the term is that it is never used for a single mound or depression but rather to designate the character and origin of the general kame type of topography found only in glaciated regions. (R.M.F.)

KANGAROO. Mammalia, Marsupialia. Pouched mammals of Australia and adjacent islands. The typical kangaroos, *Macropus*, have large hind legs and a strong tail. They sit upright and move by springy leaps, not touching the front feet to the ground. The largest kangaroos reach a height of more than six feet and a weight of two hundred pounds.



Kangaroo.

Moderate and small sized members of the group which resemble the true kangaroos in form are called wallabies. The rock wallabies (*Petrogale*, *Peradoreas*) differ in the slender tufted tail and the hare wallabies (*Lagorchestes*) are small animals with an evenly furred tail.

Tree kangaroos (*Dendrolagus*) have the hind legs only moderately large and the tail long and evenly furred. They are arboreal, as the name suggests.

The Australian rat kangaroos and the Tasmanian jerboa kangaroo resemble the animals for which they are named, although one of the rat kangaroos has a bushy tail.

All of these animals eat vegetation and some cause severe damage to crops. (A.W.L.)

KANGAROO RAT. Mammalia, Rodentia. Burrowing **rodents** of the western United States with long tufted tail and long hind legs. Related to the pocket mice and kangaroo mice. Several genera. (A.W.L.)

KANKA. A local Indian term for stone, which has been applied by some geologists to **concretions** of **calcium** carbonate that occur in otherwise unconsolidated sediments or **alluvium**. (R.M.F.)

KAOLINITE, KAOLIN. Kaolinite is the most common of a group of hydrous **silicates** of **aluminum** which result from the breaking down by weathering of mineral aluminum silicates such as the **feldspars**, **nepheline**, etc. Kaolinite when pure corresponds to the formula $H_4Al_2Si_2O_9$, and occurs in white, clay-like masses. Impurities may cause various colors or tints. Microscopic study shows kaolinite to be **crystalline** and **monoclinic**; it is also found, very rarely in **hexagonal** scales. It has a perfect basal **cleavage**, is flexible but not elastic; hardness, 2–2.5; specific gravity, 2.6–2.63; luster, pearly to dull; color, white when pure, as described above, but may be yellow, red, blue, or brown; translucent to opaque. Kaolinite is a mineral of widespread occurrence, well distributed throughout the world. The finest kaolinite locality in Europe is said to be in France, from whence the clay is obtained for porcelain ware. Cornwall and Devonshire in England supply large quantities of this mineral. In the United States Pennsylvania, Virginia, Colorado, Georgia, and South Carolina contain deposits of kaolinite. The word kaolin or kaolinite is said to be a corruption of a Chinese word *kauling*, the name of a locality where this mineral is found. Kaolinite is very important commercially in the manufacture of china and pottery. (E.S.C.S.)

KAPOK. This is a downy substance obtained from the inside of the seed-pods of several species of trees known as silk-cotton trees. Its principal use is in pillows and mattresses and some types of life preservers. Java produces a large part of the marketed crop. (R.M.W.)

KARAKUL. The short, tightly curled wool of lambs of certain Asiatic breeds of domestic sheep. The lambs are killed very young to secure the most curly wool. The pelts are known as astrakhan or karakul, the latter term applying especially to those of better quality. (A.W.L.)

KARYOLYMPH. Cell.

KARYOPSIS. Grass Family.

KARYOSOME. Cell.

KATABOLISM. Metabolism.

KATACLASTIC. Cataclastic.

KATAMORPHISM. Anamorphism.

KATER'S PENDULUM. Kater devised a number of rigid **pendulums** for comparing the accelerations of gravity at different places on the earth. Any pendulum of fixed length, carried from place to place, will swing in periods inversely proportional to the square root of the value of this acceleration, g, at the respective stations. Therefore if the pendulum has been timed at a station at which the value of g is accurately known, its period at any field station gives at once the value of g at that station.

Kater's best known pendulum is reversible, being provided with two knife edges, facing each other, and carefully adjusted to be at conjugate points with respect

to each other It follows that when such a pendulum is accurately timed, and the distance between the two knife edges accurately measured, the value of g can be calculated by using the formula for the period T of an ideal simple pendulum $T = 2\pi\sqrt{\frac{l}{g}}$, or $g = \frac{4\pi^2 l}{T^2}$ When this is applied to the Kater's pendulum, l is taken as the distance between the knife edges Such a pendulum can thus be used for absolute gravity measurements See **Gravitation and Gravity** (L D W)

KATYDID. Insecta, Orthoptera Large winged **insects** with long hind legs formed for jumping and very long slender antennae They belong to the family of long-horned **grasshoppers** The true katydid is found throughout the United States east of the Rockies and sings normally in three syllables which have been interpreted as ka-ty-did Other insects of a different subfamily are commonly called katydids because of their similar appearance and habits All of these insects are bright green and have leaflike wings A pink form of the katydid occasionally appears. (A W L)

KAURI GUM. Resins.

KEA. Parrot.

KEBER'S ORGAN. Paired glandular organs of **bivalve** mollusks which serve as accessory organs of excretion They are associated with the wall of the **pericardial cavity** or of the **auricles** (A W L)

KELP. Algae.

KELVIN SCALE. Thermometry.

KENNELLY-HEAVISIDE LAYER. Ionosphere.

KEPLER (1571–1630) Johann Kepler was born at Weil in Wurtemburg in December, 1571, the son of an army officer His father lost his personal fortune early in Johann's life and was forced to take up tavern keeping, with the result that the boy spent his childhood as a pot boy His mother was a woman of violent temper and young Johann was glad to escape to the University of Tubingen, where he was graduated second on the list At the University he became an ardent follower of the **Copernican** doctrine and devoted practically his entire life in the attempt to prove this theory to the satisfaction of the world His health was always frail and his eyesight very faulty, but he was a born thinker and speculator

His first field of speculation was an attempt to determine why there were six planets and to find some connection between this number, their periods of revolution, and their distances from the sun His first result was a fanciful "regular solid" theory which was published in a book in 1597, but which we have no time to discuss here This book came to the notice of **Tycho Brahe,** who was then at Prague, and he invited Kepler to come there as his mathematical assistant Kepler accepted the post with some hesitation, for Tycho was a firm believer in the **Ptolemaic** theory while Kepler was an ardent Copernican

At Prague Kepler was offered a handsome, but seldom paid, salary, and in 1601 he settled down there as "Imperial Mathematician" At that time Tycho was engaged in the compilation of his mass of observational material into a set of tables of the planets, but he died before the work could be completed On his deathbed he entrusted his observational material to Kepler, and they could not possibly have fallen into better hands

The completion of Tycho's Tables would have required a large force of calculators, and the imperial funds of Bohemia were depleted by frequent wars The funds were so depleted that Kepler's own salary could not be paid, and he was forced out of astronomy for a time and took up the study of **refraction** of light. He made a long careful study of this problem, but never was able to hit upon the true explanation He did, however, publish a number of rules for lens construction which were much used by opticians He was the first to suggest the use of **conic sections** for lens surfaces other than perfect spheres, for the purpose of reducing the **spherical aberration** After the discovery of the telescope Kepler made several improvements in the design of that important astronomical instrument

In spite of his work on optics, Kepler did not neglect the astronomical observations entrusted to him by Tycho, and he worked for a long time on the problem of determining an accurate set of tables of the motions of the planet **Mars** It is probably fortunate that he chose this planet first, for its **orbit** has the greatest **eccentricity** of any planet known at that time, with the exception of Mercury, for which observational material was very meager Kepler soon found out that the circles of the Copernican hypothesis could never satisfy the accurate observations of Tycho, and eventually abandoned the circle as an orbit in favor of the ellipse In "De Motibus Stellae Martis," published in 1609, we find the first two of the three **Keplerian laws of planetary motion** The third law appears in "De Harmonica Mundi," published in 1619

In spite of domestic troubles of all sorts Kepler persisted in his work on the observations of Tycho, and ultimately completed the so-called Rudolphine Tables This publication marks an era in astronomy, for it was the first really accurate set of astronomical tables which navigators had ever possessed They were the forerunners of the present Nautical **Almanacs**

Following the publication of these tables, largely out of his own very limited funds but with some assistance from Vienna, Kepler's domestic troubles rapidly multiplied and his health failed He died in poverty in spite of the fact that large sums of money were due him on account of unpaid salaries at Prague (W K G)

KEPLERIAN LAWS OF PLANETARY MOTION. After years of incredible labor in attempting to develop a theory of planetary motion which would satisfy the accumulation of planetary positions determined by Tycho Brahe, Johann **Kepler** decided to abandon the superstition that the circle is the only perfect curve and hence must be followed by the planets In the early part of the seventeenth century he announced three fundamental laws of planetary motion which satisfied Tycho's observations These laws may be stated as follows

(1) Each planet moves in an ellipse with the sun at one focus
(2) The radius vector of each planet passes over equal areas in equal intervals of time (The law of areas)
(3) The square of the period of revolution of a planet about the sun is proportional to the cube of the mean distance of the planet from the sun

When first published, the laws were without theoretical foundation, being empirically derived from observational data They created a tremendous stir and were declared heretical since they abandoned the circle as the only possible path for a planet About fifty years later **Newton** was able to show that the laws are a direct consequence of motion under the action of the **law of universal gravitation** It has also been shown that all types of **orbital motion** are characterized by these Keplerian laws

The harmonic law as first stated by Kepler was independent of the masses of the bodies involved, but Newton was able to show that the masses are actually involved and obtained a more rigorous expression for it Assume M_1 to be the mass of one body, M_2 to be the mass of the other, R to be the mean distance between the two bodies, P the sidereal period of revolution of one about the other, and K a numerical constant involv-

ing the constant of universal gravitation and we have: $K(M_1 + M_2) = \frac{R^3}{P^2}$ The masses of the planets are all inappreciable in comparison with the mass of the sun, and accordingly the expression $K(M_1 + M_2)$ is virtually a constant when considering the motions of the planets about the sun In cases such as **binary star** orbits, and motions of **satellites** about primaries, the rigorous expression of the harmonic law is of immense value in the determination of masses of celestial objects

While the development of the theory of relativity has necessitated slight modifications in the original laws of planetary motion, nevertheless, together with the law of universal gravitation, they form the basis upon which the entire structure of celestial mechanics and related fields rest (W K G)

KERATIN. A chemically complex material of which horns, nails, claws, hoofs, and the scales of reptiles, birds, and mammals are formed Hair and feathers also contain much keratin It is present in the external layers of the skin, where it develops by the transformation of clear granules of keratohyalin of lower layers (A W L)

KERATOPHYRE. The name given by Gumbel, in 1874, to **felsitic** and **porphyritic** rocks resembling **hornfels**, and which occur in the Bavarian Alps Later the use of the term was restricted to **porphyries** and **porphyrites** but differing from them by the abundance of **anorthoclase** instead of either **orthoclase** or the soda-lime feldspars The term has also been restricted to rocks of this type which are pre-**Tertiary** in age (R M F)

KERATOSA Demospongiae.

KERNITE. Colemanite.

KEROGEN. Oil shale.

KEROSENE Hydrocarbons.

KERR ELECTRO-OPTICAL EFFECT. Electric and Magnetic Double Refraction

KERR MAGNETO-OPTICAL EFFECT. Magneto-Optical Rotation

KESTREL Aves, Falconiformes A **falcon** of Europe and Asia The common species is also called the windhover and a smaller related species is known as the lesser kestrel (A W L)

KETENES Aldehydes, Ketones, and Related Compounds.

KETO-FORM. Tautomerism.

KETONES Aldehydes, Ketones, and Related Compounds

KETTLE HOLE During the melting stages of the continental glaciers of the **Pleistocene Period** large masses of ice were imbedded in the stratified **drift** The melting of these huge ice blocks resulted in the slumping of the loose material to form well-defined and steep-sided depressions These depressions may be as much as one hundred feet deep and a mile or more in diameter, often containing small lakes, whose surfaces represent the level of the ground water in the surrounding glacial sediments (R M F)

KEUPER. Copper-bearing shales (See **Triassic**)

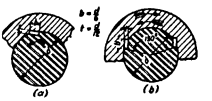
KEY In mechanical design, the key is a small specially shaped piece of metal designed to prevent motion between a hub and shaft on which it is mounted The key is used in a **keyway** Keys are classified thus

Sunk keys, in which the keyway is milled in the shaft.

Flat keys, in which the keyway is a flat portion of the shaft

Friction keys, which hold by pure friction between key and shaft

The key is frequently constructed of steel, and in the simplest form is a plain prismatic piece of steel of rectangular cross-section Keyways of one-half the depth of the key are sunk in the outer surface of the shaft and the inside of the hub Although the stress on a key so held would seem to be provocative of shear on the plane between the two parts, actually the chief source of failure is crushing and deformation of the keyway or key. The simple rectangular key is sometimes difficult to fit exactly, and to remove once it has been fitted Other keys have been invented which are, in some respects, superior types The Woodruff key is semi-circular, and fits in a semi-circular keyway This key automatically adjusts itself to the angle between hub and shaft, and is self-tightening The Lewis key is excellent in action, but costly to manufacture and install It has the disadvantage of requiring two keys for reversible drives Other variations of keys include tapered keys, pin type keys, and wedge type keys (F T M)



Lewis key

Special flat key Saddle key.

KIANG. Mammalia, Perissodactyla A wild **ass**, *Equus hemionus*, of Tibet and Mongolia, also called the kulan (A W L)

KILLDEER Aves, Charadriiformes A North American **plover**, *Oxyechus vociferus*, named for its call Breeds throughout temperate North America and winters as far south as northern South America (A W L)

KILLIFISH Pisces, Teleostei Small fishes (**Pisces**) of fresh and salt water The family Cyprinodontidae is known as the killifish family, and in it the genus *Fundulus* contains the typical killifishes The common killifish is also called the mummichog (A W L)

KILOGRAM. Originally the kilogram was dependent upon the **gram** as the standard unit of **mass** in the **metric system** The kilogram was simply 1000 grams, and the gram, in turn, was defined in terms of the centimeter and the density of water Now, however, the kilogram is the standard, and the gram is defined as one-thousandth part of it The primary standard kilogram is the mass of a cylinder of platinum kept in the archives of the French government at Sèvres It was constructed with the object of duplicating and perpetuating the original gram in a form practicable for use, unfortunately, it was made too large by about 27 parts in a million (See **Liter**) (L D W)

KILOWATT. A unit of **power**—defined as one thousand watts—which ordinarily serves as the commercial measure for electrical power Electrical power of one kilowatt used steadily for one hour involves an energy consumption of one kilowatt-hour A kilowatt is equal to about 1 34 horsepower (F T M)

KIMBERLITE The name applied to a mica **peridotite** which occurs at Kimberley and other places in South Africa, the source of rich deposits of **diamonds**. These valuable **gem stones** were originally found in the decomposed kimberlite which, being colored yellow by limonite, was termed "yellow ground" Deeper workings disclosed the less altered rock, kimberlite, which the miners call "blue ground" (E S C S)

KINEMATICS. The physics of abstract motion, without regard to forces or bodies of matter, which are

treated under **Mechanics.** Two aspects need special consideration the motion of points, and the motion of rigid figures Whatever system of space coordinates is found simplest may be used, and may be transformed from one system to another as desired

The motion of a point is completely specified by giving each of its three rectangular coordinates (for example) as a function of the time, that is, by writing its "equations of motion"

$$\left.\begin{aligned} x &= f_1(t), \\ y &= f_2(t), \\ z &= f_3(t) \end{aligned}\right\} \qquad (1)$$

In many cases the information represented by these equations is supplied only indirectly in the statement of a problem For example, an expression may be given for the component of the linear **velocity** or the linear **acceleration,** as a function of either the time or the distance In such case a differential equation is first obtained Thus if it is specified that the X-component of the acceleration is constant and equal to a, the differential equation is

$$\frac{d^2x}{dt^2} = a, \qquad (2)$$

and the corresponding equation of (uniformly accelerated) motion is its solution,

$$x = \tfrac{1}{2}at^2 + v_0t + x_0, \qquad (3)$$

in which the integration constants x_0, v_0, stands respectively for the initial distance (value of x when $t = 0$) and the initial velocity By eliminating t from the equations of motion (1) three geometric equations may be arrived at, one in x,y, one in x,z, and one in y,z, any two of which determine the path of the moving point in space

Again, if the Y-component of acceleration is proportional to the coordinate y and of opposite sign,

$$\frac{d^2y}{dt^2} = -k^2y, \qquad (4)$$

may be written in which k^2 is a positive constant The solution of this is

$$y = A \sin kt + B \cos kt, \qquad (5)$$

which is a general equation of **simple harmonic motion**

A rigid three-dimensional figure has six **degrees of freedom** These require six equations of motion, which may, for example, express the three components of linear motion of the centroid of the figure with respect to the three rectangular axes, and the three components of angular motion or rotation about the same three axes In such a case it is often convenient to use the notation of vector analysis It may be shown that any motion of a rigid figure is at any given instant equivalent to a linear motion of its centroid in some definite direction, plus a rotation of the figures about some definite axis through the centroid

The laws and equations of kinematics are of constant service in problems of **kinetics.** (L D W)

KINETIC ENERGY. The most obvious way in which a body can manifest **energy** is to be in motion Experience impels us to get out of the way when we see a rapidly moving, massive object approaching We know that the more massive it is, and the faster it moves, the more work (and the more damage) it will do when it strikes A simple course of reasoning based on **Newton's laws of dynamics** leads to the formula $E = \frac{1}{2}mv^2$ for the kinetic energy (in absolute units) of a mass m moving with a speed v Thus a stone of mass 100 grams moving with a speed of 1000 centimeters per second has $\frac{1}{2} \times 100 \text{ g} \times 1000^2 \text{ cm}^2/\text{sec}^2 = 50{,}000{,}000 \text{ g cm}^2/\text{sec}^2$ (or ergs) of kinetic energy When the moving body is brought to rest by a force of average value f, and continues to move a distance, d, after this force is applied, it does an amount of work, fd, equal to its kinetic energy $\frac{1}{2}mv^2$ If d is very small, f will be large

Thus, if the stone in the above example were stopped in a space of 0 01 centimeter (as in striking a hard obstacle), we should have $0\,01 \text{ cm} \times f = 50{,}000{,}000 \text{ g cm}^2/\text{sec}^2$, or $f = 5{,}000{,}000{,}000 \text{ g cm/sec}^2$ (or dynes), which is equivalent to 5100 kilograms or more than 5 6 tons

The kinetic energy of a body rotating with angular speed ω (radians per second) about an axis for which its moment of inertia is I, is $E = \frac{1}{2}I\omega^2$, or $2\pi^2In^2$, where n is the number of rotations per second The theory of **relativity** gives slightly higher values for the kinetic energy, but the differences are negligible except for very great speeds (L D W)

KINETICS. This branch of physics deals with the effects of forces or of torques upon the motions of material bodies There are separate articles on **dynamics of rotation, moment of inertia, centrifugal force, precession, orbital motion,** and **mechanics.** The basis of the subject, so far as the classical theory is concerned, consists in **Newton's laws of dynamics,** which may be extended to include **d'Alembert's principle** of kinetic equilibrium

The motions of a particle or of a rigid body may be either "free" or "constrained", that is, it may be at liberty to move in any manner in obedience to the applied forces or torques, or there may be present material barriers which limit its linear motion to a certain path or surface, or its rotation to a certain axis Thus, a projectile or a planet is free to travel and to rotate as it will, but a railway train has to follow a fixed track and a grindstone revolves, or a **pendulum** swings, about a fixed axis These latter cases may be dealt with by considering that the barriers offer opposing **forces** or **torques** in equilibrium with those components tending to cause motion against them, and by treating as "effective" only those components acting in directions in which motion is permissible A simple problem of this type is that of a block of mass m sliding without friction down an inclined plane inclined at an angle α (See figure 1) Its weight mg (in which g is the acceleration of gravity) is resolved into components f and p, along and perpendicular to the plane, only the former of which is effective This force $f = mg \sin \alpha$, acting on the mass m, gives it the constant acceleration $a = f/m = g \sin \alpha$ Therefore the motion of the block along OB is expressed by

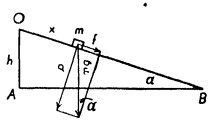


Figure 1

$$x = \tfrac{1}{2}g\,t^2 \sin \alpha + v_0t + x_0,$$

in which $x = Om$, x_0 is the initial value of x, and v_0 is the initial velocity (See **Kinematics**) An interesting problem of constrained motion is to determine what path from O to B the block would slide down in the least time, it turns to be not a straight line, but a **cycloid.** Many kinetic problems are greatly simplified by applying the conservation of **energy** principle Thus for any path, the final speed of the block starting at O and sliding to B is easily shown to be $\sqrt{2gh}$, where h is the vertical height of O above B

Suppose the two blocks of Figure 2 are connected by a flexible cord which runs over a frictionless, weightless pulley Block W_1 has a weight of 100 lbs, and rests on the surface with a coefficient of friction of 2/10 The weight W_2 is 40 pounds How is the system accelerated? Inspection would show that W_2 is lowered, pulling W_1

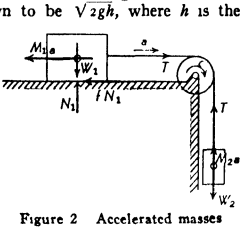


Figure 2 Accelerated masses

to the right However, if a (the acceleration) were assumed opposite to the direction shown the results would have a negative sign, which would mean that a was originally assumed in the wrong direction. By d'Alembert's principle (it follows directly from this principle that a problem in kinetics may be resolved into one of statical equilibrium if the resultant of the effective forces of all particles of a body is reversed and assumed to act as an external force holding the body in equilibrium), take the reversed effective forces M_1a and M_2a acting at the center of gravity of the bodies, and, for simplicity, assume also, that the point of attachment of the cord is co-linear with the center of gravity The forces acting on the sliding block are W_1, fN, t, and M_1a If this is now reduced to a problem of static equilibrium, the sum of the horizontal components equals zero, and the sum of the vertical components equals zero, that is,

$$M_1a + fN - T = 0$$
$$W_1 - N = 0$$

The vertical components of the block, W_2 equated to zero, become

$$M_2a + T - W_2 = 0$$

Substitution of the numbers given in the example yields the following

$$\frac{100}{32\ 2}a + .4N - T = 0,$$
$$100 - N = 0$$
$$\frac{40}{32\ 2}a + T - 40 = 0$$

Simultaneous solution gives the result

$$a = 4\ 6 \text{ feet per second}^2.$$

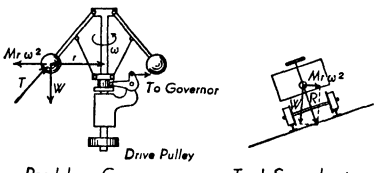
In rotational motion, the moment of the reversed effective forces has a magnitude of $I\alpha$, wherein α is, as before, the angular acceleration, and I the moment of inertia of the body about the axis of rotation In the preceding example, had the pulley not been considered weightless, it would have been necessary to consider a difference between pulls of the cords which, multiplied by the radius of the pulley, is a torque $I\alpha$, in which I is the moment of inertia of the mass of a pulley about its axle

$$(T_2 - T_1)r = I\alpha$$

From the above it is seen that to the mass and shape of the pulley, and its radius should have been introduced, had it been necessary to consider the kinetics of the rotating body

The point through which the resultant of the inertia forces of a rotating body acts is its center of percussion This point is on a line joining the axis of rotation and the center of gravity, and at a distance from the center of rotation of $\frac{R_0^2}{R}$ R_0 is the **radius of gyration** about the axis of rotation, and R is the distance from the axis of rotation to the center of gravity The center of percussion is that point on a compound pendulum at which a normal force might be applied with no effect at the center of rotation, other than the tendency to rotate about this center If a batter bats a ball at the center of percussion of the bat, no force perpendicular to the bat is felt at the hand. The ball should be hit at the center of percussion, or the bat may sting the hands by the shock of the reaction

The kinetics of rotating bodies or of bodies moving in curved paths necessarily involves normal acceleration, whether tangential acceleration is present or not Thus centrifugal force, which is the inertia force resulting from rotational motion, is present in many of the practical applications of kinetics, such as the hoop tension in flywheels, the automatic governor, the super-elevation of tracks and roadways (See Figure 3), etc If a body moves in a circular path, or in a curved path having instantaneous radius of curvature of r, it is subject to normal acceleration of $r\omega^2$, or $\frac{v^2}{r}$ (ω angular velocity, v linear velocity), and there arises a set of inertia forces outwardly directed from the curved path, whose resultant, $Mr\omega^2$ or $\frac{Mv^2}{r}$, acts through the center of gravity of the body This force is the centrifugal force



Pendulum Governor *Track Superelevation*

Figure 3 Centrifugal force

Pendulums are bodies suspended freely from a pivot, which swing in the arc of a circle The force which maintains the pendulum swinging is, for one type of pendulum, the attraction of gravity, and for another, elasticity of material The simple pendulum is a mass suspended at the end of a weightless string The compound pendulum is a rigid body swinging about a pivot located at any point in the body other than at the **center of gravity** Both the simple and compound pendulum vibrate in the arc of a vertical circle The torsional pendulum is a body which is suspended by a wire or rod, and which rotates about the axis of the rod or wire in the arc of a horizontal circle The center of gravity of the body must lie on the axis of the supporting wire or rod The period of a simple pendulum is $2\pi\sqrt{\frac{e}{g}}$ which shows that the time taken for a complete oscillation is independent of the mass, and depends only upon the length of the pendulum, g being the **acceleration** due to gravity The period of a compound pendulum is $2\pi\sqrt{\frac{R_0^2}{gR}}$ Both R_0 and R have the same notation as previously used and are measured from the pivot of the pendulum The period of a torsional pendulum is $2\pi\sqrt{\frac{I_0}{K}}$ in which I_0 is the moment of inertia of the suspended body taken about the axis of the suspension and K is a constant which depends on the material, length and shape of the cross-section of the suspension

Principles of kinetics may also be applied to problems involving balancing of rotating masses, the counter balancing of crankshafts, connecting rods, etc See **Balance.**

Many of the problems of kinetics may be worked either by applying d'Alembert's principle and solving statically, or by the principles of work and energy In some cases there is little difference between these methods, but in others one of these methods may give a much simpler solution than the other When a body is moved against a resistance, work to the amount of the resistance times the displacement is done This resistance may be an external force, such as friction or gravity, or it may be inertia forces obtained during acceleration. If the line of action of the force is not in line with the direction of the displacement, only the component in the direction of displacement does work. Should the force vary in magnitude with the displacement, as is true of the work done in compressing a spring, it will be necessary to find the work as the integral of Fds, where F is the force acting at the instant of the elementary displacement ds When a body is accelerated it gains the energy which is expended in overcoming the inertia forces during the acceleration period. The energy of motion is kinetic energy, contrasted to the energy of position, known as potential energy The formula for kinetic energy is.

$$E = \tfrac{1}{2}MV^2$$

When a body of mass M, moving in rectilinear motion with a velocity V_1, has applied to it a force F for a certain length of time t, it has been subjected to a change of momentum of $M(V_2-V_1)$, and has acquired kinetic energy of magnitude $\frac{1}{2}M(V_2^2-V_1^2)$. The rate at which this work was added is a quantity known as power.

$$\text{Power} = \frac{E}{t} \text{ in which } E = \text{energy and } t = \text{time.}$$

Power is a rate, whereas work and energy are quantities. Power is the rate at which work is done, or energy is consumed. The common unit of power is the horsepower, which is 33,000 ft.-lb. of work done in a minute. The energy contained in a body which is rotating at an angular speed α, and which has a moment of inertia of I_0 about the axis of rotation, is $\frac{1}{2}I_0\omega^2$. In compound motions, the energy of translation and rotation may be summed:— when a cylinder rolls down an incline without slipping, the kinetic energy stored in it at the bottom of the incline is the sum of the energy of rotation about the axis of the cylinder plus the energy of translation of the cylinder moving with the linear velocity of its axis. Most of the problems of kinetics may be approached either from the standpoint of work or energy or from that of reversed effective forces. A great many of the propositions may be analyzed graphically. All of the propositions of statics may be treated graphically if desired. The graphical method is a great boon, in that when there are many forces to be considered, it saves time, and promotes accuracy. So great is the usefulness of graphical methods in statical mechanics that there has grown up around the methods, a specialized subject known as **graphical statics.** See **Impulse, Momentum, Efficiency, Governor, Gyroscope.** (F.T.M.)

KINETIC THEORY. Many phenomena formerly attributed to unknown or hypothetical forces are now known to be due to the invisible motions of small particles, molecules, atoms, or electrons. Notable among these are gas and **vapor pressure, evaporation,** and **diffusion of fluids.**

Gases expand indefinitely when released, not because of repulsion between the molecules as formerly supposed (though the **Joule-Thomson effect** in hydrogen may involve this), but because the molecules are in rapid motion and do not stop unless they collide with something. Air is not "forced" out through a tire puncture; only those air molecules pass out which, in their aimless wanderings, happen to encounter the opening. Molecules also pass in from the outside; but since there are several times as many per unit volume inside as outside, many more pass out than in. This continues until, a statistical **equilibrium** being reached, the air inside is no more dense than that outside, and the tire is "flat." The rapidity with which this takes place emphasizes the speed of the molecular motion and the relative insignificance of the "internal friction" opposing it.

What appears to be a steady pressure is due to the incessant impacts of the gas molecules on any surface exposed to them. If n molecules of equal mass m are released in an enclosure of volume v, and if their speeds are $u_1, u_2, \ldots, u_n$, it is easy to show that the average pressure set up by these impacts, neglecting the effects of collisions and gravity, is

$$p = \frac{m}{3v}(u_1^2 + u_2^2 + \cdots + u_n^2). \quad (1)$$

This may be written

$$p = \tfrac{1}{3}\frac{nm}{v}\frac{\Sigma(u^2)}{n};$$

or since nm/v is the gas density ρ, and $\Sigma(u^2)/n$ is the mean square molecular speed $\overline{u^2}$,

$$p = \tfrac{1}{3}\rho\overline{u^2}. \quad (2)$$

This relation gives the mean square speed as $\overline{u^2} = 3p/\rho$; from which it may be shown that the average speed is

$$\bar{u} = \sqrt{\frac{8p}{\pi\rho}}, \quad (3)$$

easily determined since p and ρ are measurable. (See **Maxwell Distribution Law.**) Again (1) may be written

$$pv = \tfrac{2}{3}(\tfrac{1}{2}mu_1^2 + \tfrac{1}{2}mu_2^2 + \cdots + \tfrac{1}{2}mu_n^2) = \tfrac{2}{3}E; \quad (4)$$

in which E is the total kinetic energy of linear motion of the molecules. From this it follows that the absolute temperature T of the gas bears a constant ratio to this total kinetic energy, and hence to the average translational kinetic energy of the molecules.

Further analysis shows that when gravity is considered, the pressure in an undisturbed pure gas of uniform temperature, at an elevation h, is given by

$$p = p_0 e^{-3gh/\overline{u^2}} \quad (5)$$

in which p_0 is the pressure at the zero of elevation. This is a form of Laplace's "law of atmospheres," useful in barometric altitude determinations.

A quantity much used in kinetic theory is the "mean free path," which is the average distance traversed by a molecule between collisions. There are ways of calculating this and also the effective diameters of molecules, and these data lead to many conclusions as to frequency of collisions, rate of diffusion, etc. (See **Brownian Movement.**) (L.D.W.)

KINETOGENESIS. An evolutionary theory of E. D. Cope which assumes that animal structure is shaped by mechanical stresses due to movement. In relation to length of limb, stresses along the axes of the bones are supposed to have lengthened them, whether these stresses were due to repeated impact against the ground as in the hoofed animals or to stretching as in the arms of the primates. (A.W.L.)

KINGBIRD. Aves, Passeriformes. A large North American **flycatcher.** The most common species is found from the Atlantic to beyond the Rockies and is called the **bee martin** and tyrant flycatcher as well as the kingbird. This species and the several others found in the west and south are noisy and quarrelsome birds. (A.W.L.)

Kingbird. *Tyrannus tyrannus.* Dark slaty-gray above, with a concealed orange spot on the top of head. White below. Tail black, with a white band across the tip.

KING CRAB. Xiphosura.

KINGFISHER. Aves, Coraciiformes. Birds (**Aves**) of many species, mostly with strong sharp beaks used for catching fish. Some species eat insects and reptiles more than fish and have broader beaks, hooked at the tip. One of the species, *Dacelo gigas,* with a broad beak lives in Australia and the Papuan Islands and has been named from its peculiar call the laughing jackass. Kingfishers are found on every continent. (A.W.L.)

KINGLET. Aves, Passeriformes. Very small birds (**Aves**) related to the gnatcatchers. The two North American species are the golden crowned (*Regulus satrapa*) and the ruby crowned (*Corthylio calendula*). Both are grayish and olive with a bright crown patch. In the golden crowned kinglet this patch is orange in the male and yellow in the female, and is concealed. In the ruby crowned it is bright red and is exposed. It occurs only in the male. The goldcrest and firecrest of Europe are related species. (A.W.L.)

KINGSBURY THRUST BEARING. This is a special type of **babbitted** bearing for supporting large rotating masses, such, for example, as the principal bearing of a vertical shaft hydro-electric turbine Very small frictional losses with large bearing pressures and high velocities are made possible by dividing the bearing surface into a number of pivoted segments which tilt in such a way as to scrape a wedge of oil between them and the rotating collar against which the bearing is mounted (F T M)

KINKAJOU Mammalia, Carnivora An animal, *Cercoleptes caudivolvulus*, related to the raccoons, which resembles the common cat slightly in appearance and has a long prehensile tail It is yellowish brown in color The species ranges from central Mexico to Brazil Also called jupura (A W L)

KINORHYNCHA. Minute worms, not exceeding a millimeter in length, which live in sand and mud on the ocean floor The body is made up of rings but the internal organs are unsegmented They progress by thrusting out and retracting the head and sometimes adjacent segments

The relationships of these animals are uncertain They are sometimes included in the phylum **Rotifera** as a separate class. One order, Echinodera, is recognized (A W L)

KIPPER A European name for the breeding male of the Atlantic **salmon** A cured (Yarmouth) herring (A W I)

KIRCHHOFF'S LAW OF RADIATION. Thermal Radiation.

KIRCHHOFF'S LAWS OF NETWORKS Two laws relating to electric networks carrying steady currents The general case is that of n points or junctions, each one of which is connected with each of the $n-1$ remaining points by a conductor containing a source of electromotive force Kirchhoff's two statements are as follows

1 If conductors forming part of a network carrying a steady current meet at one point, the sum of the currents flowing toward the point is equal to the sum of those flowing away from it, or the algebraic sum of all the currents in these conductors is zero

2 Starting at any one of the junctions of such a network and following a succession of the conductors which form a closed path, around either way to the starting point, the algebraic sum of the products formed by multiplying the resistance of each conductor by the current through it is equal to the algebraic sum of the electromotive forces encountered on the journey (In this reckoning, we call all currents moving with us positive, and all electromotive forces tending to cause such currents positive)

Maxwell has set forth a general method of calculating the currents and the relative potentials of the junctions when the resistances and electromotive forces in the several branches of a network are given For a network of n points, this method involves the solution of $n-1$ simultaneous, first-degree equations The work is often simplified, however, by the circumstance that some of the conductors or some of the electromotive forces are absent (L D W)

KIROUMBO. Aves, Coraciiformes. A peculiar bird (**Aves**) of Madagascar and several similar species of other Pacific islands Related to the rollers (A W L)

KISSING BUG Insecta, Hemiptera A name applied late in the nineteenth century to a supposedly deadly **bug** which was said to bite human beings about the face It probably applies to some of the large predacious bugs of the family Reduviidae, commonly called **assassin bugs.** One species known as the big bedbug enters houses and sucks human blood, inflicting a painful but by no means dangerous wound (A W L)

KITE. Aves, Falconiformes Large birds (**Aves**) of prey related to the eagles They are found on all continents Three species, the swallow-tailed kite, *Elanoides forficatus*, white-tailed kite, *Elanus leucurus*, and Mississippi kite, *Ictinia mississiensis*, occur in North America (A W L)

KITTIWAKE. Aves, Charadriiformes *Rissa* Marine birds (**Aves**) of the far north, resembling gulls One species lives in the north Pacific and a second in all polar seas of the north (A W L)

KIWI. Aves, Apterygiformes *Apteryx* Stoutly built flightless birds (**Aves**) of New Zealand The several species are all about as large as domestic fowls They have strong legs, a long curved beak, slender hairlike feathers, and rudimentary wings which are concealed by the plumage of the body (A W L)

KLIPSPRINGER. Mammalia, Artiodactyla A very small African **antelope,** *Oreotragus oreotragus* It is an active and agile animal which inhabits rocky and mountainous country The males have very short horns (A W L)

KNOT. Aves, Charadriiformes A small European wading bird, *Calidris canutus*, one of the **sandpipers**

The knot is a term used to indicate a speed of one **nautical mile** (6080 feet) per hour The determination of this quantity is one of the vexing problems of navigation and various methods have been devised for measuring it

The oldest, and perhaps the most accurate, method for determining the speed of a ship employs the log chip and line The log chip is a wooden quadrant loaded with lead along its circular edge to make it float upright in the water This is attached to the log line by a three-legged bridle When the chip is thrown over the stern of the ship it immediately exerts a drag on the line and this is allowed to run freely over the taffrail The rate at which the line runs out is equal to the speed of the ship relative to the water For measuring the rate at which the line runs out, a sand glass was originally used For speeds of four knots or under a sand glass of twenty-eight seconds was used, for higher speeds a fourteen seconds glass was used The line is divided into lengths of forty-seven feet and three inches and marked by short pieces of fish line threaded through the line and having one, two, three, etc, knots tied into them The distance between successive marks is arrived at by the proportion the distance between successive marks is to the nautical mile in feet as twenty-eight seconds is to the number of seconds in one hour

To use the log chip and line two operators are needed, one to tend the line and the other to watch the glass The first observer tosses over the chip and allows the stray line to run out until a marker passes through his fingers indicating the beginning of the measured line As this marker passes his fingers he signals the operator with the glass who immediately turns it and, when the last grain passes, he in turn signals the line tender who checks the line and reads off directly the "knots" that have passed through his fingers This indicates the speed of the ship in nautical miles per hour This method for determining the speed of the ship gives only the instantaneous speed, and is subject to errors due to stretching or contracting of the line and errors in the timing

Many different types of "patent logs" have been devised which give not only the instantaneous speed of the ship, but also distance traveled The most common type of "patent log" consists of a spinner which is towed well astern of the ship, out of the influence of the wake, and the rotation of the spinner is carried to a recording instrument on the ship by a braided line The rate of rotation of the spinner is proportional to the rate of

travel of the ship through the water and the recording instrument indicates both the speed at any instant and also the total distance traveled from the time that the log was started. Patent logs are subject to many errors and are frequently fouled by cleaning rags and other debris thrown overboard from the ship. Other types of patent logs have been devised which employ the principle of the **venturi tube,** but none of these have proved very satisfactory in actual practice.

The revolution of the screw of ship may be used as an indication both of the speed of the ship and the distance traveled. Many corrections must be applied to the readings of the "revolution counter" in order to obtain the desired results. These corrections depend upon the trim of the ship, the state of the sea, and the speed of the ship.

In actual practice ships use several different types of patent logs, checking them at frequent intervals by means of the log chip and line or by running over measured distances, and also by the revolution counter of the screw. The average value of the different methods, after proper corrections have been applied, is used in determining the distance traveled in working up the **dead reckoning.** (A.W.L., W K G.)

KOALA. Mammalia, Marsupialia. *Phascolarctos* A curious pouched **marsupial** mammal of eastern Australia. It is much like the toy teddybear in appearance and is sometimes called the native bear. An arboreal animal. (A.W.L.)

KOEL. Aves, Cuculiformes. **Cuckoos** of the Oriental and Australian regions. (A.W.L.)

KOHL-RABI. Brassica.

KOLM. The term applied to highly bituminous "coal-like" lenses which occur in the lower **Paleozoic,** alum-shales of Sweden The ash of this "coal" contains a relatively high content of the **radioactive minerals** which have been used to determine the age of the formations in which they occur. (R M F)

KONZI. Mammalia, Artiodactyla. An African **antelope** belonging to the hartebeest group. (A.W L)

KORIGUM. Mammalia, Artiodactyla An **antelope** of central Africa, also called the Senegal antelope. One of the hartebeest group (A W L)

KORIN. Mammalia, Artiodactyla A central African **antelope,** one of the gazelles. (A.W.L.)

KORSAKOFF'S PSYCHOSIS. Ethyl Alcohol.

KRA. Mammalia, Primates. The crab-eating **macaque,** *Macacus cynomolgus,* a monkey of the Oriental region. (A.W.L.)

KRAIT. Crait.

KRENNERITE. Sylvanite.

KRYPTON. Symbol: Kr Atomic number: 36. Atomic weight: 83 7 Density: 3.708 grams per liter, 0° C, 760 mm, or 2 87 when air is 1 00. Melting point: — 157° C. Boiling point: — 152 9° C.

Krypton is a colorless, odorless gas, of negative chemical properties with ordinary materials Discovered by Ramsay and Travers in 1898, in ordinary **air** to the extent of 1 part krypton in about 1,000,000 air. (R K S)

KUDU. Mammalia, Artiodactyla African **antelopes** of two species, the common (*Strepsiceros strepsiceros*) and the lesser kudu (*S imberbis*) The males have long spiral horns. (A W L)

KUMQUAT. Citrus Fruits.

KUNDT CONSTANT. Faraday Effect.

KUNZITE. Spodumene.

KYANITE. The mineral kyanite is an **aluminum silicate,** corresponding to the formula Al_2SiO_5 It is **triclinic,** and has a good **cleavage** parallel to the **macropinacoid.** Its hardness varies considerably depending on the crystallographic direction from 5 to 7 25, specific gravity, 3 56–3 67, luster, vitreous to pearly, color, commonly blue to white, but sometimes gray to green or nearly black; transparent to translucent. Usually found in long bladed crystals or columnar to fibrous structures. Kyanite is found in such **metamorphic** rocks as **gneisses** or mica **schists.** Of the many European localities for fine specimens might be mentioned the Ural Mts, Russia; Czechoslovakia, Austria, Trentino, Italy, the St Gotthard region, Switzerland, and France In the United States: Chesterfield, Massachusetts, Litchfield, Connecticut, and Gaston County, North Carolina, have furnished fine specimens Kyanite derives its name from the Greek work meaning *blue,* in reference to the delicate blue of the inner portions of the bladed crystals (E S C.S.)

L

L SERIES. X-Ray Spectra.

LABARIA. Reptilia, Sauria A poisonous South American **snake** belonging to the pit vipers. It ranges from eastern Brazil north into the Guianas Related to the jararaca. (A.W.L.)

LABIUM. 1. A lip or lip-shaped structure. 2. The posterior element of the insect's mouth parts, derived from a pair of jointed appendages.

The labium consists typically of three segments with a pair of appendages called labial palpi. The basal segment is the submentum, the next segment the mentum, and the terminal segment the ligula The ligula is sometimes complex, consisting of a median glossa, sometimes very long, and two basal lobes known as paraglossae of very variable size. The labial palpi arise from the base of the ligula and consist of four segments or less. In some species the palpus is attached to a distinct part called the palpiger. (A.W.L.)

LABOR (CHILDBIRTH). The process of separation of the mature or nearly mature **fetus** and **placenta** from the interior of the **uterus** and its expulsion from the mother

The first stage of labor begins near the end of the tenth lunar month. The onset of labor is marked by the onset of increasingly severe cramp-like pains in the lower abdomen. Their frequency slowly increases. The pains are due to muscular contractions of the uterus which brings about dilation of the **cervical** opening of the uterus in the **vagina.** At this time there may be a little blood with the vaginal discharge—"the show." After the pains have continued for a variable time—usually twelve to fifteen hours—there is a gush of considerable fluid from the vagina due to rupture of the membranes, "bag of waters," with escape of the amniotic fluid.

A short time after the rupture of the membranes the second stage of labor begins. The labor pains increase in severity, frequency, and duration. During this stage the child passes from the uterus, through the dilated cervix and vagina to the outside world The **umbilical cord** is severed at this time. The second stage of labor usually is about two hours for the first pregnancy. For succeeding pregnancies the time is shorter.

After birth of the child the third stage of labor begins. At first the labor pains cease, the uterus contracts and becomes much smaller After a few minutes contractions begin again and the placenta (after-birth) is expelled. This last procedure may be completed by the obstetrician. Considerable blood may be lost during this stage.

Normal labor varies in duration for the three stages, depending on the size of the child, size of the mother's pelvis, and the character of muscular contractions. The three stages usually take about eighteen hours—sixteen for the first, two hours for the second, and fifteen to thirty minutes for the third stage. The birth of the first child usually takes six hours longer for the three stages. Labor is definitely prolonged in women over thirty and is shortest and easiest about eighteen years of age. Mechanical interference (forceps) is more often needed in the older mother. (R.S.M.)

LABRADORITE. Feldspar.

LABRUM. The anterior or upper element of the insect's mouth parts. It is not derived from jointed appendages like the other mouth parts and is usually a simple flap, movably attached to the front of the head. (A.W.L.)

LABYRINTH. In mechanical terminology, the labyrinth is a form of gland designed to prevent excessive leakage of a fluid endwise along a shaft, by causing the path which must be taken to be tortuous and involved, similar to a labyrinth. The chief advantage of a labyrinth is the elimination of mechanical contact which is present with packing of any type. There is no actual mechanical contact between the members of the labyrinth. The labyrinth gland is commonly used to seal the opening through which the shaft of a turbine passes through the casing at the high pressure end The small amount of steam which finds its way through the labyrinth may be collected and used for heating purposes. The difference between the pressure inside the casing and outside is composed of the friction on the sides of the labyrinth and the pressure consumed in making the many turns of the labyrinth. (F.T.M.)

LABYRINTHODONTS. Fossil Amphibia.

LACCOLITH. An intrusive, **igneous rock** mass which has been injected along the bedding plains of **sedimentary** formations in such a way as to dome the overlying strata. Typical laccoliths have been fed by **dikes** and are mushroom-shaped with symmetrical domes and flat floors. Because of the mechanics involved in their origin, laccoliths are formed in the upper portion of the **lithosphere** where the static pressure of the overlying formations is not too great to prohibit their local uplift by the intruded **magma.** (R.M.F.)

LACERTILIA. Reptilia.

LACEWING. Golden-eye.

LACINIA. Maxilla. Also a movable appendage of the **mandible** of some isopod **crustaceans,** the **lacinia** mobilis. (A.W.L.)

LACQUER. Resins; Nitrocellulose; and **Paints.**

LACTAMS. Aminoacids, Polypeptides, and Proteins.

LACTIC ACID AND LACTATES. Lactic acid alpha-hydroxypropionic acid ($H\ C_3H_5O_3$ or $CH_3 \cdot CHOH\ COOH$) is a colorless liquid, melting point 18° C, boiling point 122° C at 15 mm. pressure, miscible with water, alcohol or ether in all proportions. **Calcium** lactate, on account of its solubility characteristics, is of importance in the separation and recovery of lactic acid. Calcium lactate plus dilute **sulfuric** acid yields lactic acid plus calcium sulfate, and the latter may be separated by **filtration.** Lactic acid may be obtained by **evaporation** of the filtrate in **vacuum.** Lactic acid, when heated at atmospheric pressure, changes to lactide; when oxidized cautiously, changes to pyruvic acid; when heated with dilute sulfuric acid yields **acetaldehyde** plus **formic acid.** Lactic acid may be obtained (1) by the fermentation of **lactose,** "milk sugar" (thus accounting for the presence of lactic acid in sour milk), **sucrose,** molasses, **glucose,** starch (corn starch, potato starch) in the presence of **calcium** carbonate forming calcium lactate, from which lactic acid is obtainable, (2) by reaction of glucose and **sodium** hydroxide solution under proper conditions, (3) by reaction of sodium hydroxide solution and alpha-chloropropionic acid, (4) by reaction of

acetaldehydecyanhydrin and water. The physiological formation of lactic acid in the animal organism is responsible for the fatigue of muscles

The following are esters of lactic acid

Methyl lactate ($CH_3CHOHCOOCH_3$), boiling point 145° C.

Ethyl lactate ($CH_3CHOHCOOC_2H_5$), boiling point 154° C

Lactic acid is used in the textile and farming industries, and in certain food industries, e g , pickles, essences. See **Isomerism and Stereoisomerism.** (R K S)

LACTIDES. Acids, Carboxylic and Related Compounds.

LACTIMS. Aminoacids, Polypeptides, and Proteins.

LACTONES. Acids, Carboxylic, and Related Compounds.

LACTOSE. Carbohydrates.

LACUNAR TISSUE. A tissue peculiar to **echinoderms.** It occurs in strands containing associated spaces which serve as circulatory channels Unlike true blood vessels these spaces have no epithelial lining (A W L)

LADY BUG. Insecta, Coleoptera Small oval **beetles,** strongly convex and with relatively small legs The common name applies chiefly to the more common red species, marked with black and white, but the family Coccinellidae to which they belong contains many others (A W L)

LADY'S-SLIPPER. Orchid Family.

LAGOON. Barrier Beach.

LAKE HERRING. Pisces, Teleostei Fresh water **herrings** of several species, all important food fishes. Also called **ciscoes.** These fishes occur in the Great Lakes and many smaller bodies of water They include the most important commercial species of the Great Lakes fisheries (A W L)

LAKES. Dyes.

LAMARCKIAN THEORY. A theory of organic **evolution** first expressed in 1809 by the French scientist, Jean Baptiste Lamarck Lamarck formulated two principles, first that use strengthens and develops an organ and that disuse weakens it and causes it to become atrophied, and second that the results of use and disuse are inherited and so influence the development of a species through a succession of generations The first of these principles is abundantly proved, while the second is not true

In discussions of evolutionary theory since Darwin's work was published the term acquired characters has become synonymous with the organic changes which Lamarck emphasized and the inheritance of acquired characters, or Lamarckian evolution, has been generally discredited Closer perusal of Lamarck's work, however, indicates that he emphasized the reaction of the organism to environmental conditions as a source of change The results of this reaction are not inherited as such, but whether the reaction in one generation adds to the capacity of the next generation for similar reaction is neither proved nor disproved, hence the Lamarckian theory still has a valid place in organic evolution (A W L)

LAMBERT. Brightness.

LAMELLA. In botany the lamella, or the middle lamella, is the compound layer composed of the primary walls and the cement-like intercellular substance which occurs between the primary walls of two **cells.**

In zoology the term lamella is used with two common meanings It may be, (1) A thin leaf or plate, such as a lamella of bone, (2) A flat plate formed by the fusion of **ctenidial filaments** in the **bivalve** mollusks Two lamellae united by bridges of tissue form a **gill** through which water circulates under the influence of **ciliary** action in the persisting open spaces This form of gill is the source of the name **Lamellibranchiata** applied to the class containing these animals (R M W, A W L)

LAMELLAR VECTOR. Irrotational Vector.

LAMELLIBRANCHIATA. The bivalve mollusks, a class of the phylum **Mollusca** including the **clams, mussels, oysters, scallops** and related species Many of these animals are valuable for food, and pearls and mother of pearl are produced by them The class is also named Pelecypoda

Bivalve mollusks differ from other members of the phylum in the following characters 1 The body is transversely compressed 2 The **mantle** forms two lobes extending down along the sides of the body In most species these lobes unite at the posterior end to form two passages, an upper excurrent and a lower incurrent siphon Currents of water carry food and oxygen into the mantle cavity through the lower opening and a current bearing wastes passes out of the upper 3 Each mantle fold secretes a valve of the shell formed of calcareous matter covered outside by a horny periostracum and inside by nacre, commonly called mother of pearl The two valves of the shell are joined by a hinge ligament and the articulation is strengthened in some species by interlocking teeth 4 The gills are thin plates on each side of the body in most species They are formed of united ctenidial filaments 5 The foot is a muscular wedge-shaped protuberance at the anterior end of the body

All bivalves are aquatic Most species creep slowly by thrusting the foot into the muddy or sandy bottom but some propel themselves by jets of water squirted from the siphons or forced from the mantle cavity by rapidly closing the valves The species vary from fresh water forms about one-eighth inch long to giant marine shells more than a yard long

The class is divided into four orders

Order Protobranchiata Gills in the form of small leaflets, two rows on each side of the body Marine species

Order Filibranchiata Marine **mussels, scallops,** etc Gills composed of filaments united only by ciliary junctions

Order Eulamellibranchiata Gill filaments united to form continuous plates Fresh-water **clams** or mussels, marine clams, **oysters, shipworms,** etc

Order Septibranchiata Gills replaced by a horizontal partition between the upper and lower divisions of the mantle cnamber A few marine species

See also **clam, mussel, mother of pearl, pearl,** and **oyster.** (A W L)

LAMINARIA Algae.

LAMMERGEIER Vulture.

LAMPREY. Cyclostomata.

LAMPROPHYRE. An old group term originally proposed by Gumbel and later redefined by Rosenbusch to include **basic** dike rocks of **porphyritic** texture whose phenocrysts are **femic** minerals such as **augite, hornblende** and **biotite.** The term is derived from the Greek meaning *glistening,* and referring particularly to the abundant biotite which occurs in the particular variety of Lamprophyre called **Minette.** (R M F)

LAMP SHELL. Tongue shell; and **Invertebrate Paleontology.**

LANCELET. Cephalochordata.

LANCEOLATE Shaped like a lance, that is, narrow and tapering to a point, as in lanceolate leaves (R M W)

LANDSCAPE MARBLE. A British popular and trade term for **argillaceous limestones** of Liassic (lower **Jurassic**) age quarried near Bristol, England, and characterized by a tree-like pattern (R M F)

LAND SUBDIVISION. The standard system of subdivision of lands for legal and other purposes is that employed in the United States land subdivision system, which involves the location of subdivisions with regard to a set of principal axes In this system the units of subdivision are the township and the section The origin is the intersection of a true parallel of **latitude** called the base line, and the true **meridian** called the principal meridian Some thirty-five of these origins have been established and wholly, or in part, govern surveys in most of the states of the Union, outside the original thirteen colonies Secondary axes are established at intervals of twenty-four miles north and south of the base line, and east and west of the principal meridian These divide the area into quadrangles bounded by meridians and parallels The meridians are each twenty-four miles long, but while the southern boundary of each quadrangle is twenty-four miles in length, the northern boundary, in the northern hemisphere, is less than twenty-four miles, due to the convergence of meridians These twenty-four mile boundaries are termed standard parallels and guide meridians The parallels are, of course, continuous, but the meridians, with the exception of the principal meridian, are broken at the parallels On the other hand, the parallels are curves, and the meridian lines are straight

Each of these quadrangles is divided into sixteen parts by north and south range lines at six mile intervals, and by east and west township lines at six mile intervals The area enclosed by range lines and township lines is slightly less than thirty-six square miles It would be thirty-six square miles except for the convergence of the range lines which are meridional in nature Beginning with the eastern side of the township, the sections are laid off by section lines north and south and east and west, at one mile intervals Thus there are thirty-six sections in a township, each of which is one mile square except on the westerly edge, where, due to the convergence of the meridional section lines, the sections will have a latitudinal dimension of less than one mile with the deficiency being greater in the northern sections than in the southern

The base line and principal meridian are used for legal descriptions of all sections whose survey relates to their origin Any given township may be located by giving it a range number east or west from the principal meridian, and a township number north or south from the base line, for example, range 6 East, township 7 South The section lines divide each township into thirty-six sections, which are numbered consecutively from east to west in the first tier, west to east in the second, and so on, beginning with number one in the northeast corner, and ending with number thirty-six in the southeast corner (F T M)

LANGUR. Mammalia, Primates *Semnopithecus* A group of Old World **monkeys** characterized by slender build and by extremely long tails The legs are longer than the arms They eat principally the leaves and young shoots of trees Langurs live only in Asia and some of the East Indian islands

Among the species of langurs that bear distinctive names are the hanuman, lutong, douc, negro monkey, leaf monkeys, bear monkey, white monkey, and purple-faced monkey (A W I)

LANTERN FLY. Insecta, Homoptera Any member of the family Fulgoridae, which differs from the related leaf hoppers and other families in having the antennae inserted at the sides of the head The North American species are small but one giant Brazilian species has a wing spread of six inches A large prominence on the head of this species was once said to be luminous, hence the name lantern fly has persisted although none of these insects is actually luminous (A W L)

LANTHANUM. Symbol La Atomic number 57. Atomic weight 138 92 Density 6 15 Melting point 826° C Type of compound La_2O_3 Color of salts Colorless Discovered by Mosander in 1837 A member of the **cerium** sub-group of the rare earth metals. (R K S)

LAPILLI. During volcanic eruptions there may be thrown into the air quantities of melted rock which cools into solid fragments before it falls back on the earth This material is classified roughly according to size Fragments two or three inches or more in diameter are called **bombs,** those of smaller size down to the dimensions of bird shot are called lapilli, still finer particles are called volcanic ash or dust Derived from the Latin *lapillus,* a little stone (E S C S)

LAPIS LAZULI. Lazurite.

LAPLACE, PIERRE SIMON, MARQUIS DE (1749–1827) Pierre Simon Laplace was born in Normandy on March 28, 1749 His father was a small farmer and unable to provide his son with an education but fortunately some rich neighbors took an interest in the boy He attended a military school at Beaumont and showed such aptitude as a mathematician that, upon graduation, he was made an instructor in mathematics In 1767, after having done considerable research in the field of mathematical analysis, he went to Paris and obtained recognition from the great **D'Alembert.**

D'Alembert obtained a professorship in mathematics for Laplace at the Ecole Militaire in Paris Here he immediately set to work to apply his mastery of analysis to problems in celestial mechanics and, in 1773, he presented a paper to the Academy of Sciences in which he made the first step toward the establishment of the mathematical stability of the **solar system** This first paper was followed by a long series in which **Lagrange** and Laplace collaborated and which were alternately published over their individual signatures Many other memoirs were published dealing with various difficult problems in **celestial mechanics,** such as the theory of the motions of the **satellites** of **Jupiter,** and the dependence of the acceleration of the moon upon certain **perturbations** in the orbit of the earth

By the end of the eighteenth century the time had arrived when the work of three generations of mathematicians on gravitational theory could be systematized and Laplace undertook the task His Mecanique Celeste, a 5 volume work published between 1799 and 1825, is a monumental treatise on gravitational theory, and is still regarded as a classic in celestial mechanics. While the longer work was in progress Laplace published a more popular work, Exposition du Systeme du Monde, in an appendix to which the famous Laplacian nebular hypothesis made its appearance

In addition to his work on celestial mechanics and gravitational theory, Laplace published many mathematical studies on other types of physical problems such as the equilibrium of rotating fluid masses, and the attraction of a non-spherical body for an external object In his work on the latter problem he introduces the potential function and the so-called Laplacian coefficients which play an important part in the general subject of **spherical harmonics.** He also published a masterly

treatment of the general theory of **probability** and issued a number of semi-popular memoirs on the same subject

During his latter years, Laplace retired from the Ecole Militaire and spent his life in retirement at Arcueil where he was visited by mathematicians from all over the world, and died on March 5, 1827 His long list of honors from various scientific societies the world over would fill many pages (W K G)

LAPLACE'S EQUATION. **Laplace's** equation is a partial differential equation of the second order which is of wide application in mathematical physics In **rectangular coordinates** it takes the form.

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} = 0$$

As an example of its application for any point (x, y, z) of space where there is no free electricity (i e, no such "space charge" as exists in an electron tube in operation), or for any point in a conductor carrying a steady current, the electric potential satisfies Laplace's equation if u is used to represent it The same is true of the temperature at any point of a thermal conductor in which heat is flowing steadily The integrals of this equation, with properly chosen constants, furnish the solution of many problems in electricity, gravitational and magnetic **potential,** heat, and hydrodynamics

If we replace the right hand side of Laplace's equation by $-4\pi\rho$ we obtain Poisson's equation The left hand side of Laplace's equation is often denoted in **vector** notation by $\nabla^2 u$ The operator $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} = \nabla^2$ is called the Laplacian

A harmonic **function** is a single valued continuous function which satisfies Laplace's equation (L D W, L L S)

LAPWING. Aves, Charadriiformes *Vanellus* Birds (**Aves**) of several species resembling the plovers in appearance and habits They occur in Europe, Asia, Africa and the Americas. (A W L)

LARAMIDE REVOLUTION. **Cretaceous.**

LARK. Aves, Passeriformes Song birds (**Aves**) of many species, confined to the northern hemisphere The skylarks of Europe and Asia are the most famous members of the group because of the quality of their song The common European species, *Alauda arrensis,* is established in Oregon and North America also has a native species, the horned lark, *Otocoris alpestris* The **meadowlark** is more closely related to the blackbirds and orioles. (A W L)

LARVA. An immature form of animals that undergo **metamorphosis** between emergence from the egg and the attainment of adult life The larva is often very different from the adult

The larvae of many invertebrates of **sessile** habit, such as the **sponges** and some **coelenterates,** are ciliated (**cilia**) organisms which swim about for a time before attaching themselves to the permanent support where they are to develop In the two **phyla** mentioned the larva is little more than a ciliated **gastrula.** It is filled with solid endoderm in the coelenterates and is called a planula

The **flukes** also begin life as a ciliated larva known as a miracidium This form gives rise to more complex larvae called rediae and these in turn produce tailed larvae called cercariae The cercaria is transformed into the adult In the same phylum the tapeworms hatch as six-spined hexacanth larvae and pass through a bladderworm **stage** before becoming adults.

Roundworms of many species pass through one or more larval stages in which they are wormlike but differ in habits and in some structural details from the adults

Some of the segmented worms, **mollusks, echinoderms,** and **chordates,** hatch as complex larvae with localized zones of cilia for locomotion The trochophore or trochosphere larva of **annelids** and mollusks has a ciliated alimentary tract with mouth and anus 90 degrees apart and a belt of cilia around the middle of the body Larvae of echinoderms also have a bent alimentary tract but the cilia are arranged in one or more bands, sometimes of intricate form These larvae bear various names bipinnaria, auricularia, pluteus, of the starfishes, sea cucumbers and sea urchins and brittle stars, respectively, or collectively the dipleurula The bipinnaria resembles the tornaria larva of **Balanoglossus**

Among the **arthropods** the high development of metamorphosis is accompanied by great diversity of larval forms In the class **Crustacea** these forms seem to represent previous evolutionary stages and are named after groups of the class whose adults they resemble Among them are the Nauplius, Cypris, and Cyclops larvae and many others A single individual may pass through several of these stages in the course of its development Insects present an entirely different type of metamorphosis in which the larval characteristics appear to have been acquired later in the course of evolution than those of the adult, as an adaptation to special conditions (**Cenogenesis**) In species with complete metamorphosis only the first immature stage is called the larva In this stage butterflies and moths are called caterpillars, some of the beetles grubs, and many flies maggots Species with less complex metamorphosis are called nymphs or naiads during development (in gradual and incomplete metamorphosis respectively)

See also **Actinula, Ephyra, Glochidium, Hydratuba, Hypopus, Pilidium, Scyphistoma,** and **Veliger.** (A W L)

LARVACEA. The appendicularians A class of minute marine animals belonging to the subphylum **Tunicata** These forms have a trunk and tail and resemble the larvae of the tunicates (A W L)

LASSO CELL. **Colloblast.**

LATERAL. A force which acts on a structure or a structural member in a transverse direction is sometimes called a lateral load The wind blowing upon the exposed surface of a **bridge** or building at right angles to its length or upon the stationary or moving traffic using the bridge constitutes one type of lateral load The sway of a moving train on a bridge or the centrifugal force transmitted if the bridge is on a curve are types of lateral loading A moving crane supported on girders exerts a side thrust on the girders which may also be included in this classification

Trusses and **girders,** which constitute the main load-carrying members of bridges, are not ordinarily designed to carry side loads of this nature, and consequently have very little strength in that direction For this reason, the trusses or girders of a bridge are joined together in a horizontal plane by a system of lateral bracing composed of **struts** and diagonals The diagonal members are known as laterals This lateral bracing stiffens the whole bridge and opposes any sidewise **deflection** or vibration (C W C)

LATERAL LINE ORGANS. Sensory organs located on the head and in a line along the side of the body in the fishes (**Pisces**) They are unlike the sensory organs of terrestrial vertebrates but are supposed to perceive vibrations of low frequency (A W L)

LATERAL MORAINE. The **talus** or other material from the sides of a glacial valley accumulate upon

the glacier and are carried away by it. Thus the mass of debris distributed along the lateral edges of the glacier is called a lateral **moraine** In the case of valley glaciers which have disappeared, their former existence may often be proved by the traces of lateral moraines left along the sides of the valley. (R M F)

LATERITE. The sub-aerial decay of rocks in tropical regions, having a distinctly moist or rainy climate, results in the development of a residual, reddish, and usually sticky soil frequently containing **concretions** The principal products of lateritization are the hydrated oxides of **aluminum** and **iron** either in the crystalline or amorphous form If the concentration of iron oxide is sufficiently high the laterite may be valuable as an iron ore If, on the other hand, the concentration of alumina is high the laterite may be valuable as an ore of that metal (R M F)

LATEX. Latex is a milky substance found in many plants It is a complex emulsion in which such substances as **proteins, alkaloids, starches, sugars, oils, tannins, resins,** and **gums** are found In most plants the latex is white, but in some it is yellow, in others, orange or scarlet

The cells or vessels in which latex is found make up the laticiferous system There are two very different ways in which this system may be formed In many plants the laticiferous system is formed from cells laid down in the **meristematic** region of the stem or root Rows of these cells are formed The cell walls separating them are dissolved, so that continuous tubes, called latex vessels, are formed This method of formation is found in the **poppy family**, in the rubber plant, *Hevea brasiliensis*, and in the Cichorieae, a section of the **composite family** distinguished by the presence of latex in its members Dandelion, lettuce, hawkweed, and salsify are members of the Cichorieae

In the **milkweed** and **spurge** families, on the other hand, the laticiferous system is formed in a very different way Early in the development of the seedling latex cells are differentiated As the seedling grows these latex cells grow, forming a branching system which extends throughout the plant So in the mature plant the entire latex system results from the growth of a single cell or group of cells which were present in the **embryo.**

The laticiferous system is found in all parts of the mature plant, including roots, stems and leaves, and sometimes the fruits It is particularly noticeable in the cortical (See **Cortex**) tissues

Many functions have been attributed to latex Some regard it as a form of stored food, while others consider it a sort of excretory substance in which waste products of the plant are deposited To still others it is a substance which protects the plant in case of injuries, the latex exuding and drying to form a covering which prevents the entrance of harmful bacteria and fungi Similarly it may be a protection against browsing animals, since in some plants it is very bitter, and in others, poisonous

Many products useful and valuable to man are obtained from latex First among these is **rubber,** obtained from the latex of many plants **Chicle,** widely used as the base of chewing gum, is another latex product So also is **opium,** with its many derivatives (R M W)

LATHE. Much of the cutting action needed to form the parts of machines and other articles of commerce is done during the **turning** of circular objects, such as **shafts, pulleys, gear blanks, pins, screws, axles,** etc While there are other ways of making these parts, such as grinding, casting, carving, the method in which the work is rotated while a stationary cutting tool is pressed against it is probably the most common means of producing these circularly shaped parts The completed object is received from this process in a finished or semi-finished state The machine which performs a cutting action on this type is known as a lathe.

There are many different types of lathes, because of the wide field which would be covered by cutting action of this character A lathe, simply described, is a bed or foundation carrying bearings for a rotating head or spindle in which the work is clamped or otherwise held, and a means for conveying rotative motion to this spindle Upon the bed is also mounted a moving carriage, a part of which is a tool post The cutting tool is fastened in. this post, and by means of a secondary motion of the carriage, is caused to bear against the work, which is in rotation The relative motion between the two parts causes a chip to be sheared off the work As the tool is moved endwise on the work, a cut equal to the thickness of the chip may be taken off its entire surface

A primary classification of the lathe might be into general purpose and special purpose lathes The special purpose lathes, such as the gun-boring lathe, the pulley-turning lathe, the car-axle lathe, etc, are so different from one another as to be impossible of description in a limited space Another subdivision might be the production lathe, the jobbing lathe, and the precision lathe Still another classification is based on the extent to which the tool is automatically carried In the plain lathe, the tool must be entirely manipulated by hand, even to the extent of holding the tool against a fixed rest in the wood-turning lathe The screw-cutting lathe has a lead screw which moves the carriage so that all the operator has to do is to reset it and adjust the cut In the automatic screw-cutting lathe, the entire series of screw-cutting operations is carried out by the lathe. If the lathe is driven from the countershaft by a flat belt, and speed changes are made by means of step pulleys, the layout is known as the cone drive The unit drive, wherein the power is derived from a motor mounted on the lathe, or from a single-step pulley, has speed changes made by speed change gears mounted in the lathe head

The size of a lathe is usually given by the swing and length, the swing being the normal diameter of work that may be cut on the lathe, while the length is the distance between head stock and tail stock centers when the tail stock is in its extreme position An engine lathe is one which has a lead screw to move the carriage automatically The back-geared lathe has a small countershaft mounted on the head of the lathe, which, engaged, is a **gear train** to reduce the speed of the lathe spindle by half Thus a three-step pulley-driven lathe which is back geared has six speeds

A precision lathe is usually a bench type. Instead of having a large heavy base with legs, it is arranged for mounting rigidly upon a bench It differs from the heavy type lathe in construction, not in principle The fineness of adjustment of moving parts, the finish, the bearing pressures, and the perfection of the lead and cross-feed screws are of a higher order The capacity, as far as length and swing are concerned, is smaller, because precision work is most frequently required in small parts The precision lathe has a definite place in instrument making, research, experimental and inventors' workshops

The turret lathe is a semi-automatic production type which is suitable for any job in which a number of operations are to be performed on the work, each of which requires a tool of different shape or cutting edge Each tool is held on a different side of a turret which is mounted on a carriage, and which, after the carriage returns from one operation on the work, automatically swings a new tool into place for the next operation The turret lathe is adaptable for quantity production where the conditions do not warrant building a special machine for one job, since the turret lathe may be rigged differently for the machining of different parts. (F T.M.)

LATITUDE. The celestial latitude of a point on the **celestial sphere** is the **spherical coordinate** measured from the plane of the **ecliptic** along a great circle passing through the object and the poles of the ecliptic

Because of the fact that the earth is not a perfect sphere there are several different sorts of terrestrial latitude in use In Figure 1 we have *PEP'E'* an **ellipse** representing a section of the earth in the plane of a **meridian** *C* is the geometric center of the earth and the line *COZ'* is the line to the geocentric **zenith** of the point *O* The angle *ECO* (φ') is the geocentric latitude of the point *O*

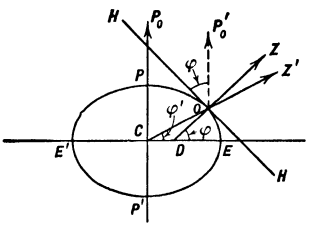


Figure 1 Astronomic and geocentric latitudes

The line *DOZ* represents the direction of **gravity** at the point *O* and extends to the astronomic zenith of *O* The angle *EDZ* (φ) is the astronomic latitude of the point *O* The difference between the astronomic and geocentric latitude of a point, the angle $COD = \varphi - \varphi'$, is defined as the reduction of latitude for the point *O*

Because of local influences, such as massive mountains in the vicinity, the direction of the plumb line may not be strictly perpendicular to the surface of the earth The geographical latitude of a point is the angle, measured in the plane of the local meridian, between the equator and a line drawn perpendicular to the theoretical **geoid** (surface of the earth) through the point in question The difference between astronomic and geographic latitude is always relatively small, but by no means an inappreciable angle, and is known as station error Station error is commonly between 4 and 6 seconds of arc, but occasionally amounts to 30 or 40 seconds

In Figure 1 *CP* represents the axis of rotation of the earth, which, if extended, will pierce the celestial sphere in its pole of rotation The parallel line OP'_0 is the line from the observer at *O* to the pole of rotation of the celestial sphere and the line *HOH* represents the plane of the astronomic **horizon** at *O* HOP'_0 is the **altitude** of the pole of rotation at *O* and inspection of the figure will indicate that this is equivalent to the angle *EDZ* This gives rise to the common definition that the astronomic latitude of a point is the altitude of the pole of rotation of the celestial sphere at the point.

Astronomic latitude may be determined in a variety of ways by observation of the celestial objects The most direct method is to observe the altitude of some object on the meridian whose **declination** is known In Figure 2 we have a representation of the celestial sphere drawn in the plane of the local **meridian** of the point *O* In the figure, *HOH'* represents the plane of the horizon, *HPZQH'* represents the local meridian, *OP* the direction of the pole of rotation, *OQ* the direction of the equator $HOP = \varphi$ (the astronomic latitude of *O*), and $H'OQ = 90 - \varphi$ Since *H'S* represents the altitude of a celestial object *S* which is on the meridian, and *QS* represents the **declination**, δ, of the object, we have at once the relationship that $\varphi = \delta + 90° -$ altitude. This is the method of determination of latitude most commonly used at sea and

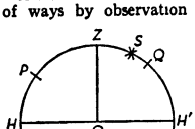


Figure 2.

presents two fundamental difficulties to the navigator The instant that the object is on the meridian must be accurately known and also the declination of the object observed In case both the Greenwich **time** and the **longitude** are known, the instant that the object should reach the meridian may be calculated in advance from the **right ascension** of the object, and the observation of altitude is taken at the predetermined instant Before chronometers came into use it was necessary to watch the object very carefully and record the maximum altitude attained by the object In case the object was the sun, the time that the maximum altitude was obtained was the local apparent noon and was used by the navigating officer for setting the watch time for the ship If the observed object is a star the declination may be immediately obtained from star catalogues, but in case the sun, whose declination is changing rapidly, is observed, the Greenwich time of observation must be used to obtain the declination from the **ephemeris.**

In case the meridian observation is missed on account of clouds or for any other reason, the **astronomical triangle** may be solved to obtain the latitude if the local time of observation and the declination of the object are both known In case the object is observed very close to the meridian and the approximate latitude as well as the local time is known, the observation may be "reduced to the meridian" by tables published in a variety of places such as Bowdich American Practical Navigator

A meridian altitude of an object is always effected by the correction for **astronomical refraction** which is always subject to error unless the object observed is close to the zenith For accurate determination of latitude for purposes of geodetic surveying the **zenith telescope** is used and the method will be described under the description of this instrument (W K G)

LATTICE. Crystal Structure.

LAUDANINE. Alkaloids.

LAUE PATTERN. Crystal Structure; X-rays.

LAUGHING GAS. Nitrous oxide (See Nitrogen.)

LAVA. Molten material which has poured out on the surface of the earth and, due to relief of pressure, may have lost much of its original gas and water content during its relatively rapid consolidation The term lava is used for both the liquid and the consolidated state of the igneous material Lava may be erupted either by volcanoes or from fissures The most extensive lava flows are fissure eruptions, such as the Columbia Plateau **basalts** in Oregon or the plateau basalts of the Deccan, India, which are derived from basic **magma** Had this magma, either basic or acid, cooled slowly beneath the surface of the earth under great pressure and with all its original gases, the resulting rock would have had a coarser texture and somewhat different mineral content (R M F)

LAVENDER. Mint Family.

LAVENDER OIL. Volatile oils.

LAWYER. Pisces, Teleostei A fresh-water fish (**Pisces**) related to the cods Also known as the **burbot** and ling Most common in northern North America (A W L)

LAZURITE. The mineral lazurite or lapis lazuli has been used since ancient times for jewelry and other ornamental purposes Ground to powder it forms the pigment ultramarine, now, however, largely superseded by artificial preparations Lapis lazuli is a mixture of minerals, lazurite being the chief component This mineral is isometric, and chemically a **sodium, calcium, alumi-**

num sulfo-chloro-silicate Lapis lazuli has a hardness of 5–5 5, specific gravity 2 4, color, various shades of blue, luster, vitreous to greasy, translucent to opaque Localities are Afghanistan, Siberia, Chile, and California (E S C S)

LEAD Symbol Pb (plumbum) Atomic number 82 Atomic weight 207 22 Density 11 34 Hardness 1 5. Melting point 327 5° C Boiling point. 1620° C. (**Isotopes:** page 239)

Lead is a white to bluish-gray metal, soft, malleable, and slightly ductile, tarnishes in air, forming a film of oxide, forms oxide scum upon heating the molten metal in air, soluble in dilute **nitric acid**, **hydrochloric** or **sulfuric acid** attack lead only slightly, the extent depending markedly upon the concentration and the temperature, slowly dissolves in water and consequently the use of lead constitutes a health hazard due to its toxic effect, attacked by solutions of organic **acids** or **sodium** hydroxide Lead is the end-product of the **uranium-radium** and **thorium** series Discovery prehistoric Lead is one of the four most largely produced and utilized metals, and considerable scrap metal is recovered Used (1) in construction and apparatus where workability is demanded, and definite resistance to corrosion is supplied by the metal, (2) as a constituent of various alloys, especially solder, type metal, pewter, and fusible alloys, (3) for storage battery plates, (4) for shot and bullets, (5) as a protective coating for iron and steel

Lead occurs principally as sulfide ore (**galenite**, galena PbS) in Missouri, Idaho, and Utah of the United States, Broken Hill of New South Wales, Mexico, and Spain The sulfide ore is roasted in air, resulting in a variable mixture of sulfide, sulfate, and oxide The temperature is then raised with the exclusion of air, whereupon the sulfide reacts both with sulfate and with oxide to form **sulfur dioxide** gas and molten lead, which latter is drawn off and cast into blocks Another method of obtaining lead is by fusion of the sulfide with scrap iron metal, thus yielding molten **ferrous** sulfide **slag** and molten lead separable by difference in densities The refining of lead is conducted (1) by passing air over the surface of molten lead and removing the oxidized layer or "scum," (2) by **electrolysis** of lead fluosilicate solution in **hydrofluosilicic acid**

Acetates lead acetate, "sugar of lead" ($Pb(C_2H_3O_2)_2 3H_2O$), white crystals, soluble, formed by reaction of lead oxide and **acetic acid**, and then crystallization Used (1) to furnish a soluble lead salt, (2) as a mordant in dyeing and printing textiles, (3) as a paint and varnish drier, basic lead acetate, white crystals, soluble, formed by reaction of lead acetate solution and lead oxide, and then crystallization Used (1) as a coagulating, clarifying, and de-acidifying agent for many organic solutions, (2) in weighting silk

Arsenate lead arsenate, arsenate of lead ($Pb_3(AsO_4)_2$), white precipitate, formed by reaction of soluble lead salt solution and **sodium** arsenate solution Used as an insecticide

Azide lead azide (PbN_6), (1) white precipitate, formed by reaction of soluble lead salt solution and **sodium** azide solution, (2) white solid, formed by reaction of sodamide ($NaNH_2$) upon heating in nitrous oxide (N_2O) gas Used as a detonator

Borate lead borate ($Pb(BO_2)_2$), white crystals, insoluble, by reaction of lead oxide and **boric acid** solution Used as a paint and varnish drier, and in preparing special types of **glass**

Bromide lead bromide ($PbBr_2$), white precipitate, formed by reaction of soluble lead salt solution and **potassium** bromide solution, melting point 373° C

Carbonates lead carbonate ($PbCO_3$), white precipitate, formed by reaction of soluble lead salt solution and **sodium** carbonate solution in the cold, basic lead carbonate, formed by reaction of (1) soluble lead salt solution and hot **sodium** carbonate solution, (2) lead sheets, **carbon dioxide** and **acetic acid**, for "white lead" paint pigment, the quality depending largely upon the conditions of the reaction

Chlorides lead chloride ($PbCl_2$), white precipitate, formed by reaction of soluble lead salt solution and **hydrochloric acid** or **sodium** chloride solution in the cold, markedly soluble in hot water, melting point of lead chloride 501° C, lead tetrachloride ($PbCl_4$), yellow liquid, formed by reaction of lead dioxide or chloride and concentrated **hydrochloric acid** in the cold, is explosive on warming

Chromates lead chromate, "chrome yellow" ($PbCrO_4$), yellow precipitate, by reaction of soluble lead salt solution and **sodium** dichromate or chromate solution, melting point of lead chromate 844° C Used as a pigment, basic lead chromate, red solid, insoluble, formed by heating lead chromate and sodium hydroxide solution

Fluoride lead fluoride (PbF_2), white precipitate, formed by reaction of soluble lead salt solution and **sodium** fluoride solution, melting point of lead fluoride 855° C

Hydroxide lead hydroxide ($Pb(OH)_2$, probably a basic hydroxide, formed), white precipitate, formed by reaction of soluble lead salt solution and **sodium** or **ammonium** hydroxide solution, soluble in **nitric acid** or excess sodium hydroxide, insoluble in ammonium hydroxide, yields lead oxide and water at 130° C

Iodide lead iodide (PbI_2), yellow precipitate, formed by reaction of soluble lead salt and **potassium** iodide solution, melting point of lead iodide 402° C

Nitrates lead nitrate ($Pb(NO_3)_2$), white crystals, soluble, formed by reaction of lead oxide and **nitric acid**, and then crystallization, decomposes on heating leaving lead oxide residue Used to furnish a soluble lead salt, basic lead nitrate, formed by reaction of lead nitrate solution and lead oxide

Oxalate lead oxalate (PbC_2O_4), white precipitate, formed by reaction of soluble lead salt solution and **ammonium** oxalate solution, yields plumbous oxide on heating at 300° C out of contact with air

Oxides lead suboxide (Pb_2O), black solid, formed by heating lead oxalate at 300° C out of contact with the air, lead oxide, lead monoxide, "litharge," "massicot" (yellowish), "yellow lead oxide" (PbO), yellow solid, insoluble, formed by heating in air any of the following lead metal, lead dioxide, trilead tetroxide, or lead nitrate Melting point of lead oxide 888° C, easily reduced to lead metal by heating with dry reducing agents Used (1) for making many lead compounds, (2) in the manufacture of storage **battery** plates, (3) in compounding **rubber**, (4) in certain **glasses** and enamels for ceramic ware, trilead tetroxide, plumbo-plumbic oxide, "minium," "red lead" (Pb_3O_4), red solid, formed by heating lead oxide at 400° C for some time, at higher temperatures decomposes to form lead oxide and oxygen, with **hydrochloric acid** yields lead chloride and chlorine gas, with **nitric acid**, lead nitrate and dioxide Used (1) as a paint pigment especially on iron and steel, (2) in certain glasses and enamels for ceramic ware, (3) in packing metal pipe joints, (4) in compounding rubber, plumbic oxide, lead sesquioxide (Pb_2O_3), reddish-yellow solid, by reaction of **sodium** hypochlorite solution and lead hydroxide, lead dioxide, "brown lead oxide" (PbO_2), brown solid, formed (1) by reaction of trilead tetroxide and **nitric acid**, and then separating the dioxide precipitate from the solution of lead nitrate, (2) by **electrolysis** (at the anode) of lead oxide in the grids of the storage battery (lead metal simultaneously formed at the cathode) Used (1) as an oxidizing agent, e g, in matches, (2) as one electrode of the lead storage battery

Phosphate lead phosphate ($Pb_3(PO_4)_2$), white precipitate, by reaction of soluble lead salt solution and **sodium** phosphate solution

Sulfates lead sulfate ($PbSO_4$), white precipitate, formed by reaction of soluble lead salt solution and **sulfuric acid** or **sodium** sulfate solution; basic lead sulfate, "sublimed white lead," white solid, formed (1)

by reaction of lead sulfate and lead hydroxide in water (slow reaction), (2) by roasting galenite in a current of air. Used as a paint pigment.

Sulfide: lead sulfide (PbS), brownish-black precipitate, formed by reaction of soluble lead salt solution and **hydrogen sulfide** or **sodium** or **ammonium** sulfide, soluble in dilute nitric acid.

Tetraethyl lead ($(C_2H_5)_4Pb$), colorless liquid, decomposes at 125° C., formed by reaction of ethyl chloride and lead **sodium amalgam**. Used as an "anti-knock" in small concentrations in **gasoline** motor fuel. (R.K.S.)

LEAD POISONING. This form of metal poisoning is often seen as an occupational disease. There are about one hundred and fifty occupations that may expose the worker to this form of poisoning, either from inhaling lead dust or absorbing it through the skin. These occupations include the manufacture of white and red **lead**, rubber, printing materials, storage batteries, pottery, etc. It is much less common now than twenty years ago due to better factory conditions. The poisoning may also occur from use of hair dyes, cosmetics, and food or water that are contaminated with lead.

Lead is a cumulative poison, the metal being stored in the solid portion of the body skeleton. For this reason, even after exposure has ceased, the excretion of lead from the body may continue for years.

The symptoms of chronic poisoning are great weakness, marked constipation, intestinal colic, marked anemia, palsy, and, at times, psychic manifestations.

The red **blood** cells of a poisoned patient on microscopic examination, after staining, show a peculiar stippling that is characteristic of this disease. (Figure 2, Plate B, facing page 148.) The deposit of lead sulfide about the blood vessels near the margins of the gums causes a visible "lead line" that is often seen.

The prognosis is good in most cases of lead poisoning, although symptoms may persist for many years. Palsy and mental symptoms in advanced cases may be permanent.

Treatment is directed towards relief of symptoms, removal of the cause, and increased excretion of lead from the body. (R.S.M.)

LEAF. The leaf is a most important organ of the plant, since it manufactures most of the food material of that plant. Typically leaves consist of a broad thin lamina borne on a slender stalk and green in color.

The leaf originates as a small protuberance from the surface of the growing tip of the stem. Numerous divisions of the cells of this protuberance produce a structure from five to eight cells thick. Many of these leaf primordia are borne together on the stem tip, and, together with any protecting scales which may cover them, form the **buds** of the stem. At first all the cells of these leaf primordia are alike. Very early in their existence, however, certain cells become distinct by their somewhat elongated shape. These cells are the beginnings of the **vascular** elements. Cell divisions continue in these small bodies until there are present in the bud recognizable but very small leaves which are folded in various ways. In woody plants this development takes place in the year previous to that in which the leaf will unfold. With the advent of the new growing season, growth of the many minute cells of these tiny leaves is very rapid, so that within a few days' time the leaf has unfolded and grown to its mature size. During this enlargement many changes have taken place in the cells of the leaf.

Leaf of apple, illustrating all parts—blade, petiole, and stipules.

The mature leaf is commonly composed of two distinct parts, the broadly expanded, thin green blade, and the petiole or stalk which supports it and connects it with the stem. In many plants there is formed at the base of the petioles a pair of outgrowths called stipules, which in some plants may take the form of a complete sheath. This sheath is well developed in members of the **Carrot Family.** Sometimes the petiole is completely lacking, the blade being attached directly to the stem; leaves of this kind are called sessile leaves. Less frequently the blade of the leaf is lacking, the petiole being expanded into a flattened object looking much like a blade. Certain Australian trees, species of *Acacia* and *Eucalyptus*, exhibit this peculiarity. Leaves of such plants often show progressive changes from those having well-developed blades to those in which the blade is completely lacking, showing clearly that the flattened portion present is a modified petiole. Such flattened petioles are not uncommon, but usually the blade is present, as is the case in the lemon tree. Leaves may be deciduous, falling off at the end of a single growing season, or evergreen and persistent through several seasons. In nearly all cases the leaf fall is brought about by the development of a definite **abscission layer.** In many plants such a layer is formed not only at the base of the petiole but also at the point where the petiole joins the blade.

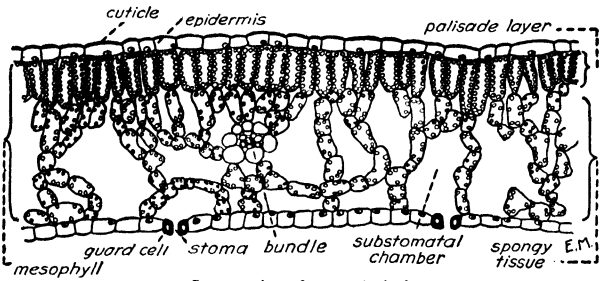
The shape of the blade is extremely varied, ranging from very slender linear leaves to those which are broader than they are long. The margin of the leaf may be entire, that is, without indentations of any sort, or toothed or lobed in various ways, until some are incised nearly to the midrib. If the leaf is completely divided into separate segments it is said to be a compound leaf, in contrast with the undivided leaves, which are simple leaves, no matter how deeply they may be lobed. If the sections of a compound leaf all come from a common point, the leaf is said to be palmately compound; if they are borne along a central axis, the leaf is pinnately compound. While such infinite variations do exist, the leaves of any single species of plant are recognizably constant in shape.

The blade of the leaf is supported by a framework of veins which are also very characteristically arranged. In many leaves, especially in **dicotyledons**, one vein, usually extending through the center of the blade, is more prominent than the others. This is called the main vein or midrib. The others are lateral veins. In most dicotyledons the veins branch abundantly to form an intricately anastomosing network, which reaches all parts of the leaf. In most **monocotyledons** the midrib and lateral veins extend in parallel lines from base to apex of the leaf. Between these many minute veinlets exist, too small to be readily seen, reaching all parts of the leaf.

The cellular structure in leaves is very constant. (See next page for illustrations.) Covering the entire surface of the leaf is the epidermis, a layer of tabular cells. On the upper surface of the leaf the epidermal cells are frequently covered with a layer of cutin, a waxy substance which is impervious to water and so greatly reduces the loss of water by evaporation from the leaf surface. Epidermal cells contain a scant peripheral **cytoplasm,** and a large central **vacuole** full of cell-sap. Usually there are no **chloroplastids** present in the epidermal cells. The cells of the epidermis of the lower surface are similar to those of the upper, but with a less evident cuticle. In the epidermis of the leaf, particularly that of the lower surface, there are many minute openings, called **stomata**, which permit a ready exchange of gases between the interior of the leaf and the external air. All cells occurring between the upper and lower epidermal layers are called **mesophyll** cells. Beneath the upper epidermis the mesophyll cells form a very distinct layer, called the palisade mesophyll. These are elongated cells with their long axis perpendicular to the surface of the leaf. They

contain large numbers of chloroplastids. In them, furthermore, active **photosynthesis** takes place. Occupying all the rest of the leaf is a loose tissue composed of irregularly arranged rounded cells known as the spongy mesophyll. Numerous intercellular spaces separate these cells from one another. Ramifying through the leaf just below the palisade cells are the veins. Each vein is composed of three types of cells. Some of them are thick-walled **xylem** cells which carry water and dissolved mineral matter to all parts of the leaf. Others are **phloem** cells which carry food substances away from the green cells of the leaf where they are elaborated. The xylem cells are towards the top of the leaf, the phloem cells towards the bottom. Outside these and often forming a conspicuous tissue are masses of **fibers**, thick-walled cells which give support to the leaf.

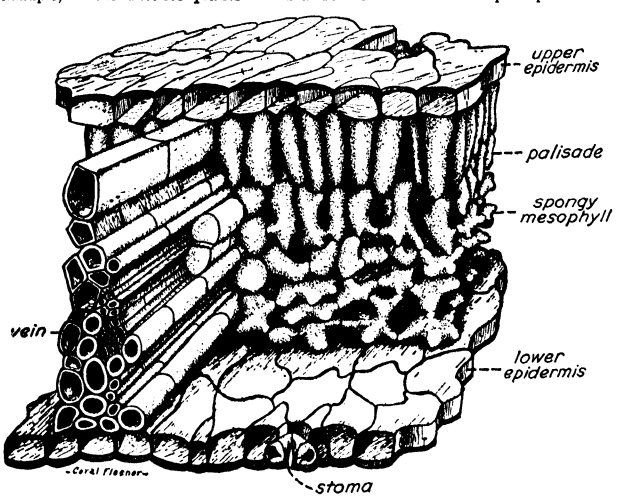
Leaves are often greatly modified. (Various types of leaves are illustrated on the following page). In many plants they become greatly enlarged and fleshy, and serve as organs of storage of water and foodstuffs. Many rock garden plants, such as species of *Sedum*, have leaves of this type. Of similar nature are the scale-like leaves which form the greater part of many bulbs, such as those of many lilies. The common onion is composed of the closely enwrapped bases of leaves, swollen with food material. In other plants modification of the leaves becomes extreme as, for example, in the **Pitcher plants** and **bladderworts.** times only the stipules are thus modified, as in the Carrion flower, *Smilax herbacea*. Many plants of the legume family have pinnately compound leaves, some of the segments of which are changed into tendrils. Weirdest of all are the leaves of species of *Nepenthes*, one of the pitcher plants. (See article on **Insectivorous Plants,** where this leaf is described.)



Cross section of an apple leaf.

In a few plants the leaf becomes a vegetative reproductive body, having in the notches of its margin, at its tip, or less commonly on its surface, groups of **meristematic** cells which, when the leaf is mature, give rise to tiny plants which remain attached to the parent leaf for some time. Among the plants in which reproduction of this type occurs are species of *Bryophyllum* and *Kalanchoë*.

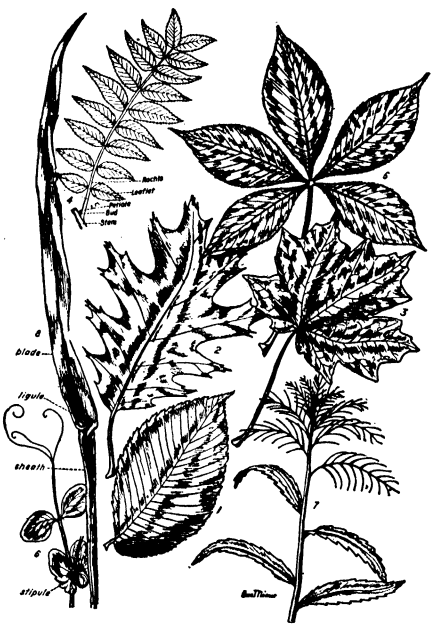
The principal function of the leaf is to carry on **photosynthesis.** To do this the leaf must receive adequate light. Leaves are not distributed haphazardly on the stem, but in a very definite way which assures them the maximum of light. In many plants the leaves are in pairs on opposite sides of the stem. Each successive pair usually grows out at right angles to the pair beneath it, thus preventing overshadowing. Leaves may occur in whorls, in which case there will be three or more leaves growing from each node of the stem. In many plants the leaves are alternate, each node bearing a single leaf. In every case alternate leaves arise from the stem in such a way that a line passing around the stem and through the junction of the petiole with the stem forms a regular spiral. Examination of this spiral shows that the leaves are distributed on it in a very exact mathematical arrangement. In the simplest case the leaves are in two longitudinal rows along the stem, every third leaf being directly above the first; in the next arrangement there are three longitudinal rows, the fourth leaf of the spiral being above the first. In another, and very common, arrangement, there are five rows of leaves, with the sixth leaf above the first. Other more complicated arrangements are found. A common way of indicating the arrangement of leaves on a stem is by means of common fractions. The fraction may be determined by starting at any one leaf and passing by the shortest way around the stem to the next higher



A portion of the blade of a leaf cut so as to show the internal structure. The cell contents are not represented.

In other plants, such as the common barberry, the leaf is reduced to sharp-pointed branched spines; in many cases all gradations between these spines and typical leaves may be found on a single branch. In some plants, as the Locust, *Robinia Pseudacacia*, only the stipules are modified to short sharp spines. Many plants have leaves modified into tendrils, slender thread-like objects which twine tightly around any suitable object with which they may come in contact. Sometimes only the tip of the blade functions in this way, and some-

leaf and so on until the leaf vertically above the first is reached; the number of turns about the stem from the first to the last leaf gives the numerator of the frac-



Types of leaves. 1, 2, elm leaf and oak leaf, both pinnately netted veined; 3, maple leaf, palmately netted veined; 4, black walnut leaf, pinnately compound; 5, buckeye leaf, palmately compound; 6, a pea leaf, with stipules, tendrils, and two unmodified leaflets; 7, portion of a plant of the water mermaid, *Proserpinaca*, with upper leaves modified by immersion in water; 8, grass leaf.

tion, and the number of leaves passed gives the denominator. The fractions obtained form a very exact mathematical series; they are $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, $\frac{8}{21}$, $\frac{13}{34}$, etc. The arrangement of leaves on a stem is called phyllotaxy.

Sometimes the exact arrangement is more or less obscured by twisting of the stem during growth. The leaves themselves turn considerably during their growth, petioles twisting to one side or the other, or elongating unequally, in such a way as to bring the blade into a position to receive the most favorable light. (R.M.W.)

LEAF HOPPER. Insecta, Homoptera. Any insect of the large family Cicadellidae or Jassidae. They are small to moderate jumping insects which often come freely to light.

Many species are of economic importance, and since they have sucking mouths, they must be attacked with contact poisons such as nicotine sulfate or kerosene emulsion. These sprays are effective against the tender immature insects but the adults cannot readily be killed. (A.W.L.)

LEAF INSECT. Insecta, Orthoptera. Large insects of the Old World tropics related to the walking-stick insects. They have leaflike wings and in some species the body and legs are extended in flat processes which also resemble leaves. (A.W.L.)

LEAF MINER. Larval insects which work in the soft tissue of leaves between the upper and lower epidermis. They are necessarily small and are sometimes able to complete their development on a very small part of the food available in a single leaf. The burrow or mine shows as a brownish or transparent patch in the leaf and its form is characteristic of the insect making it. The larvae of many of the smallest moths and of some sawflies are leaf miners. (A.W.L.)

LEAST-ACTION PRINCIPLE. Action.

LEAST COMMON MULTIPLE. The least (or lowest) common multiple of several polynomials is the polynomial of lowest degree which contains each of them as a factor. It is usually found by factoring the polynomials separately, and then finding the least common multiple by inspection. (L.L.S.)

LEAST-ENERGY PRINCIPLE. A principle relating to stable equilibrium, and having very wide application. If a system is in stable equilibrium, any slight change in its condition or configuration requiring the performance of work will put it out of equilibrium, so that, if the system is now left to itself, it will return to its former state and in so doing will give up the energy imparted when it was disturbed. Consider, for example, a block of wood floating in a pail of water. If the block is lifted slightly, work is done and the center of mass of the wood-water system as a whole is raised, so that it now has more potential energy. The same would be true if the block were pushed a little farther into the water. In either case, when the block is released, it resumes its former level and the potential energy of the system diminishes to its former minimum value. This illustrates the general principle, which is that a system is in stable equilibrium only under those conditions for which its potential energy is at a minimum.

The principle of least energy is one aspect of the principle of virtual work (See **Equilibrium of Forces**). (L.D.W.)

LEAST SQUARES, METHOD OF. The method of least squares is a statistical method for obtaining the most probable value of a quantity from a set of **physical measurements**, and for obtaining a quantity which is an indication of the precision of the most probable value.

In the development of the theory of the method of least squares two lines of attack have been employed: the observational and the mathematical. In each of these certain fundamental assumptions are necessary. In the observational method the assumption is made that the arithmetic, mean of a series of equally reliable observed values of a given quantity, each observation being freed from all systematic **errors of measurement**, is the most probable value of the quantity. To approach the theory from the purely mathematical point of view it is assumed that the accidental errors of observation follow the **Gaussian distribution.** These two assumptions are, in fact, interdependent. If they are justifiable for the given set of observations, then it may be proved that the sum of the squares of the residuals will be a minimum. If from an individual observation we subtract the most probable value of the quantity, a residual is obtained. It is the purpose of the method of least squares to determine a quantity from a series of observations, whether directly observed, indirectly observed, or computed from observational material, such that the sum of the squares of the residuals shall be a minimum.

In the discussion of the Gaussian distribution it is found that the probability of occurrence of a residual of magnitude x may be expressed by $P = \frac{h}{\sqrt{\pi}} e^{-h^2x^2}$. In this

expression h is a measure of the precision (or relative agreement) of the individual observations of the measured quantity In practice it is customary to express the precision of a measured quantity, as obtained from a number of independent observations from which all systematic errors have been removed, by certain functions of h rather than by h itself In practically every case the function is inverse in character, i e , the smaller the value of the precision indicator the greater is the value of h The standard method for indicating precision adopted by most American and English workers in the physical sciences is the so-called probable error, which is symbolically expressed by the double sign $\pm$ If the probable error of a most probable quantity A is $\pm R$, then the chance that the true value of the quantity is between $A + R$ and $A - R$ is equal to the chance that the quantity has any value whatsoever outside of these limits For example, if the length of a certain rod is published as 356 25 centimeters $\pm$ 0 15 centimeter, then the chance that the true length of the rod is between 356 40 centimeters and 356 10 centimeters is equal to the chance that the length is anything outside of these two limits Other methods for expressing the precision of a set of observations are in use, such as, for example, mean error, standard deviation, radical mean square error, etc The meanings of these and other terms for expressing precision will be found in treatises on statistical analysis The symbol $\pm$ should be reserved for probable error as defined above and should not be used for other terms for expressing precision, unless adequate notice is given to the reader The methods for actually computing the precision measures of directly observed quantities, indirectly observed quantities, and quantities obtained by computation from observed values, involve too much detail to be included in a work of this character

It should be carefully noted that the expression of the precision of a set of observational data is based upon certain fundamental assumptions and that if these assumptions are not valid for the particular set of observations, then the expression of precision is meaningless It has been found that in most cases the accidental observational errors in the fields of astronomy, geodesy, and physics satisfy the Gaussian distribution law and hence least-square adjustments of the results are justifiable This is not the case in the fields of biology and psychology, where one-sided variations in the observational material may occur to produce unsymmetrical distribution of the observational errors In such problems great care must be exercised in expressing the precision of the results A least-square discussion can never improve the quality of the observations, neither can it remove the effects of systematic errors, although a careful discussion of the residuals may indicate the presence of systematic errors It must never be assumed that the method of least squares is some magical process which can be indiscriminately applied to all types of observational or statistical data (W K G)

LEAST TIME PRINCIPLE. Fermat's Principle.

LEAST WORK. The three equations of static **equilibrium** (See **Statics**) are insufficient to determine the analysis of certain types of structures which, in consequence, are called statically indeterminate structures The analysis of such structures belongs to the general subject of mathematical theory of elasticity Several methods of attack have been devised, but none has had so wide an application as the principle of least work When a structure, either simple or complex, is loaded, there is a certain amount of energy stored in it by virtue of the deformation of its several elastic components The theory of least work is based on the fact that the natural phenomena attending the deflection of a stressed structure is that the individual parts will be so deflected that the load will be carried with a minimum storage of energy in the elastic members In the least-work theory, there are two basic propositions The first is that the linear displacement of the point of application of a load of an indeterminate structure, in the direction of the load, equals the first **derivative** of the energy stored in the elastic structure, taken with respect to the load The second theorem is that the magnitudes of statically indeterminate reaction forces are such as to make the elastic energy of the system the best possible (See **Least-Energy Principle.**) (F T M)

LEATHER-JACKET. Insecta, Diptera The tough-skinned **larvae** of some species of **crane flies** They live in the ground in pastures, hay fields, and grain fields and are sometimes serious pests Since they come to the surface at night they can be destroyed by the use of poison baits. (A W L)

LEATHER. Tannins.

LE CHATELIER LAW. Equilibrium.

LECHER OSCILLATOR. Electric Oscillations and Electric Waves.

LEECH. Hirudinea.

LEEK Allium.

LEEWAY. The difference between the actual direction in which a ship is moving relative to the surface of the water and the direction in which the keel of the ship is pointing is known as leeway Leeway is usually produced by the pressure of the wind against the side of the vessel and is much more pronounced in the case of sailing vessels than in internally powered ships The amount of leeway can best be determined by observing the angle between the wake of the vessel and the line of the keel

In determining the true **course** of the vessel the leeway is treated in the same manner as a **compass correction** In case the wind is blowing against the left side of the vessel the vessel is said to be on the port tack and the true course will be to the right of the course indicated by the keel Hence for a ship on the port tack leeway has the same effect as an east or positive compass correction, on the starboard tack leeway is applied as a west or negative correction (W K G)

LEG. A jointed appendage, used for locomotion on a solid supporting surface by walking, running, or jumping The jointed appendages of **arthropods** and of **vertebrates** are both termed legs The term is applied to similar structures used for other purposes, such as swimming or burrowing, but those which have undergone great modification have also received special names The anterior appendages of birds and primates are distinguished as **wings** and **arms**, respectively, but in quadrupedal vertebrates they are still called legs (A W L)

LEGENDRE FUNCTIONS. The **differential equation**

$$(1 - x^2)\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + n(n+1)y = 0$$

is called Legendre's equation It cannot be solved in terms of elementary functions It defines a new class of functions, called the Legendre functions, they are also sometimes called surface zonal harmonics Let n be a positive integer

Legendre functions of the first kind (also called Legendre polynomials or Legendre coefficients) may be defined by

$$P_n(x) = \frac{(2n-1)(2n-3)\cdots 3\cdot 1}{n!}\left[x^n - \frac{n(n-1)}{2(2n-1)}x^{n-2} + \frac{n(n-1)(n-2)(n-3)}{2\cdot 4(2n-1)(2n-3)}x^{n-4} - \frac{n(n-1)(n-2)(n-3)(n-4)(n-5)}{2\cdot 4\cdot 6(2n-1)(2n-3)(2n-5)}x^{n-6} + \cdots\right].$$

$P_n(x)$ is a particular solution of Legendre's equation

Legendre functions of the second kind may be defined by the series

$$Q_n(x) = \frac{n!}{(2n+1)(2n-1)\cdots 3\cdot 1}\left[\frac{1}{x^{n+1}} + \frac{(n+1)(n+2)}{2(2n+3)}\cdot\frac{1}{x^{n+3}} + \frac{(n+1)(n+2)(n+3)(n+4)}{2\cdot 4(2n+3)(2n+5)}\cdot\frac{1}{x^{n+5}} + \cdots\right],$$

when the series is convergent $Q_n(x)$ is another particular solution of Legendre's equation Then the general solution of Legendre's equation is $y = c_1P_n(x) + c_2Q_n(x)$, where c_1 and c_2 are arbitrary constants (L L S)

LEGUME. Fruit.

LEIBNITZ' RULE FOR SUCCESSIVE DERIVATIVES OF A PRODUCT. This is a formula for the n^{th} derivative of the product of two functions in terms of the successive derivatives of the factors It is

$$\frac{d^n}{dx^n}(uv) = \frac{d^nu}{dx^n}v + \binom{n}{1}\frac{d^{n-1}u}{dx^{n-1}}\frac{dv}{dx} + \binom{n}{2}\frac{d^{n-2}u}{dx^{n-2}}\frac{d^2v}{dx^2} + \cdots + \binom{n}{r}\frac{d^{n-r+1}u}{dx^{n-r+1}}\frac{d^rv}{dx^r} + \cdots + \binom{n}{1}\frac{du}{dx}\frac{d^{n-1}v}{dx^{n-1}} + u\frac{d^nv}{dx^n}$$

The coefficients are binomial coefficients (L L S)

LEMBERG'S SOLUTION A solution of logwood (See Tannins) digested in aqueous aluminum chloride which is used as a stain and reagent for distinguishing between calcite or aragonite and dolomite Both calcite and aragonite are stained violet by the reaction while dolomite remains unchanged (R M F)

LEMMA. The lower one of the two bracts which immediately subtend the floret in the spikelet of grasses (R M W)

LEMMING. Mammalia, Rodentia Small animals of northern latitudes The European lemmings resemble the woodchuck in form but are much smaller, and the American species, *Synaptomys*, are like short-tailed mice The common lemming, *Lemmus lemmus*, of northern Europe is noted for its occasional migrations Many thousands of the animals take part in these migrations, crossing mountains, fording streams, and always pushing straight on until they enter the sea and are drowned (A W L)

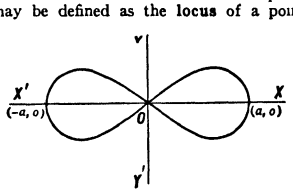
LEMNISCATE The lemniscate is a plane curve which may be defined as the locus of a point which moves so that the product of its distances from the points $(-a, 0)$ and $(a, 0)$ is equal to a^2

Its equation in rectangular coordinates is

$$(x^2+y^2)^2 = 2a^2(x^2-y^2),$$

and in polar coordinates is

$$r^2 = 2a^2\cos 2\theta. \qquad \text{(L L S)}$$



Lemniscate

LEMON. Citrus fruits.

LEMON GRASS OIL. Volatile oils.

LEMUR. Mammalia, Primates The most primitive animals of the order containing man and the apes and monkeys Lemurs have a well-developed thumb and great toe, like the other primates, but the second toe bears a sharp claw instead of a nail The body is generally more like that of a squirrel than like the apes and monkeys and the face in many species is peculiarly expressionless, with large staring eyes

Lemurs constitute a family Lemuridae, containing, in addition to the species named as lemurs, the indri, the sifakas or propitheques, the galagos, the awantibo, the pottos, the lorises or slow lemurs, and the avahi They center in Madagascar but a few species occur in eastern Africa, southern India, and islands of the Oriental region The tarsiers and the aye-aye are closely related to the true lemurs (A W L)

LEMUROIDS. Paleocene.

LENARD RAYS. Cathode Rays.

LENGTH OF PLANE CURVE ARC. The length of a curve arc is defined as the limit of the length of a broken line inscribed in the arc, as the number of pieces increases indefinitely and each piece approaches zero

Let s represent arc length from a fixed point on a plane curve whose equation in rectangular coordinates is $y = f(x)$

Then

$$ds^2 = dx^2 + dy^2,$$

and

$$\frac{ds}{dx} = \sqrt{1+\left(\frac{dy}{dx}\right)^2}, \qquad \frac{ds}{dy} = \sqrt{1+\left(\frac{dx}{dy}\right)^2},$$

and the arc length is

$$s = \int_a^b \sqrt{1+\left(\frac{dy}{dx}\right)^2}\,dx = \int_c^d \sqrt{1+\left(\frac{dx}{dy}\right)^2}\,dy$$

If the equation of the curve in polar coordinates is $r = f(\theta)$, then

$$ds^2 = dr^2 + r^2d\theta^2,$$

and

$$\frac{ds}{d\theta} = \sqrt{r^2+\left(\frac{dr}{d\theta}\right)^2},$$

and arc length is given by

$$s = \int_\alpha^\beta \sqrt{r^2+\left(\frac{dr}{d\theta}\right)^2}\,d\theta$$

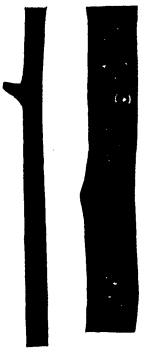
If the curve is given by parametric equations: $x = f(t)$, $y = g(t)$, then

$$\left(\frac{ds}{dt}\right)^2 = \left(\frac{dx}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2 \qquad \text{(L L S)}$$

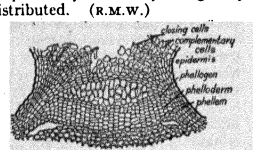
LENSES. Mirrors and Lenses.

LENTICELS. The young stems of plants are covered with a single layer of cells known as the epidermis As the stem grows older, this epidermis is lost, and replaced

by a thicker protective tissue known as a **periderm**. The outer cells of the periderm have walls which are suberized and impervious to gases. The living cells within the stem require an exchange of gases with the outside atmosphere. This exchange occurs through lenticels. A lenticel is a mass of thin-walled **parenchyma** cells loosely arranged so that air spaces are numerous. Through the lenticel gases pass readily. Lenticels appear on the surface of the stem as rough masses, usually protruding somewhat, and either circular or somewhat elongate in shape. They are very irregularly distributed. (R.M.W.)



Stems of apple tree showing external view of lenticels.



Section through lenticel of cherry. (From Eames and MacDaniels' *Introduction to Plant Anatomy.*)

LENZ'S LAW. A general law of **electromagnetic induction**, stated by H. F. E. Lenz in 1833. It points out that the electromotive force induced by the variation of magnetic flux, with reference to a conductor, in the manner discovered by Faraday, is always in such direction that, if it produces a current, the magnetic effect of that current opposes the flux variation responsible for both electromotive force and current. An outstanding illustration is the drag on a generator armature; if the armature circuit is closed, the rotation is opposed by a torque arising from the reaction between the field and the current in the armature conductors. Power must therefore be applied to drive the machine; and the greater the armature current, the more power is required. The effect known as magnetic damping depends upon this principle. A copper disk, when spun between the poles of a strong magnet, quickly comes to rest because of the opposing torque. This arrangement serves as a speed regulator in watt-hour meters. The oscillations of **galvanometer** coils are often damped in a similar manner. (L.D.W.)

LEO (The lion) (Map page 306). The **constellation** of Leo is one of the most easily distinguished of all of the **zodiacal** constellations. The "sickle" of this, the fifth sign of the zodiac, is known to all watchers of the spring and early summer skies. The brightest star in the group, Regulus, is a **double** star but cannot be resolved with telescopes smaller than three-inch aperture because of the fact that in small instruments the bright star masks the fainter one. Gamma Leonis is one of the finest of the doubles with its two components of approximately the same magnitude, one yellow and the other orange in color.

The constellation is also noted for the location of the **radiant point** of the **Leonids**, one of the best known **meteor** showers. (W.K.G.)

LEONIDS. The name Leonids is applied to that **meteor shower** which has probably attracted more attention than any other. Each year, about the twelfth of November, a number of meteors are observed coming from a **radiant point** in the **constellation** of **Leo**. Records of the appearance of this shower are found back as far as A.D. 585. The Leonid shower is one in which meteors are distributed all along the orbit, so that a radiant point may be determined practically every year, and also there is a very strong condensation of the meteors into a swarm through which the earth **used** to pass every 33 years. Probably the greatest display was in November, 1833. Quoting from Silliman's Journal of that year we find: "To form some idea of the phenomenon, the reader may imagine a constant succession of fireballs, resembling rockets, radiating in all directions from a point in the heavens." One observer counted 650 during fifteen minutes. During the interval between 1833 and 1866 a great deal of computing was done on the Leonid shower and November 13 was predicted as the date of passage of the earth through the main swarm. The prediction was fulfilled, and at Greenwich, England, eight observers actually counted 8000 meteors, 4860 of them being counted between one and two o'clock in the morning. However, brilliant as the shower was at that time, it apparently was not as striking as the display in 1833. In 1899 there was a moderately good display of the Leonids, but nothing comparable to the showers of 1866 and 1833. The newspapers had promised so much to the general public that the failure of the shower to come up to the expectations proved a rather serious blow to astronomy. The explanation for the failure of the shower to live up to its prediction is to be found in the fact that Jupiter passed very close to the swarm during 1899 and deflected it from the earth's orbit. Further **perturbations** have so deflected the orbit that in 1932, 1933, and 1934 no real shower was observed, although enough meteors were seen during each November to permit of a determination of the radiant point.

It is not possible to make any definite predictions for the future. It should be pointed out, however, that in the centuries preceding 1833 there are several instances where we find no record of striking displays on the basis of the 33-year period. It is very possible that perturbations may again bring the main swarm into such a position that the earth will again pass through it, giving rise to showers comparable with that of 1833. (W.K.G.)

LEOPARD. Mammalia, Carnivora. A large **cat** of the Oriental region and Africa. Its fur is tawny, marked with black rings and spots, although a black variety occurs in which the spots are faintly traceable. A species known as the snow leopard, *Felis uncia*, lives at high altitudes in central Asia, and in southeastern Asia a short-legged species called the clouded leopard, *F. nebulosa*, is found. The former is spotted and the latter blotched and striped. The cheetah, *Cynaelurus jubatus*, of India and Africa, is a slim long-legged animal marked with small black spots on a tawny to reddish ground. It has been trained for use in hunting and is also called the hunting leopard. (A.W.L.)

LEPIDODENDRON. Paleobotany.

LEPIDOLITE. This member of the **mica** group of minerals is a **silicate** of **potassium**, **lithium** and **aluminum**, sometimes with **sodium**, **fluorine**, or rarely **rubidium**. Crystals of lepidolite are **monoclinic** but often pseudo-**hexagonal**; **cleavage**, basal and perfect, being susceptible of splitting into thin laminae; hardness, 2.5–4; specific gravity, 2.8–3.3; luster, pearly; color, reddish to violet, grayish blue, gray to white. A variety carrying rubidium is a yellowish gray; translucent. It usually is found as granular to scaly masses, in short stocky prisms or less often in easily cleavable sheets. Lepidolite is characteristic of **pegmatite** veins, frequently being associated with other lithium-bearing minerals such as **tourmaline**, **spodumene**, **amblygonite**, and others. It occurs in the Ural Mountains, Czechoslovakia, the Island of Elba, and Madagascar, where it is often found in large sheets. It is found in the pegmatites of New England, California, South Dakota, and New Mexico. The name lepidolite is derived from the Greek meaning scale. (E.S.C.S.)

LEPIDOPTERA. The **butterflies**, **skippers**, and **moths**. An order of insects characterized by sucking mouths in the adult stage, complete metamorphosis, a

larva with biting mouth parts, and two pairs of wings covered at least in part with a vesture of flattened scales. The second order of insects in size, with about 90,000 known species.

Butterflies and moths are widely distributed and because of their bright colors are among the animals known to everyone The butterflies are diurnal and so are readily observed, but most moths are nocturnal, hence many beautiful species are rarely seen unless they are sought Skippers are an intermediate group more nearly like the butterflies The most magnificent species of all three forms are tropical but representatives are found even in the Arctic regions.

The adults visit flowers for nectar or take no food In the larval stage most species are plant feeders but a few carnivorous forms are known and some are scavengers The order includes many economic species, among them the clothes moths, the bee moth, and the cut worms (A W L)

LEPROSY. A chronic infectious disease caused by the bacillus *leprae* The disease presents a great variety of signs and symptoms depending on what tissue or organ of the body is involved The disease usually results in death either directly or indirectly

Leprosy is a disease of antiquity, and there is evidence that it has existed at least since two thousand years B C. References to the disease are found in the Old Testament While it has been common in the Orient for several thousands of years, it appeared as a scourge in Europe in the eleventh and twelfth centuries, and did not subside until the sixteenth century when segregation of the victims was carried out on a large scale At present the disease occurs endemically and sporadically, chiefly in the Orient, Australia, Asia, on the Mediterranean, and in Central and South America There are various other foci of sporadic cases such as some parts of northern and central Europe, the West Indies, Louisiana, Minnesota, and South Carolina in the United States, and several in Canada Occasional cases are encountered in the larger seaports, both Atlantic and Pacific

The mode of infection is not definitely known, but it probably occurs by inhalation, though only after long continued and intimate contact Unsanitary and unhygienic conditions aid in its transmission Insects may play an intermediary role

The organism causing the disease resembles closely that of tuberculosis It is found in great numbers in the nodules occurring under the skin, in discharges from the nose and throat, and in discharges from ulcers It was first discovered in 1873 by Hansen

The period of incubation is variable It may be from a few months to twenty or thirty years The symptoms of the disease depend largely on the tissue attacked Usually it takes one of two forms (1) nodular leprosy where the skin is primarily attacked, or (2) anesthetic leprosy, where there is an involvement of nervous tissue A mixed form also occurs showing symptoms of both forms

In the first stages of nodular leprosy, brownish-red spots appear on the skin, usually on the limbs and face, covering large and small areas of the skin Later nodular thickenings appear at these sites The face may show the so-called leonine appearance, due to the thickening of the skin in the region of the forehead, eyes, lobes of ears and around the nose and mouth The entire skin assumes an unhealthy, dusky appearance Some of the thickened areas ulcerate and fingers and toes may rot off Ulceration also appears in the nose and throat and the voice becomes hoarse The eyes are affected similarly, and blindness may result This form of the disease may last ten, twenty years, or longer without treatment Many of the patients die of complicating disorders such as pneumonia, nephritis, tuberculosis, exhaustion and malnutrition

The outlook for recovery in leprosy has been considerably improved by modern treatment Lepers do not die directly from their disease but usually from tuberculosis, nephritis, or infection.

As a general treatment chaulmoogra oil, or preparations derived from this oil are used either by subcutaneous or intravenous injections. This has actually arrested cases of leprosy, when the disease was not too far advanced. Leprosy is not hereditary. (R.S.M.)

LEPTITE. Granulite.

LEPTOCARDIA. Cephalochordata.

LEPTOSTRACA. Crustacea.

LESBIANISM. Perverted sexual practices between women Homosexuality (R S M)

LESION. Any wound, injury, diseased area or area of local degeneration. (R.S.M)

LETTUCE. *Lactuca sativa* Composite Family.

LEUCINE. Aminoacids, Polypeptides, and Proteins.

LEUCITE. The mineral leucite is a metasilicate of potassium and aluminum corresponding to the formula $KAl(SiO_3)_2$ It is isometric at a temperature of about 600° C and psuedo-isometric at lower temperatures, at which the mineral may possibly be monoclinic or even triclinic. The external forms remain isometric It has a conchoidal fracture, is brittle, hardness, 5 5–6, specific gravity, 2 45–2 50, luster, vitreous, color, white or some shade of gray, translucent to opaque It is commonly found in the more recent lavas of high alkali content Leucite is seldom reported from plutonic rock types It is a relatively rare mineral It is found plentifully at Vesuvius and Monte Somma and elsewhere in Italy, and in Germany in the Tertiary volcanic district of the Eifel In the United States leucite has been found in the Leucite Hills of Wyoming, the Highwood Mts of Montana and as pseudomorphs in New Jersey and Arkansas Its name is derived from the Greek word, referring to its white color (E S C S)

LEUCO BASE. Dyes.

LEUCOCYTE. Blood.

LEUCON. Synonymous with rhagon Porifera.

LEUKEMIA. A diseased condition of the tissue forming white blood cells in which abnormal numbers of mature and immature leucocytes appear in the blood stream When the bone marrow, from which granular leucocytes originate, is involved, the leukemia is of the myeloid type (See Figure 6, Plate B, facing page 148) When lymphoid tissue is involved, the leukemia is of the lymphoid type, non-granular immature cells being thrown out into the blood stream in all stages of development

The cause of leukemia is unknown In some respects the disease resembles an infection and in other respects simulates a tumor formation

The disease occurs in various animals as well as in human subjects It is a relatively uncommon disease

The onset of this disease occurs gradually and since anemia occurs with the disease, symptoms characteristic of it—weakness, pallor, intestinal disturbances, shortness of breath may be the first to appear The spleen becomes greatly enlarged and its weight alone may cause a dragging sensation in the left abdomen Basal metabolism is increased and fever of some degree is usually present In the lymphatic form all the lymph glands are enlarged Death occurs in leukemia from exhaustion due to progressive anemia, an intercurrent infection, or from hemorrhage Remissions lasting for varying periods of time may occur during the chronic form of the disease but death is the eventual outcome in all cases Acute leukemia runs a rapid course, usually a few days

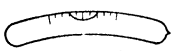
or weeks The chronic types vary in duration of life In those cases where remissions occur patients may live for several years, occasionally as long as ten or eleven years

There is no curative treatment In certain of the chronic forms palliative treatment only may be offered by **X-ray** and **radium** and by transfusions (R S M)

LEUKOPENIA. A decrease in the normal number of leucocytes in the **blood** stream This is a normal accompaniment of certain stages of some diseases while in other diseases it is of grave prognostic significance (R S M)

LEUKORRHEA. A whitish mucoid discharge from the vagina This may normally occur in slight degree at the end of a menstrual period but where marked or persistent, is a sign of infection or disease in the **uterus, cervix,** or **vagina.** (R S M)

LEVEL. The familiar device commonly known as the spirit level finds place not only in the tool kits of bricklayers and carpenters, but is an essential feature of many delicate physical, astronomical, and engineering instruments It depends upon the simple principle that an air-bubble seeks the highest point of the container holding the liquid in which it is formed The glass tube of a level is either slightly curved, like a sausage, with convex side upward, or is ground with a curved inner surface

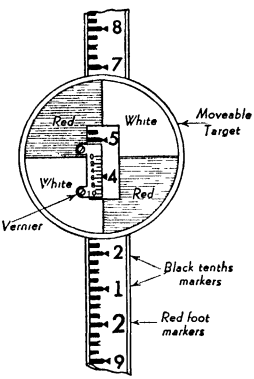


Bubble tube of spirit level, with curvature somewhat exaggerated

If such a tube is supported on a rigid base, the bubble contained therein always comes to equilibrium at the same point whenever the base has the same given inclination to the horizontal If the instrument, with its base, be now reversed end to end, the bubble will move to a new position unless the base is exactly horizontal in both positions By not moving, the bubble indicates that the surface is horizontal along that direction If the bubble does move, horizontally can be obtained by adjusting until the bubble occupies a point midway between the two positions, then a second reversal should produce no change If the tube is provided with a scale, the level may be made a very sensitive instrument for measuring angular changes of inclination The larger the radius of curvature of the tube, the more sensitive is the level

A surveyor's level is an instrument for determining differences of elevation directly It is of use in obtaining comparative levels of two points, or in defining the profile of a certain path, such as a roadway, drainage ditch, etc A level of this type has an accurately made bubble level which is attached to and made exactly parallel with, a telescope In the wye level this telescope rests in Y-shaped supports These supports are held in turn by the instrument base, which may be adjusted by hand, and which is attached, usually by screwing, to the top of a tripod, upon which the instrument rests when in use The bubble tube being parallel to the center of the telescope, the latter will automatically be leveled, ready for a horizontal sight, when the bubble tube is level The dumpy level has the telescope and supports cast in one piece or rigidly connected Since there are fewer movable parts than in the wye level it can be adjusted more easily and remains in adjustment for a longer period of time In use, a level is set up and the base is leveled up by means of leveling screws, until the bubble stays in the center of the bubble tube however the telescope is rotated The telescope barrel contains a ring having cross-hairs, so that when an object is viewed through the eyepiece, the cross-hairs will center on the center of the object being sighted The imaginary line which joins the optical center of the objective and the cross-hairs in the tube is known as the line of sight This line should coincide with the line of collimation The latter is usually the geometric **axis** of the telescope The telescope is slightly different from the ordinary field glass, which has no cross-hairs to be focused on the eyepiece Some levels are erecting, that is, provide an upright image, while others of a more precise or simplified type, produce an inverted view of the object and are known as inverting levels The dumpy level is of the latter type (L D W, F T M)

LEVEL ROD. The length of sight which may be taken with a surveying instrument may be increased—also the facility and accuracy with which the reading is taken—by the employment of a special rod upon which to take a sight A level rod, then, is a measuring stick graduated and plainly marked in feet and tenths of feet, with the subdivisions and numerals receiving a special treatment to render them easily distinguishable Size and coloring of the graduations are of great aid to this end The rod is usually of wood, metal bound, having metal fittings Telescopic features permit a twelve foot rod, for example, to be compressed to six feet in length for ease in carrying A large movable circle with cross lines, known as a target, aids in centering the cross-hairs of the instrument upon the rod (Sometimes this target is equipped with a **vernier** making it possible to read elevations to thousandths of a foot The leveling man sets the center of the target which is read by the rodman)



Level rod (Vernier target unnecessary except for levelling requiring highest degree of precision)

(F T M)

LEVER. Machines.

LEVULOSE. Carbohydrates.

LEYDEN JAR. The earliest form of electrical **condenser**, attributed to two or three investigators, but generally credited to Muschenbroeck of the University of Leyden (1745) It is said that the discovery arose from an attempt to fix or imprison electricity by making a solution of it in water A glass bottle contained the water, into which dipped a nail driven through the cork The bottle was held in the hand while the water inside was charged from a **static machine** by means of the nail When the operator, with his hand still around the bottle, touched the connecting wire, he received a severe shock In the usual form of Leyden jar, the hand and the water are replaced by outer and inner coatings of tin or aluminum foil, the inner coating being provided with a rod and chain for convenience in charging These condensers have low capacitance, but are rugged enough to withstand considerable voltages and are useful for many electrostatic experiments In one interesting form the coatings are removable, leaving the glass jar itself charged A highly charged Leyden jar may, incidentally, be somewhat dangerous to the operator, unless carefully handled. (L D W)

LIANAS. In the tropics climbing plants often have woody stems of considerable size, which are called lianas Many families of plants contain lianas Some lianas are of economic importance, species of *Landolphia,* native in the forests of Africa, yield **rubber.** The means by which lianas hold themselves in place are many. Some have tendrils which twine tightly around any available support Others have **adventitious roots** which attach

them to the stems of sturdier plants, still others are provided with hooks of different kinds, which prevent them from sliding from their support The stems of many lianas twine tightly around each other, and other plants Lianas are often a very conspicuous feature of tropical forests, hanging in long festoons and trailing irregularly in tangled masses over the ground (R M W)

LIBIDO. A normal sexual desire (R S M)

LIBRA. (The scales or the balances) (Map, page 306) Libra is a small constellation best known because it is the seventh sign of the **zodiac** and its symbol is taken for the autumnal **equinox** (i e, the point where the sun apparently crosses the celestial **equator** from north to south) The brightest star in the constellation is a wide **double** which can easily be resolved by a field glass This star carries the Arabic name Zuben el Genubi, the southern scale (W K G)

LIBRATIONS. The term libration is applied in astronomy to many periodic oscillations In particular it is applied to slight apparent oscillations of the **moon,** whereby observers on the earth are enabled to observe somewhat more than fifty per cent of the moon's surface There are three principal librations of the moon a libration in lunar **latitude,** a libration in lunar **longitude,** and a diurnal (or daily) libration

The libration in lunar latitude arises from the fact that the orbit plane of the moon is inclined at about 6 5° to the plane of the moon's equator This produces an effect relative to the earth similar to the terrestrial effects relative to the sun which produces the **seasons** During one half of the **month** the north lunar pole is directed slightly toward the earth, while during the remainder of the month south lunar pole is toward the earth

The libration in lunar longitude is due to the fact that while the rotation of the moon is quite uniform with a period equal to the period of revolution about the earth, nevertheless the orbital motion is not uniform but is in accordance with the **Keplerian law of areas** Consider that a certain point on the surface of the moon is directly toward the earth on a date when the moon is in **perigee.** Since the moon is moving more rapidly in its ellipse at perigee than at any other part of its orbit, by the time that the **elongation** has increased to 90° the selected point has not completed one quarter of a rotation and is not directly toward the earth The result is that the observer will see a slightly different hemisphere of the moon than he did at perigee By the time the moon has reached apogee the selected point will again be toward the observer and he will have the same view of the moon as at perigee At this point the moon's orbital motion is a minimum and the selected point will complete a quarter rotation before a quarter revolution is completed and another slightly different hemisphere of the moon will be visible

The diurnal libration is due to the fact that when the moon is rising the observer sees slightly "over the top" of the moon and at setting slightly under the bottom This is really a libration of the observer rather than a libration of the moon but is classed with the latter

The combined result of the librations is that about 41 per cent of the moon is always visible from the earth, or would be if the sun were shining upon it, 41 per cent is never visible, and the remaining 18 per cent is either visible or invisible depending upon the particular position of the moon relative to the earth

The term libration is also applied to certain periodic **perturbations** in the orbits of members of the **solar system.** (W K G)

LICHENS. Lichens are perennial plants which are of very great interest because of their unique nature For while lichens are treated as plants, and separated into genera and species just as other plants are, in reality they are rather a combination of two plants growing together in an association so intimate that they appear as one Indeed, either of the component plants alone possesses none of the characteristics shown by the two in combination Such an association of two organisms, living together and apparently of mutual benefit to each other, is called **symbiosis;** lichens are often cited as outstanding examples

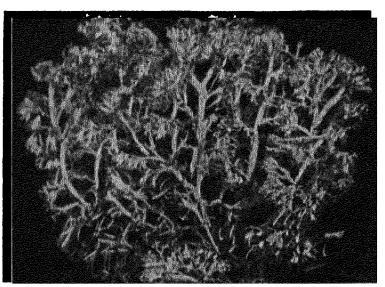
The components of a lichen are always an alga and a **fungus.** The algal constituent is usually one of the simple green **algae,** or, more rarely, a blue green one The alga can live perfectly well by itself, and is often found growing free on rocks or tree trunks in regions where the lichen would exist The fungal component is usually a member of the **ascomycetes.** In lichens growing in cooler regions it is always one of this group There are certain lichens found in the tropics, however, in which the fungal component is a **basidiomycete.** In the lichen, the fungus is by far the most important member of the association, and of the two components it alone is capable of fruiting, although the algal cells do divide and so increase in number Lichens having an ascomycete fungus are usually called ascolichens, while those with a basidiomycete are called basidiolichens or hymenolichens It is very difficult to see how such an association came about, and to determine whether it is really a case of symbiosis or whether it is not parasitism, one of the plants living on the other Unquestionably the fungus benefits from the presence of the alga, since the latter carries on **photosynthesis,** making food materials which are used by the fungus The latter, lacking **chlorophyll,** cannot manufacture its own food It is possible that the alga benefits by the added moisture gathered by the fungus, that the latter protects the alga against desiccation Certainly the association is well established, and seemingly has been so for a long period of time Lichens have been "made" artificially, that is, the two components have been grown separately in pure cultures, and when brought together have produced a lichen So lichens can be formed anew, always with a very constant appearance characterizing the particular form considered

Lichens are found nearly everywhere where civilization has not killed them They are found on the surface of rocks and soil they occur on the bark of trees in the tropics they may be found on the surface of thick evergreen leaves of trees a few species even grow on rocks submerged by the tides They are found on mountain tops which are not perpetually covered by snow. They occur from the tropic regions to the polar regions which are not permanently ice-covered But, being slow growing organisms and affected adversely by various gases, they are not usually found in the vicinity of large cities

The shape of the lichen body or thallus, is very diverse Some species are flat crusts growing on or even in the surface of the substratum, whether the latter be trunk of tree or barren rock Lichens of this type are called crustose In others the thallus is split up into many radiating divisions, and is called a foliose lichen Many others have an erect, often much branched thallus and are called fruticose lichens The color of the thallus may be yellow, orange, brown, gray or black

The greater part of the lichen thallus is composed of **fungus** hyphae, which form a compactly tangled mass The algal cells, usually called gonidia because of the early conception that they were the reproductive cells of the plant, occur in an irregular loosely arranged layer near the outer surface of the thallus Short irregular branches from the fungus hyphae grow tightly around each algal cell, sending into it short absorbing structures called haustoria The surface of the lichen is composed of enlarged thick-walled fungus cells which form a compact layer over the more loosely-arranged central portions In many of the crustose and foliose lichens there are many **rhizoids** which anchor the plant firmly

One of the ways in which a lichen reproduces is by means of soredia. These are minute bits of lichen, formed on the surface, and composed of one or more of the gonidia together with a small mass of closely associated hyphae. Often these soredia are so numerous as to give to the lichen a powdery appearance. Either through disintegration of the lichen body, or because the continuity of the hyphae breaks down, soredia become free from the thallus. They are then easily spread by wind or by water. They may even be carried about unintentionally by the many small insects and other animals which feed on lichens. Lichens also reproduce by means of **spores**; that is, the fungus component forms special reproductive structures very similar to those formed by similar fungi not forming lichen thalli. In the ascolichens these reproductive structures are open cups or mounds, called apothecia. Commonly these apothecia are of a different color from that of the thallus. Inside each apothecium is a layer of asci, containing ascospores which are freed onto the surface of the ascus-containing layer and disseminated by wind or other agencies. An ascospore from a lichen apothecium can become a lichen only when it chances to reach an algal cell and can form an association with it. Since this will happen only rarely, reproduction of lichens is mainly accomplished by asexual or vegetative means. The formation of spores by the fungus would appear to be a persistence of a habit which was necessary when the fungus lived independently, but is of no value in its present condition.



A lichen; reindeer moss, *Cladonia rangiferina*. (From Smith, *Lichens*, Cambridge University Press.)

It has been mentioned that lichens are a foodstuff for many of the lower animals. But some of them are also eaten by higher animals. Reindeer moss, *Cladonia rangiferina*, is the principal food of the reindeer, and may also be used as fodder for other animals. Reindeer moss, not a moss at all, is an erect much-branched lichen which grows abundantly over wide stretches of barren soil. The dense grayish-green tufts grow continuously at the tops, becoming 6–10 inches tall and attaining great age. Another lichen, *Cetraria islandica*, or Iceland moss, may be used as stock food. In habit it resembles reindeer moss but is coarser and less branched. The latter species may also be eaten by man. Like all lichens it contains an abundance of acid which gives a bitter astringent taste and causes violent digestive distrubances if eated in any quantity. To get rid of this, the "moss" is gathered when moist, it being soft and pliable then, thoroughly washed to remove the bitter substances and dried. In this condition it may be stored, or it may be powdered first. To use this powdered "moss," it is soaked in water to remove the cetraric acid present, and boiled. It forms a tasteless jelly which is used in making soups, bread and porridges. Another lichen, known as rock tripe (*Gyrophora hyperborea*), likewise bitter and nauseating, if boiled and treated like Iceland moss, becomes edible, if not palatable, and has been eaten by Arctic travellers in times of need. The manna of the Bible probably refers to another lichen, *Lecanora esculenta*, which occurs in desert lands.

In former times many lichens were used medicinally, as treatment for lung troubles, as purgatives, and as tonics. In part the use of lichens in medicines is explained by the old theory of **Doctrine of Signatures.**

Another and more important use of lichens was as a source of dyes. To obtain the dye the soaked lichen was treated with an alkaline substance, which acted on the acid of the lichen. The purple dye, orchil, was obtained from *Rocella tinctoria*, a lichen of the seaside, in this manner. Only animal fibers can be dyed by it. Another blue dye, litmus, is obtained from *Lecanora tartarea*. Litmus is prepared as a dark brown powder which is soluble in water. Litmus paper is paper which has been soaked in litmus solution. Acids cause litmus to turn red; while alkalis, even in small quantities, will make it blue. Holland produces nearly all the litmus used. Many other lichens yield dyes, some of them blue, others red or crimson, brown and yellow. Today, however, they are little used, modern synthetic dyes having supplanted them.

In those days when powdered wigs were in fashion, another and important use was made of lichens. This was as a hair powder, because of the fact that powdered lichens would retain for a considerable time any fragrance that was given them. So the lichens were packed with sweet-smelling flowers, or other fragrant substances, then dried and powdered. Often other substances, such as musk, were used with the powdered lichen. (R.M.W.)

LICHI. Mammalia, Artiodactyla. An African **antelope.** The species inhabits swamps in the south central part of the continent. (A.W.L.)

LICORICE. *Glycyrrhiza glabra*. Leguminosae. Licorice is obtained from an herb of southern European countries. The plant grows four or five feet tall and has many pinnately-compound, pale green leaves and purplish flowers resembling those of the perennial pea. The fruit is a smooth pod containing several seeds. Licorice is a yellowish substance extracted from the rootstock. In water it swells to a jelly-like mass. It is used in medicines to hide the taste of unpleasant-tasting substances and in the treatment of head colds. But by far the greater part of the licorice root imported is used as a flavoring in chewing tobacco. (R.M.W.)

LIFE ZONE. A geographical area characterized by approximate uniformity of temperature conditions. The life zones are conditioned both by latitude and by altitude, hence a given zone need not be continuous but may, for example, appear at intervals along a mountain range. These zones are of limited value in the study of animal distribution.

In North America three principal zones are recognized, the Boreal, the Austral, and the Tropical. The first is subdivided into the Arctic, the Hudsonian, and the Canadian, ranging from the conditions of the far north to those of Canada and some parts of the northern United States and of more southern mountain regions. The second includes a Transition zone and the Upper and Lower Austral, and the last is not subdivided. (A.W.L.)

LIGAMENT. 1. The connection between the two parts of the shell of **bivalve** mollusks. 2. A strong fibrous band spanning the joint between the ends of two bones in the vertebrates. **Connective tissue. Joint.** (A.W.I.)

LIGATURE. A thread-like material or wire used for tying off blood vessels or other structures of the body during surgical operations. The material may be absorbable as catgut or non-absorbable as silk or linen or metal wire. Ligatures are made in various grades of thickness and tensile strength. (R.S.M.)

LIGHT. This term properly refers to the **range of electromagnetic radiation** frequencies associated with **vision,** though the physicist is apt to think of more objective manifestations, such as **photovoltaic effects,** and sometimes even oversteps the limits of the visible range by calling **infrared** or **ultraviolet** radiation, and even **x-rays,** "light" The wave lengths of visible light extend approximately from 4000 angstroms (extreme violet) to 7700 angstroms (extreme red) Compared with radiation as a whole, this is an extremely limited range It appears to be an inevitable limitation, however, on account of the strong absorption of most substances for radiation on both sides of it The **quantum theory** of radiation applies of course to light, the energy quanta of which are called photons Some of the optical phenomena so readily interpreted on the wave theory, such as **reflection, refraction, interference, diffraction,** and polarization of light, offer difficulties when studied in terms of quanta, the laws of **photoelectric phenomena, photoconductivity,** the **spectrum,** etc, become, on the other hand, much more intelligible **Geometrical optics** is easily expressed in terms of either The well known **Huygens' principle** and **Fermat principle** apply to any radiation, including light, as does the **electromagnetic constant** representing the speed of radiation in a vacuum Discussions of **photometry** and of **color** are, however, usually in terms of visual sensation and hence are confined to light proper, though the physical ideas involved are not subject to such limitation (L D W)

LIGHT CURVE. In the study of **variable stars** and in kindred problems in astronomical research, it is desirable to graphically represent the variation of radiation intensity with time A diagram in which light intensity, on any convenient scale, is plotted as ordinates against time as abscissae is known as a light curve As the number of observations increases it is frequently possible to detect a periodic variation in the light intensity After a provisional period has been determined, some convenient epoch is selected and all of the observations are reduced to the cycle of variation embracing the selected epoch by the use of the provisional period In order that the resulting points may fall on a regular curve, it is frequently necessary to apply a number of corrections to the provisional period The curve drawn through the plotted points, all reduced to the selected epoch by means of the repeatedly corrected period, is known as the mean light curve Examples of light curves will be found in the articles on **long period variables** and on **Cepheids.** (W K G)

LIGHTNING. The electrical condition of the earth's surface and of the atmosphere is quite different in stormy weather from its normal, fair weather state Over a level stretch of country in fine weather, there is distributed a negative surface charge estimated at about 0 00027 electrostatic unit per square centimeter or 0 0014 coulomb per square mile Above this, the electric potential of the atmosphere increases with elevation at the rate of about 100 volts per meter, the upper atmosphere being, apparently, positively charged The earth, the atmosphere, and the **ionosphere** thus form a vast condenser, through the dielectric of which there is constant leakage because of ionization What maintains the charges against this leakage is not well understood

In a rapidly developing rainstorm clouds become charged, positively at the top and negatively below. According to C T R. Wilson, this is brought about by the differential falling rate of large and of very small drops, the former becoming for some reason negatively and the latter positively charged The cloud thus acts as a huge **static machine** with drops as carriers, which operates until the electric stress becomes so great as to cause a discharge of lightning between the charged surfaces of the same cloud, or between two clouds, or between a cloud and the induced charge on the earth under it. These activities of course greatly modify the distribution of charge and potential in the surrounding area, changes which can be detected by electrometers suitably placed

It has been estimated that over the entire earth the frequency of lightning averages about 100 flashes every second and that this rate of discharge represents something like 4,000,000,000 kilowatts of continuous power. The flashes are often very long, sometimes several miles, and have been estimated to be from 4 to 6 inches in diameter Often several flashes, each of very short duration, follow in quick succession over nearly but not quite the same path, thus producing the illusion of forking. "Sheet lightning," so called, is merely the reflection or scattering of light from distant flashes by clouds "Ball lightning" is a very rare manifestation not at all understood Observers describe it as a small incandescent, hissing globe, moving slowly along in the air, sometimes indoors, now and then touching obstacles and scorching them, sometimes exploding (L D W)

LIGHTNING ARRESTER. Lightning arresters are applied to electric lines which are exposed to direct or induced **lightning** disturbances, in order safely to conduct the high frequency or high voltage lightning disturbance to ground These may be divided into two types, those used on power circuits, and those used on communication circuits The former presents the more difficult problem, since a power **arc** tends to follow the **ionized** path created by lightning

A lightning arrester on a power circuit should normally have so high a resistance to current that at the normal line voltage there will be only a negligible leakage of current through the arrester Upon reception of abnormal voltages, this arrester should provide a direct and positive path to the ground, and should interrupt any power arc that may tend to follow the high voltage surge At present several arrangements satisfy these requirements The simplest form of lightning arrester is a horn gap, in which two horns, one on the line, and one connected to the ground, are separated by a small set gap above which they flare to a wider separation When excessive voltage causes break-down of the resistance of this gap, and a discharge to ground, the power arc which follows will usually be extinguished by the electro-magnetic and thermal effects of the arc, which cause it to rise higher on the horns until extinguished by their divergence creating an ever longer arc path On the high voltage transmission lines employed today this extinguishing action is not always reliable, and various types of film and valve arresters have been devised The first of these was the aluminum **cell,** or electrolytic arrester It was necessary to connect this arrester to the line through a horn gap, and since its continued operation required periodic recharging, it necessitated some attendance, which is unnecessary in the more recently perfected valve-type arresters Typical of the latter is the oxide film arrester, which consists of a number of cells in series. A cell is made of a **lead** oxide compound held between metal plates The assembled cell is covered with lacquer insulation, and a certain number of them is built up into a stack which can be connected from line to ground The cell would be a good conductor but for the lacquer A discharge of lightning punctures the latter and causes local heating, which changes the nature of the oxide from conductor to insulator This cuts short the current which the line voltage forces to follow the lightning discharge These dry type arresters do not need daily attendance.

The protection of communication circuits and antennae is simpler due to the lack of high voltage on these circuits A common type consists of two carbon blocks held at a definite spacing in porcelain These are connected from the circuit to ground so that an abnormal voltage will break down the gap and ground itself Since there is no power voltage behind the arc, the gap clears itself as soon as the disturbance has passed. (F T M)

LIGHTNING BUG. Insecta, Coleoptera. Common **beetles** of the family Lampyridae which have a luminous organ located on the under surface of the last few segments of the abdomen They are especially active in warm damp places early in the night, flashing at intervals of a few seconds Occasionally large numbers of these insects flash synchronously, a phenomenon that has not been satisfactorily explained The light apparently serves them in finding mates. (A W L)

LIGHT YEAR The light year is a popular method of expressing large distances It is the distance that light will travel in the course of one year The **velocity of light** is approximately 186,000 miles per second or 300,000 kilometers per second and there are approximately 31,560,000 seconds in a **mean solar year** Accordingly a light year represents a distance of approximately $5\,88 \times 10^{12}$ miles (nearly six million million miles) or $9\,461 \times 10^{12}$ kilometers

For purpose of comparison with other astronomical units of distance we find that a star at a distance of one **parsec** (parallax 1″) is at a distance of 3 258 light years, and that a star at a distance of one light year is over 63,000 **astronomical units** from the earth Hence, the astronomical unit bears about the same relation to the light year as the inch does to the mile (W K G)

LIGNIN. Lignin and **cellulose** are the chief constituents of wood Lignins are complex substances of unknown composition believed to be polysaccharides In the manufacture of paper from **wood** it is necessary to remove the lignin, and this is often accomplished by treatment of the wood fibers with such agents as **sulfur dioxide—calcium** bisulfite sodium sulfate, **sodium sulfide,** or **sodium** hydroxide For the details of these various methods, see **paper** (R K S)

LIGNITE. **Coal.**

LIGNUM VITAE. *Guaiacum officinale* and *G sanctum* This is the heartwood of a tree growing native in the West Indies It is a valuable, tough resinous wood and very heavy, being the heaviest of all commercial woods A cubic foot weighs seventy-six pounds Its principal use is in the making of bowling balls, pulley sheaves and mallet heads (R M W)

LILY FAMILY. Liliaceae The Lily Family has representatives in all parts of the world, and more especially in the drier regions of the temperate zone Several members of the family are important vegetables, notably asparagus and onions, while a great many more are cultivated for ornament Among the latter are the true lilies (the genus *Lilium*), tulips, and hyacinths

Most members of the Lily Family are herbaceous plants with a shallow fibrous root system A few species of *Aloe* and *Dracaena* are shrubby or even small trees Characteristic of the family are underground rhizomes or bulbs, storage organs which enable the plant to survive in regions where protracted dry seasons occur As a rule, these plants have linear undivided leaves which do not show division into **petiole** and **blade.** The **inflorescence** of the family are very diverse In some genera the flowers are solitary, in others they occur in **racemes,** while **umbels** occur in still others The **perianth** of the flower has six separate members in two whorls of three, which are very much alike in size, shape, and color The **stamens** have conspicuous **anthers** The ovary is superior, three-celled, and bears a single **style** with a three lobed **stigma** The fruit is a capsule or a berry

Members of the genus **Allium** are extensively cultivated for food; less widely grown, but forming an important crop in western countries, is *Asparagus* In the Eastern World, bulbs of certain species of *Lilium* are used as foods In the Western World members of this genus are used entirely for ornament. White-flowered species are extensively grown indoors to flower at Easter time (R M W)

LIMA BEAN. *Phaseolus lunatus* **Bean.**

LIMAÇON. The limaçon is a plane curve which may be defined geometrically as follows Draw a circle of radius b passing through the origin of a set of rectangular axes and with its center on the X-axis Draw a secant line OS cutting the circle at B, and extend OB to P so that $BP = 2a$ As the secant rotates about O, the point P describes the limaçon, as shown in Figures 1–3

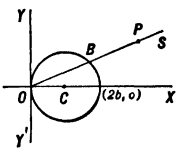
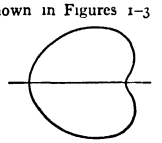
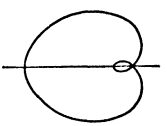


Figure 1


$a > b$
Figure 2 Limaçon


$a < b$
Figure 3 Limaçon

In **polar coordinates,** the equation of the limaçon is

$$r = a - b\cos\theta$$

If $b = a$, the curve becomes the **cardioid** (L L S)

LIMB A jointed appendage, especially of the **vertebrates** Applied usually to **primates** as a collective term to indicate both arms and legs (A W L)

LIMBURGITE An igneous rock with a glassy base, which displays **phenocrysts** of **olivine** and **pyroxene.** (E S C S)

LIME For the fruit of this name, see **Citrus Fruits.** In chemistry, lime is a term applied to **calcium** compounds Limestone, calcium carbonate, caustic lime, calcium oxide, lime water, calcium hydroxide solution; slaked lime, calcium hydroxide solid Percentage of lime expressed in analyses of chemicals is for calcium oxide (CaO) (R K S)

LIMESTONE. A general term for the great, variable group of **carbonate** rocks whose chief constituent is **calcium** carbonate, usually in the form of the mineral **calcite.** Although limestones are quite common among the **sedimentary rocks,** occurring as true limestones or marbles in all periods from the **Archean** to the present, most of them contain large amounts of impurities, of which the more common are, **magnesia, silica, iron oxide,** iron hydroxide, **clay** and organic matter Carbonate rocks relatively rich in magnesia are called magnesian limestones When the magnesia is in the form of the mineral **dolomite** the rock is called either dolomitic limestone or dolomite, according to the abundance of that mineral Limestones which are composed chiefly of shells and shell fragments are called coquina Limestones which contain **argillaceous** material are called either shaly limestone or calcareous **shales,** according to the proportions of calcite to clay Limestones which have a high **bituminous** content may be called stink stein because they emit an unpleasant sulfurous odor when struck with a hammer It has not yet been definitely determined whether fine grained relatively unfossiliferous limestones are entirely the product of ground up calcareous shells, or straight chemical precipitates, either of organic or inorganic origin. Probably, however, the bulk of the limestones, especially those formed during the earliest periods of the earth's history are composed of **drewite,** which in turn is a bacterialalgal precipitate of fresh or brackish water origin but relatively insoluble in sea water, and there-

fore preserved when transported and deposited in the sea At the present time calcareous muds are being precipitated from sea water through the reaction of **ammonium** carbonate on **calcium** sulfate, the ammonium radical resulting from the action of the putrifaction bacteria Limestones are of considerable economic importance being used as building and decorative materials, in the manufacture of portland **cement**, lime for plaster, **fertilizers**, **flux**, chemical lime, etc In 1934 the production of building limestone in the United States was 539,300 short tons valued at approximately $3,655,000 (R M F)

LIMICOLAE. An old order of birds, partially equivalent to the **Charadriiformes.** (A W L)

LIMITS. We say that the limit of a **function** $f(x)$ when x approaches a is equal to l, when for any arbitrary $\epsilon > 0$ there exists a number $\delta > 0$ such that $|f(x) - l| < \epsilon$ whenever $|x - a| < \delta$ We write $\lim_{x \to a} f(x) = l$, or $\lim_{x \to a} f(x) = l$, or $f(x) \to l$ when $x \to a$

If a variable continually increases but remains less than some constant c, it approaches a limit, and this limit is either c or some lesser number

If a variable continually decreases but remains greater than some constant c, it approaches a limit, and this limit is either c or some greater number

The limit of the sum of two variables which approach limits is the sum of those limits

The limit of the product of two variables which approach limits is the product of those limits

The limit of the quotient of two variables which approach limits is the quotient of those limits, unless the limit of the divisor is 0

A variable which approaches a limit 0 is called an infinitesimal

When a variable v increases beyond all bounds, it is said to become infinite, and we write $v \to \infty$

The symbol ∞ does not denote a number, it merely denotes a mode of variation (L L S)

LIMNOBENTHOS. Aquatic benthos **Distribution**

LIMNOLOGY A division of biology that deals with the living organisms, both plant and animal, in fresh water It includes the classification and biology of these organisms and their **ecological** relations (A W L)

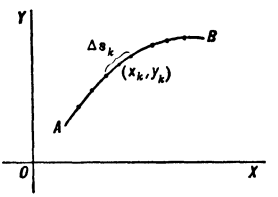
LIMNOSCELIS PALUDIS. (Ancestral lizard) **Fossil Reptiles.**

LIMONITE. The mineral limonite, hydrated oxide of **iron**, corresponds to the formula $Fe_8(OH)_8Fe_2O_9$, but is often very impure due to the admixture of sand and clay It is not found crystallized but grades from loose porous material to compact masses Its hardness is variable but pure material is 5–5 5, specific gravity 3 6–4, usual luster dull to earthy but may be silky to submetallic, color, various shades of yellowish brown, sometimes nearly black, streak, yellowish brown, opaque Limonite is a secondary mineral from the alteration of various other iron bearing ores or minerals, it is of widespread occurrence and used both as an ore of iron and as a **pigment.** Limonite has been formed in marshy and boggy areas and is frequently called bog iron ore Limonite is an important ore of iron in Lorraine, Luxemburg, Bavaria and Sweden It is found in Saxony, Austria, and England In the United States limonite is found particularly in Connecticut, Massachusetts, Pennsylvania, New York, Virginia, Tennessee, Georgia and Alabama, but these deposits are of little economic importance at the present time. (E S C S)

LIMPET. Mollusca, Gasteropoda Marine and fresh water animals related to the snails, with a low conical shell, not spirally twisted In the common limpets the shell is solid and in the keyhole limpets it is either notched in front or perforated between that point and the apex Mollusks of the family Capulidae, more closely related to some of the species with coiled shells than to the true limpets, also have shells which are not spiral and are called limpets One form, *Crucibulum*, is called the cup and saucer limpet and another, *Crepidula*, the boat limpet or slipper shell (A W L)

LIMPKIN. Aves, Gruiformes Birds (**Aves**) of two species resembling the rails but larger One, *Avamus vociferans*, ranges from Florida through the Antilles and Central America and the other, *A scolopaceus*, lives in tropical South America. Also called courlans (A W L)

LINE INTEGRAL. A line integral is an important mathematical concept which is a natural extension of the idea of the **definite integral** of a function of one variable



Let C be an arc of a plane curve, joining points A and B and let $f(x, y)$ be a **continuous function** of x and y in a region containing C Divide C into n sub-arcs by points on C and denote the k^{th} sub-arc by Δs_k Let (x_k, y_k) be any point on Δs_k, and form the sum

$$\sum_{k=1}^{n} f(x_k, y_k)\Delta s_k = f(x_1, y_1)\Delta s_1 + f(x_2, y_2)\Delta s_2 + \cdots + f(x_n, y_n)\Delta s_n$$

The **limit** of this sum (when the limit exists), as each $\Delta s_k \to 0$ (and $n \to \infty$) is called a line-integral of $f(x, y)$ along the path C, and is denoted by

$$\int_C f(x, y)ds$$

Now let $P(x, y)$ and $Q(x, y)$ be continuous functions of x and y in a region, and let C be a given path (arc of a plane curve) As before, divide C into n sub-arcs and let Δs_k denote the k^{th} sub-arc, and let Δx_k and Δy_k be the **projections** of Δs_k on the X-axis and Y-axis respectively Form the sums

$$\sum_{k=1}^{n} P(x_k, y_k)\Delta x_k \quad \text{and} \quad \sum_{k=1}^{n} Q(x_k, y_k)\Delta y_k,$$

if these sums approach limits as each $\Delta s_k \to 0$ (and $n \to \infty$), these limits are defined as line-integrals of P and Q, respectively, along the path C, and are denoted by

$$\int_C P(x, y)dx \quad \text{and} \quad \int_C Q(x, y)dy$$

The combination

$$\int_C P(x, y)dx + \int_C Q(x, y)dy,$$

which is generally written

$$\int_C (Pdx + Qdy) \quad \text{or} \quad \int_C Pdx + \int_C Qdy,$$

is the usual way in which line integrals occur

The line integral $\int_C f(x, y)ds$, defined first, can be expressed in the form $\int_C Pdx + Qdy$

Line integrals are sometimes called curvilinear integrals.

If the path C is given by an equation of the form $y = \phi(x)$, we may replace y by $\phi(x)$ and dy by $\phi'(x)dx$ in the integral $\int_C Pdx + Qdy$, and obtain an ordinary **definite integral** in one variable of the form $\int_{x_1}^{x_2} F(x)dx$

Similarly, if path C is given by an equation of the form $x = \psi(y)$

If the path C is given by **parametric equations** $x = \phi(t)$, $y = \psi(t)$, we may express P and Q in terms of t and dx and dy by $\phi'(t)dt$ and $\psi'(t)dt$, respectively, and obtain an ordinary integral of the form $\int_{t_1}^{t_2} F(t)dt$

A line integral

$$\int_C (Pdx + Qdy + Rdz)$$

along a path C in space may be defined in a similar manner to that in a plane, in this case P, Q, R are functions of three variables x, y, z

By use of **Green's theorem in the plane,** it can be shown that, if P and Q are two functions of x, y which, together with their first **partial derivatives,** are **continuous** within and on the boundary of a certain region, then the necessary and sufficient condition that the line integral in the plane $\int_C (Pdx + Qdy)$ may be independent of the path C in this region is that $\frac{\partial P}{\partial y} = \frac{\partial Q}{\partial x}$

If the preceding line integral $\int_C (Pdx + Qdy)$ be denoted by u, then $\frac{\partial u}{\partial x} = P$, $\frac{\partial u}{\partial y} = Q$

In order that the line integral $\int_C (Pdx + Qdy + Rdz)$ in space have the same value for all paths C joining the same two points, it is necessary and sufficient that

$$\frac{\partial P}{\partial y} = \frac{\partial Q}{\partial x}, \quad \frac{\partial Q}{\partial z} = \frac{\partial R}{\partial y}, \quad \frac{\partial R}{\partial x} = \frac{\partial P}{\partial z},$$

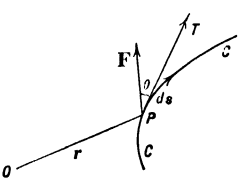
provided P, Q, R and their partial derivatives are continuous in a region surrounding the paths C

If this line integral be denoted by u, then

$$\frac{\partial u}{\partial x} = P, \qquad \frac{\partial u}{\partial y} = Q, \qquad \frac{\partial u}{\partial z} = R$$

(LLS)

LINE INTEGRAL OF A VECTOR FUNCTION. A line integral of a vector function is a mathematical motion of importance in mathematical physics



Let $F(r)$ be a **vector function** of the position vector r Then the line integral $\int_C F \cos\theta\, ds$ along a path C, where θ is the angle between F and the element of arc ds, is called the line integral of the vector function $F(r)$, and is denoted by $\int_C F \cdot dr$ in vector notation. (LLS)

LINE OF APSIDES A line which contains the major axis of an **ellipse** is known as the line of apsides of the ellipse In astronomy the term is used to indicate the line joining **perihelion** and **aphelion** points in an orbit and extending to infinity to cut the **celestial sphere** (WKG)

LINE OF NODES. The line of nodes is the astronomical term applied to line of intersection of any two fundamental planes The line of nodes for the **moon,** is the line of intersection of the plane containing the moon's **orbit** with the plane of the **ecliptic** The line of nodes for any member of the **solar system,** other than **satellites,** is the line of intersection of the plane of the orbit of the object with the plane of the ecliptic. The line of nodes for the earth is the line of intersection of the plane of the earth's **equator** with the plane of the ecliptic (WKG)

LINE OF POSITION. This term is used in navigation to indicate any line upon the surface of the earth on which a ship is known to be located In case two or more lines of position may be obtained the point of intersection of the lines is known as a **fix** and gives the position of the ship Frequently lines of position are sections of circles on the surface of the earth, in which case there will be two points of intersection These points are almost invariably so far apart that a very rough idea of the position of the ship will indicate which of the two points of intersection is the correct position of the ship The more nearly perpendicular the lines are to each other, the more accurate is the determination of the position of the ship

The simplest and most obvious method for locating a line of position is by obtaining a **compass bearing** of some landmark which may be readily located on a **chart** The line of position is drawn on the chart from the landmark with the compliment of the observed bearing For example, if a lighthouse bears northwest from a ship the line of position is drawn southeast from the lighthouse Two or more lines of position obtained in this manner give the position of the ship by a method known commonluy as **cross bearings** In case no suitable second object is available a second line of position may be obtained by determining the distance of the single observed object This distance may be obtained by measuring, by means of a **sextant** or **stadia lines** in a telescope, the angle subtended by some known distance at the shore station (e g the height of the lighthouse from base to lantern) and then solving the triangle involved either by trigonometry or by use of prepared tables to give the distance A second line of position is then a circle drawn about the shore station with the distance as radius

Many government aids to navigation, such as lighthouse and lightships, are equipped with both **submarine** and **radio signals** for use by navigators in determining lines of position when the object is obscured by fog The use of the audible fog signals for this purpose is to be avoided because of the distortion of direction produced by air currents Ships may be equipped with receivers which give the bearing from which both signals are coming to the ship The difference in time of reception of the **submarine** and **radio signals** may be used to determine the distance of the ship from the sending station

In case the ship is out of sight of land and beyond the range of the **submarine signals** the radio direction finder may be used for determining the direction of a sending station from the ship In case the ship is more than fifty miles from the sending station great care must be exercised in laying down the line of position because of the fact that **radio bearings** are **great circles** and not **rhumb lines** Tables are available for converting from **great circle** to **rhumb line** bearings, but even in this case numerous sources of error are present, such as the effect of metal in the ship on the direction of incoming radio signals

In case the ship is more than three hundred miles from land, beyond which distance radio bearings become too inaccurate to be of value, or is not equipped with suitable radio equipment, lines of position must be determined by the methods of **nautical astronomy** employing the **Sumner Line.** (WKG)

LINE SPECTRA. Atomic Spectra.

LINEAR ALGEBRAIC EQUATIONS. A linear algebraic equation in one unknown is a **polynomial equation** of the first degree, and may be written in the form $ax + b = 0$. It may be solved by transposition and division

A linear algebraic equation in two variables is represented by the general form $ax + by + c = 0$ It may be satisfied in general by an unlimited number of pairs of values of x and y The graphic representation of such an equation gives a straight line in the plane

A linear algebraic equation in three variables is represented by the form $ax + by + cz + d = 0$ It is represented graphically by a plane (L L S)

LINEAR ALGEBRAIC EQUATIONS, SYSTEMS OF. A system of linear equations in two or more unknowns is a set of linear equations which are considered together with the object of determining whether they are satisfied by one or more sets of values of the unknowns and of finding these values if such exist

A solution of such a system of equations is any set of corresponding values of the unknowns which satisfy the equations of the system

The general form of a system of two linear equations in two unknowns may be written

$$\begin{cases} a_1x + b_1y = c_1 \\ a_2x + b_2y = c_2, \end{cases}$$

that of a system of three linear equations in three unknowns may be written

$$\begin{cases} a_1x + b_1y + c_1z = d_1 \\ a_2x + b_2y + c_2z = d_2 \\ a_3x + b_3y + c_3z = d, \end{cases}$$

and similar forms for more unknowns

A system of linear equations in which the number of equations is the same as the number of unknowns may be solved algebraically by the method of elimination by addition and subtraction, or by the method of substitution, or by the method of comparison, or by **determinants** A system of two equations with two unknowns may also be solved graphically

If a system of linear equations with the number of equations the same as the number of unknowns has only one solution, the equations are said to be independent and consistent If the system has no solution, the equations are called inconsistent If the equations of the system are satisfied by an unlimited number of values of the unknowns, the equations are called dependent

An inconsistent pair of linear equations in two unknowns is represented graphically by a pair of parallel straight lines A dependent pair of linear equations in two unknowns is represented graphically by one straight line used twice

A system of two linear equations in two unknowns may be solved by the method of elimination by addition and subtraction, by multiplying both equations by such multipliers that the coefficients of one of the unknowns are the same in both equations, then adding or subtracting these equations to eliminate the one unknown, obtaining a linear equation in one unknown, which may be immediately solved, substitution of this value of the unknown in one of the original equations again gives one linear equation with one unknown Or, the second unknown may be found by eliminating the first unknown as in the preceding

In the method of substitution, one of the given equations is solved for one unknown in terms of the other and this is substituted in the other equation, obtaining one linear equation in one unknown

In the method of comparison, both of the given equations are solved for the same unknown in terms of the other unknown, these are equated, and the resulting linear equation in one unknown solved

For a system of three equations in three unknowns, the algebraic procedure for solution would be Eliminate one of the unknowns from one pair of equations and also from another pair, solve the resulting two equations for the two unknowns in them, as just described, substitute the resulting values in one of the given equations to obtain the value of the third unknown An exactly similar procedure applies to systems of more equations with more unknowns, the number of equations being the same as the number of unknowns

A system of two linear equations with two unknowns may be solved graphically by constructing the **graphs** (straight lines) of the two equations (in **rectangular coordinates**) and finding the **coordinates** of the intersection point

By making use of **determinants**, the solution of systems of linear equations may be expressed in convenient and compact form as follows

The solution of the system of equations

$$\begin{cases} a_1x + b_1y = c_1 \\ a_2x + b_2y = c_2 \end{cases}$$

is given by

$$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}}, \qquad y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}},$$

provided the denominator $\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} \neq 0$ If this denominator is zero and if the numerators are not both zero, the equations have no solution and are inconsistent, if all three determinants are zero, the equations are dependent

The solution of the system of equations

$$\begin{cases} a_1x + b_1y + c_1z = d_1 \\ a_2x + b_2y + c_2z = d_2 \\ a_3x + b_3y + c_3z = d_3 \end{cases}$$

is given by

$$x = \frac{\begin{vmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{vmatrix}}{D}, \quad y = \frac{\begin{vmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{vmatrix}}{D}, \quad z = \frac{\begin{vmatrix} a_1 & b_1 & d_1 \\ a_2 & b_2 & d_2 \\ a_3 & b_3 & d_3 \end{vmatrix}}{D},$$

where $D = \begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix}$, provided $D \neq 0$ If $D = 0$, the equations are inconsistent or dependent

A system of n linear equations in n unknowns has a single solution if the determinant of the coefficients is not zero, the value of any unknown can be expressed as a fraction whose denominator is the determinant of the coefficients and whose numerator is the determinant obtained from the denominator determinant by replacing the column of coefficients of this unknown by the column of constant terms (when these are on the right hand side of the equations) This is known as Cramer's rule, and may be expressed symbolically thus

The solution of the system of equations

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \quad \cdot + a_{1n}x_n = c_1 \\ a_{21}x_1 + a_{22}x_2 + \cdot \quad + a_{2n}x_n = c_2 \\ \qquad\qquad\qquad\qquad\qquad\quad \cdot \\ a_{n1}x_1 + a_{n2}x_2 + \cdot\cdot\cdot + a_{nn}x_n = c_n \end{cases}$$

is given by

$$Dx_1 = C_1, \quad Dx_2 = C, \cdot\cdot\cdot, \quad Dx_n = C_n,$$

where

$$D = \begin{vmatrix} a_{11} & a_{12} & \cdot\cdot a_{1n} \\ a_{21} & a_{22} \cdot\cdot a_{2n} \\ \cdot & \cdot \quad \cdot \quad \cdot \\ a_{n1} & a_{n2} \cdot\cdot a_{nn} \end{vmatrix} \neq 0,$$

and C_k ($k = 1, 2, \cdot, n$) is what D becomes when the elements of its k^{th} column are replaced by $c_1, c_2, \quad, c_n$ respectively

The system of equations is inconsistent if the denominator determinant $D = 0$ and if any one or more of the numerator determinants $C_1, C_2, \cdot\cdot\cdot, C_n$ is $\neq 0$

If the constant terms $c_1, c_2, \cdots, c_n$ of a system of linear equations are all zero, the equations are called homogeneous Such a system is therefore of the form

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \quad + a_{1n}x_n = 0, \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = 0, \\ \quad \cdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = 0 \end{cases}$$

If a system of n homogeneous equations in n unknowns has a solution other than the trivial one where each unknown is 0, then the determinant of the coefficients $D = 0$. Conversely, if in such a system the determinant $D = 0$, then the system has infinitely many non-trivial solutions

In general, a system of n equations with less than n unknowns will have no common solution, except under certain special conditions, a system of n equations with more than n unknowns will have an unlimited number of sets of values of the unknowns satisfying it (LLS)

LINEAR DEPENDENCE AND INDEPENDENCE OF FUNCTIONS If n functions $f_1(x), f_2(x), \ldots f_n(x)$ are connected by an identical relation of the form

$$c_1f_1(x) + c_2f_2(x) + \cdots + c_nf_n(x) = 0,$$

where the c's are not all 0, the functions are said to be linearly dependent If no such relation exists, they are called linearly independent

For example, $\sin x$, $\cos x$ and $\sin(x+\alpha)$ are linearly dependent, but x, e^x and $\sin x$ are linearly independent (LLS)

LINEAR DIFFERENTIAL EQUATIONS. The **ordinary differential equation**

$$\frac{d^ny}{dx^n} + P_1\frac{d^{n-1}y}{dx^{n-1}} + P_2\frac{d^{n-2}y}{dx^{n-2}} + \cdots + P_{n-1}\frac{dy}{dx} + P_ny = R,$$

in which the coefficients $P_1, P_2, \ldots, P_n$ are given **functions** of x which do not depend upon y, and R is a given function of x, is called a linear differential equation of order n

If $R \equiv 0$ (identically), the equation is called a homogeneous linear differential equation, otherwise it is called non-homogeneous

Fundamental properties of linear differential equations are the following

If y_1 is a **solution** of a homogeneous differential equation, then cy_1 is also a solution, where c is an arbitrary constant

If $y_1, y_2, \ldots, y_n$ are n **linearly independent** solutions of a homogeneous differential equation of the n^{th} order, then $y = c_1y_1 + c_2y_2 + \cdots + c_ny_n$ is also a solution, and is the **general solution.**

If y_p is a **particular solution** of a non-homogeneous differential equation (without any particular constants of integration), and if $y_1, y_2, \ldots, y_n$ are n linearly independent solutions of the corresponding homogeneous equation (of order n), and if $c_1, c_2, \ldots, c_n$ are n arbitrary constants, then the general solution of the non-homogeneous equation is $y = y_p + c_1y_1 + c_2y_2 + \cdots + c_ny_n$

Let us now consider the case of linear differential equations with constant coefficients, i.e., the case where the coefficients $P_1, P_2, \ldots, P_n$ are constants

Denote $\frac{dy}{dx}$ by Dy, $\frac{d^2y}{dx^2}$ by D^2y, etc., so that D denotes the symbolic operator $\frac{d}{dx}$ Then the differential equation can be written in the form

$$(D^n + A_1D^{n-1} + A_2D^{n-2} + \cdots + A_{n-1}D + A_n)y = R,$$

where the A's are constants and R is a function of x The expression in the parentheses may be considered as a symbolic polynomial in D, and denoted by $f(D)$, where f denotes a polynomial function. The non-homogenous equation is then $f(D)y = R$, and the corresponding homogeneous equation is $f(D)y = 0$

According to one of the fundamental theorems stated above, the solution of a non-homogeneous equation depends on the general solution of the corresponding homogeneous equation, so we consider first the homogeneous equation

For a given homogeneous equation $f(D)y = 0$, the **function** $y = e^{mx}$ will be a solution of the equation if m satisfies the **polynomial equation** $f(m) = 0$, which is called the characteristic equation or auxiliary algebraic equation

Let $m_1, m_2, \ldots, m_n$ be the roots of this equation $f(m) = 0$ (assuming the differential equation to be of the n^{th} order) Then there are three cases to consider

(1) If the roots $m, m_2, \ldots, m_n$ are real and distinct, the general solution of the differential equation is

$$y = c_1e^{m_1x} + c_2e^{m_2x} + \cdots + c_ne^{m_nx}$$

(2) If two or more of the roots $m_1, \ldots, m_n$ are equal, the solution in (1) must be modified if r of the roots are equal to a, the group of corresponding terms in (1) is to be replaced by

$$e^{ax}(c_0 + c_1x + c_2x^2 + \cdots + c_{r-1}x^{r-1})$$

(3) If **complex** values occur among the roots $m_1, \ldots, m_n$, the solution in (1) may be put in a more convenient form, by use of **Euler's theorem,** as follows corresponding to a pair of conjugate complex roots $\alpha + i\beta$ and $\alpha - i\beta$, the solution will contain the terms

$$e^{ax}(A\cos\beta x + B\sin\beta x),$$

where A and B are arbitrary constants, this can also be written

$$A'e^{ax}\cos(\beta x + B'),$$

where A' and B' are arbitrary constants

Let us now consider the non-homogeneous linear differential equation with constant coefficients

The general solution of a homogeneous equation $f(D)y = 0$ is called the complementary function of the corresponding non-homogeneous equation $f(D)y = R$, we shall denote it by y_c Then if y_p denotes any particular solution of $f(D)y = R$, the general solution of the non-homogeneous equation will be $y = y_c + y_p$

To find the particular solution y_p, various methods are available, we shall mention only a few

(1) Method of undetermined coefficients In this method we assume a form which the particular solution will take, using undetermined coefficients, which are then determined by substitution in the differential equation For the most common cases, we take the following assumed forms

I If R is a polynomial in x, say

$$R = a_0x^n + a_1x^{n-1} + \cdots + a_n,$$

assume, in general,

$$y_p = A_0x^n + A_1x^{n-1} + \cdots + A_n,$$

where $A_0, A_1, \ldots, A_n$ are undetermined coefficients, but if D^m is a factor (of highest degree) of $f(D)$, then assume

$$y_p = x^m(A_0x^n + A_1x^{n-1} + \cdots + A_n)$$

II If $R = ce^{ax}$, assume, in general,

$$y_p = Ae^{ax},$$

where A is an undetermined constant, but if $(D-a)^m$ is a factor of $f(D)$ assume

$$y_p = x^m\,Ae^{ax}$$

III If $R = c_1 \sin ax$ or $c_2\cos ax$ or $c_1\sin ax + c_2\cos ax$, assume, in general,

$$y_p = A\sin ax + B\cos ax,$$

where A and B are undetermined constants, but if $(D^2 + a^2)^m$ is a factor of $f(D)$, assume

$$y_p = x^m(A\cos ax + B\sin ax).$$

IV If $R = e^{ax}\phi(x)$, where $\phi(x)$ is a function of the type in I or III, put $y = e^{ax}z$, divide out e^{ax}, and we obtain an equation of the type in I or III.

(2) Short-cut rules

I If $R = e^{ax}$, then $y_p = \frac{1}{f(a)} e^{ax}$.

II If $R = \sin ax$ (or $\cos ax$), then

$$\frac{1}{f(D^2)} = \frac{1}{f(-a^2)} \cdot \sin ax \text{ (or } \cos ax).$$

(3) Method of successive differentiation of the given differential equation Differentiate successively the given equation and obtain, either directly or by elimination, a homogeneous linear differential equation (with right hand member 0) Solve this homogeneous equation for its general solution, which will consist of the complementary function y_c of the original equation plus additional terms involving constants of integration Substitute these additional terms in the original differential equation, equate coefficients of like terms and determine the coefficients

(4) A factoring method If $f(D)$ can be factored into linear factors $(D - m_1)$ $(D - m_2)$ $(D - m_n)$, we may reduce the given differential equation to a system of n first order linear equations thus For definiteness, suppose $n = 3$, so that $f(D) = (D - m_1)$ $(D - m_2)$ $(D - m_3)$ Put

$(D - m_1)y = u$, $(D - m_2)u = v$, $(D - m_3)v = R$

We may solve these first order linear equations successively, starting with the last, and finally obtain y as a function of x

There are also other methods, such as the method of variation of parameters, a method based on a decomposition of $1/f(D)$ into partial fractions, etc, which cannot be described here

The solutions of a few important special forms of linear differential equations (with constant coefficients) are listed here

1 The equation $\frac{d^2x}{dt^2} - k^2x = 0$ has the solution

$$x = c_1e^{kt} + c_2e^{-kt}$$

2 The equation $\frac{d^2x}{dt^2} + k^2x = 0$ has the solution

$$x = c_1 \cos kt + c_2 \sin kt = A \cos (kt + \alpha) = B \sin (kt + \beta)$$

3 The equation $\frac{d^2x}{dt^2} + k^2x = a$ has the solution

$$x = c_1 \cos kt + c_2 \sin kt + \frac{a}{k^2} = A \cos (kt + \alpha) + \frac{a}{k^2}$$

$$= B \sin (kt + \beta) + \frac{a}{k^2}.$$

4 The equation $\frac{d^2x}{dt^2} + k^2x = a \cos nt + b \sin nt$ $(n \neq k)$ has the solution

$$x = c_1 \cos kt + c_2 \sin kt + \frac{1}{k^2 - n^2} (a \cos nt + b \sin nt)$$

5 The equation $\frac{d^2x}{dt^2} + k^2x = a \cos kt + b \sin kt$ has the solution

$$x = c_1 \cos kt + c_2 \sin kt + \frac{1}{2k} t(a \sin kt - b \cos kt)$$

6 The equation $\frac{d^2x}{dt^2} + 2l\frac{dx}{dt} + k^2x = 0$ has the solution

(a) if $l^2 = k^2$ $x = e^{-lt}(c_1 + c_2t)$,

(b) if $l^2 > k^2$ $x = e^{-lt}[c_1e^{\sqrt{l^2 - k^2}\,t} + c_2e^{-\sqrt{l^2 - k^2}\,t}]$,

(c) if $l^2 < k^2$ $x = e^{-lt}[c_1 \cos \sqrt{k^2 - l^2}\, t + c_2 \sin \sqrt{k^2 - l^2}\, t]$

or $$x = Ae^{-lt} \cos (\sqrt{k^2 - l^2}\, t + \alpha)$$

$$= Be^{-lt} \sin (\sqrt{k^2 - l^2}\, t + \beta).$$

A linear differential equation of the type

$$x^n\frac{d^ny}{dx^n} + A_1x^{n-1}\frac{d^{n-1}y}{dx^{n-1}} + \cdots + A_{n-1}x\frac{dy}{dx} + A_ny = R,$$

where the A's are constants and R is a function of x, may be reduced to a linear differential equation with constant coefficients by the substitution $x = e^z$ or $z = \log x$ Such an equation is sometimes called a homogeneous linear equation, although this conflicts with another use of the term

Differential equations may occur in systems of linear differential equations in several unknown functions The general method for solving such equations is to combine the equations so as to give an equation in one unknown function, i e, eliminate all but one unknown function from the equations, and then use the previous methods (L L S)

LINEAR DIFFERENTIAL EQUATION OF FIRST ORDER. Ordinary Differential Equations of First Order and First Degree.

LINEAR FUNCTION. A linear function is a polynomial function of the first degree, and is therefore a function of the form $ax + b$, where a and b are constants and x is the variable.

The graphic representation in rectangular coordinates of any linear function $y = ax + b$ is a straight line with slope a and cutting off on the Y-axis an intercept b (L I S)

LINEAR TRANSFORMATION A linear (homogeneous) transformation of a set of variables $x_1, x_2, \ldots, x_n$ is given by a system of n linear equations

$$\begin{cases} a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = y_1, \\ a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = y_2, \\ \cdots\cdots\cdots\cdots\cdots\cdots \\ a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = y_n \end{cases}$$

with given coefficients a_{ij} (L L S)

LINEAR VECTOR FUNCTION. A linear vector function is a type form of mathematical expression which finds its principal application in certain parts of mathematical physics

Let v be a **vector variable** expressed in terms of a system of non-coplanar vectors $\mathbf{a}_1$, $\mathbf{a}_2$, $\mathbf{a}_3$ by $\mathbf{v} = v_1\mathbf{a}_1 + v_2\mathbf{a}_2 + v_3\mathbf{a}_3$ Then if

$$\mathbf{f} \equiv f(\mathbf{v}) = v_1f(\mathbf{a}_1) + v_2f(\mathbf{a}_2) + v_3f(\mathbf{a}_3),$$

and if $f(\mathbf{v})$ is continuous, then $\mathbf{f} \equiv f(\mathbf{v})$ is called a linear vector function

If $f(\mathbf{v})$ is a linear vector function, then

$$f(k\mathbf{v}) = kf(\mathbf{v}), \quad f(\mathbf{u} + \mathbf{v}) = f(\mathbf{u}) + f(\mathbf{v}) \quad \text{L L S}$$

LINEN. Flax.

LINES OF FORCE. Fields of Force.

LING. Burbot.

LINGUATULIDA Pentastomida.

LINGULA. Invertebrate Paleontology.

LININ. Cell.

LINKAGE. Electromagnetic Induction; Inductance; Coupling.

LINNET. Finch.

LINOLEUM. Flax.

LINSANG Mammalia, Carnivora *Linsanga* Slender predacious animals with short legs and very long tails Related to the civets Several species are Oriental and one African (A W L)

LINSEED OIL. Flax.

LION. Mammalia, Carnivora *Felis leo*, one of the best known species of the cat family from its long eminence as the "king of beasts" Like the tiger, the lion reaches a length of ten feet from tip to tip and a weight of five hundred pounds It is uniformly

tawny as a rule but varies from much lighter yellowish shades to very dark brown The male usually has a full mane but this also is a variable character, males with no mane have been found

Lions are nocturnal in habit and are said to be generally shy, although they will attack man under some conditions They sometimes hunt in groups, sharing the animals that they kill, and sometimes eat the carcasses of animals that they have not killed, even when badly decomposed

The lion ranges over all of Africa and into Asia as far as Mesopotamia and northwestern India Many of the specimens seen in menageries and with circuses were born in captivity. (A W L)

LIP. A fleshy fold at the external orifice of a cavity, especially those which bound the mouth of the vertebrates (A W L)

LIPARITE. The term liparite is synonymous with **rhyolite,** but used chiefly by European geologists The word was derived from the Lipari Islands where liparites are quite common (E S C S)

LIPOMA. A fatty **tumor,** one made up of fat cells They are **benign** and seldom cause pain (R S M)

LIPPMANN FRINGES. The Lippmann **interference** fringes or laminae constitute an interesting photographic demonstration of stationary waves of **light** A film of special fine-grained photographic emulsion is backed by mercury, which serves as a reflector Monochromatic light falling normally upon the film and reflected by the mercury gives rise to **interference** in stationary waves whose nodes and antinodes are in planes parallel to the reflector At the antinodes the photographic action is a maximum, while at the nodes there is none Hence when the film is developed the silver deposits in layers corresponding to the antinodes, one-half wave length apart The laminar structure therefore depends upon the color of the light Neuhauss has succeeded in making photomicrographs of the cross section of the film, resembling a cut jelly-cake

The silver layers may be made to act as reflecting planes whose spacing is just right to cause reinforcement by interference when the reflected light is of the same wave length as that to which the plate was exposed White light is thus selectively reflected, so that if part of the plate had been exposed to green light, that part would reflect green, etc Lippmann adapted this principle to the production of photographs in natural colors, but the technique of the process is very difficult and it has not come into practical use (L D W)

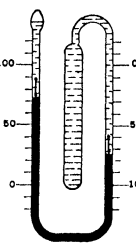
LIQUATION. A process of magnetic differentiation believed to take place as a result of the separation of two immiscible liquids from the parent **magma.** (E S C S)

LIQUEFACTION OF GASES Air.

LIQUID CRYSTALS. Cybotaxis.

LIQUID-EXPANSION THERMOMETER. This familiar instrument for measuring **temperature,** developed by Fahrenheit and others, makes use of the relative expansion of a liquid and its transparent container The use of mercury as a thermometric substance is recommended by its high boiling point (+357° C) and low freezing point (—39° C), and by the constancy of its expansion coefficient Alcohol is often substituted, because of its much lower freezing point (—114° C), and because its expansion coefficient is more than six times that of mercury, it is also lighter and cheaper Its boiling point, however, is so low (78° C) that it cannot be used for high temperatures, and it must be stained to be easily visible In some mercury thermometers an inert gas is introduced above the mercury, the pressure of which, as the mercury expands, raises the boiling point of the mercury and hence increases the range The Beckmann mercury thermometer has a very large bulb and a very fine bore with a storage reservoir for mercury at the top It is used only for differential temperature measurements, with a range of only a few degrees, and is graduated to hundredths of a degree

Some thermometers are designed to indicate the maximum or the minimum temperature attained during a given period The best maximum thermometers employ mercury, with a constriction just above the bulb at which the mercury thread separates when the temperature starts to fall, leaving the top of the column to mark the highest temperature Minimum thermometers employ alcohol, with a light, solid index or marker just inside the free surface As the temperature falls, this marker is pushed down by the surface tension, and remains at the lowest point attained In a thermometer devised by Sixe, both maximum and minimum temperatures are similarly indicated by a small iron marker, which can be adjusted by means of a magnet



A maximum minimum thermometer (Sixe's form)

Liquid thermometers are subject to certain inherent errors, among which are those due to the unequal temperature of bulb and stem and to the imperfect recovery of the volume of the bulb after heating The latter effect may accumulate over a long period, requiring recalibration from time to time, especially if the instrument is used over wide ranges of temperature (L D W)

LIQUIDS States of Matter; Hydrostatics; Hydrokinetics.

LIROCONITE. The mineral liroconite is a hydrous **arsenate** of **copper** and **aluminum** of uncertain formula It is a **monoclinic** mineral usually in very small crystals, hardness 2–2 5, specific gravity 2 9, vitreous luster, color various shades of blue, blue green and green It appears to be a secondary mineral associated with other copper compounds as **malachite.** It is found in Czechoslovakia and Cornwall, England (E S C S)

LISSAJOUS' CURVES. Harmonic Motion.

LITCHFIELDITE. A **nephelite syenite** consisting of **albite, nephelite,** and **biotite** with small amounts of **cancrinite** and **sodalite.** It derives its name from the type locality at Litchfield, Maine (E S C S)

LITCHI. *Litchi chinensis* Sapindaceae The litchi tree is a native of southern China, and has spread extensively in cultivation through many southern Asiatic countries It has **pinnately** compound leaves, the leaflets of which are **lanceolate** and leathery The small flowers are borne in **panicles,** and have no petals The fruit is roughly spherical, an inch to an inch and a half in diameter, with a hard brittle rind Within this rind is a fleshy translucent pulp, the aril, the part which is eaten When fresh it is most delectable, when dried (the form in which it appears in American markets), it is much shrunken The fruit contains a single seed (R M W)

LITER. A metric measure of volume, comparable with the quart Originally it was identical with the cubic decimeter (1000 cubic centimeters) On account of the change in the metric standard of mass and the basis upon which it is fixed, the liter is, however, now defined as the volume of 1 **kilogram** of pure water

at its maximum density (4° C), which is about 1000 027 cubic centimeters Volumetric apparatus formerly graduated in cubic centimeters is now rated in milliliters (L D W)

LITHIFICATION. Lithify Literally to turn to stone A term commonly applied to the consolidation and hardening of sediments so as to form a **sedimentary rock.** (R M F)

LITHIUM Symbol Li Atomic number 3 Atomic weight 6 940 Density 0 534 at 20° Melting point 186° C Boiling point > 1200° C Isotopes 6 (7 9%), 7 (92 1%)

Lithium is a silver-white metal, harder than **sodium** but softer than lead, tough and may be drawn into wire or rolled into sheets, tarnishes rapidly in air, preserved under naphtha, reacts with water forming lithium hydroxide solution and **hydrogen** gas Discovered by Arfvedson in 1817

Lithium occurs in **lepidolite** (lithium mica, lithium aluminosilicate, 1%–3% Li) **spodumene,** (lithium aluminosilicate, 4% Li), **amblygonite** (lithium aluminum fluorophosphate, 8% Li) in Saxony, France, Manitoba and Quebec, South Dakota, Arizona, New Mexico and California The lithium-containing mineral is digested with concentrated **hydrochloric acid** and the resulting soluble chloride, after removal of other metals, is converted into slightly soluble **carbonate** Lithium metal is obtained by **electrolysis** of fused lithium **potassium** chloride mixture out of contact with air

Chloride Lithium chloride (LiCl), white solid, deliquescent, melting point 614° C, soluble in water and in alcohol

Hydride Lithium hydride (LiH), white crystals, by heating lithium metal in hydrogen

Hydroxide Lithium hydroxide (LiOH), white solid, melting point 450° C, soluble

Oxide Lithium oxide (Li_2O), white solid, by heating lithium metal in oxygen or dry air, reactive with water to form soluble lithium hydroxide, lithium peroxide (Li_2O_2), white solid, by reaction of **hydrogen peroxide** and lithium hydroxide solution in alcohol, and later dehydration of the precipitate

Other soluble salts Lithium sulfate (Li_2SO_4), lithium nitrate ($LiNO_3$), lithium perchlorate ($LiClO_4$), (soluble in alcohol)

Slightly soluble salts Lithium carbonate (Li_2CO_3), lithium phosphate (Li_3PO_4), lithium fluoride (LiF)

Lithium carbonate and citrate are used in medicine as "litha water," a **diuretic** of doubtful value

Volatile lithium salts, such as the chloride, color the bunsen flame carmine red (R K S)

LITHOCYST. A small hollow organ containing a solid particle, found at the base of a tentacle on the margin of certain **hydrozoan** medusae It is also called an otocyst or statocyst Superficially like the tentaculocysts of jellyfishes but not fundamentally related (A W L)

LITHOGRAPHIC LIMESTONE. Jurassic.

LITHOLOGY. Literally the graphic study of rocks, hence a synonym for **petrography,** but not **petrology.** This term is usually restricted, however, to the purely descriptive macroscopic study of rocks, without the aid of the **petrographic microscope.** (R M F)

LITHOPHYSAE. Lithophysae are concentric shells of crystalline material occurring in **lavas** and are often very fragile They are usually very small but may reach a diameter of several inches The term is derived from the Greek words meaning stone, and puff up (E S C S)

LITHOSPHERE. The term lithosphere, from the Greek meaning, a stone, and a sphere, refers to the solid, rocky outer portion of the earth as distinguished from the barysphere, a term also derived from the Greek meaning heavy, and sphere, and designating the unknown interior which is supposed to consist of matter heavier than the surface materials The true lithosphere, which is formed only of the types of rocks which are now observable to the geologist, is assumed to be only approximately 60 miles thick A common but inaccurate synonym of lithosphere is "crust"

About 99 5 per cent of the solid outer crust of the earth is made up of eleven elements, combined in various ways, forming mainly **silicates** and **oxides,** and less commonly **carbonates** and **phosphates** Clarke and Washington (1925) designate as petrogenic or rock forming elements the following 22 arranged in the table in order of their abundance in the 10-mile crust of igneous and sedimentary rocks They designate as metallogenic elements **copper, zinc** and all elements of higher atomic weight (See **Chemical Composition**)

ELEMENTS IN ORDER OF THEIR ABUNDANCE IN THE 10-MILE CRUST OF IGNEOUS AND SEDIMENTARY ROCKS OF THE EARTH

	Element	Per cent		Element	Per cent
1	**Oxygen**	46 71	12	**Carbon**	0 094
2	**Silicon**	27 69	13	**Manganese**	0 090
3	**Aluminum**	8 07	14	**Sulfur**	0 052
4	**Iron**	5 05	15	**Barium**	0 050
5	**Calcium**	3 65	16	**Chlorine**	0 045
6	**Sodium**	2 75	17	**Chromium**	0 035
7	**Potassium**	2 58	18	**Fluorine**	0 029
8	**Magnesium**	2 08	19	**Zirconium**	0 025
9	**Titanium**	0 62	20	**Nickel**	0 019
10	**Hydrogen**	0 14	21	**Strontium**	0 018
11	**Phosphorus**	0 13	22	**Vanadium**	0 016
				Remainder	0 057
		99 47			0 530

Most rocks are, accordingly, silicates or aluminosilicates of five elements, namely, iron, calcium, sodium, potassium, magnesium Excluding the rare gases, helium, neon, argon, only six of the elements (namely, lithium, beryllium, boron, nitrogen, scandium, cobalt) up to and including nickel (number 28 in the periodic classification) are not contained in the above list Beyond nickel only three elements (namely, strontium, barium, zirconium) appear

Among the considerations of particular significance are (1) the high percentage of silicon, (2) the *relatively* high percentage of elements similar to silicon, namely, aluminum (3rd), titanium (9th), zirconium (19th), (3) the unique position of iron (4th) above, but number 26 in the periodic classification, (4) the positions of the alkali metals (sodium 6th, potassium 7th) and alkali earth metals (magnesium 8th, calcium 5th, strontium 22nd, barium 16th), (5) the low percentages of the familiar elements, hydrogen, carbon, nitrogen, sulfur, phosphorus, chlorine, (6) in most cases the even numbered elements are relatively more abundant than the adjoining odd numbered elements Rocks in the 10-mile crust of the Earth

Igneous rocks, 95% (75% of this is $SiO_2 + Al_2O_3$), shale, 4 (74% of this is $SiO_2 + Al_2O_3$), sandstone, 0 75 (78% of this is SiO_2), limestone, 0 25 (84% of this is $CaCO_3$), total, 100 00 (of the total 60% is SiO_2, and 15% Al_2O_3)

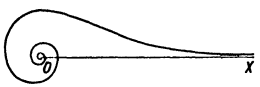
Barnett (1924) has estimated that the interior of the earth—77 5 per cent of the whole—is an irregular core of metallic substances (iron 90%; nickel, cobalt, copper 7%) in a fused state, probably more or less mixed with silicates, whilst an irregular sheet of silicates as slag, more or less mixed with metal, constitutes the remaining 22 5 per cent. (R K S, R M F)

LITMUS. Lichens; and Indicators.

LIT-PAR-LIT. A term derived from the French, meaning bed by bed, which is used to define banded **gneisses** produced by the injection of igneous material along planes of **foliation**, usually with an accompanying alteration by **contact metamorphism.** (R.M.F.)

LITTORAL. Inhabiting the shore line of the ocean in shallow waters and in the tidal zone which is periodically exposed to the air. (A.W.L.)

LITUUS. The lituus is a spiral curve represented by the equation $r^2\theta = a$ in **polar coordinates.** (L.L.S.)

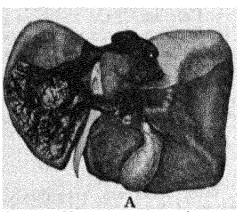


Lituus.

LIVER. A large gland associated with the **digestive system** of vertebrates. It secretes the bile which is discharged into the intestine, absorbs from the blood the products of **carbohydrate** digestion and stores them as glycogen, acts on nitrogenous wastes and returns them to the **blood** in the form of **urea** and related compounds, and destroys worn out red corpuscles. Other less striking functions have also been credited to the liver.

The bile discharged through the intestine plays an uncertain role in the digestion of fat and carries with it some of the more complex waste products of the body.

In structure the **vertebrate** liver is very complex. It develops as a hollow outgrowth of the embryonic gut just behind the stomach which forks to produce the gall-bladder and the liver. The connection with the gut persists as the common bile duct. In the adult the liver cells are arranged in cords, separated by blood channels with incomplete lining known as sinusoids. Within the cords minute bile capillaries between the cells converge to larger and larger ducts which ultimately form the main hepatic duct. The gland receives blood from an arterial supply and also from the portal vein. The latter drains blood from the capillaries of the intestine and breaks up into sinusoids in the liver. These small passages are drained by the hepatic vein.



A

Liver. View is from undersurface, showing the gall-bladder (A).

The name liver has also been applied to large digestive glands in the phyla **Mollusca**, **Arthropoda**, and **Echinodermata.** (A.W.L.)

LIVERWORTS. Bryophytes.

LIZARD. Reptilia, Sauria. Mostly small animals, some species attaining a length of several feet, usually elongate with short legs and a long tail. They are closely related to the snakes but differ in having eyelids and in having the ventral surface of the body as well as the upper covered with small scales.

The classification and nomenclature of these animals is confused. The lizards are sometimes grouped with the snakes but some authorities regard them as a separate order of **Reptilia.** (See also **Fossil Reptiles.**)

There are many species of lizards but with the exception of the poisonous **Gila monster** and the edible **iguanas** they are of no economic importance. A few of the smaller species are eaten to a limited extent.

Among the lizards whose names do not indicate the association with this group are the **geckos, iguanas, swifts, chamaeleons, chuck-walla, mountain boomer, horned toads, glass snakes, Gila monster, race runner, skinks, agamas, molochs, anolises, basilisks, scheltopusik, blind worms, monitors, teju,** and **amphisbaena.** (A.W.L.)

LLAMA. Mammalia, Artiodactyla. A domestic animal, *Lama huanacus glama,* found in the high altitudes of western South America and on lower ground in the southern part of the continent. It has moderately long legs and a long neck, and is one of the New World representatives of the **camel** family. The animal is a source of wool, hides, meat and milk and is used as a beast of burden.

The name llama is sometimes applied to the entire group including the wild **vicunia** and **guanaco** and the domestic **alpaca** as well as the true llama. Both of the domestic species are supposed to have been derived from the guanaco. The llama is the larger animal but does not produce such fine wool. (A.W.L.)

LLOYD'S MIRROR. Young's Interference Experiment.

LOACH. Pisces, Teleostei. Small bottom-feeding fishes (**Pisces**) of Europe, and Asia. They have a long slender body and a group of barbels near the mouth. The European species are eaten.

A few fishes of similar form but not closely related are called African loaches. (A.W.L.)

LOAD. Any force which acts on a body is called a load. A concentrated load is a theoretical force having a contact area infinitely small compared with the area of the surface of the body upon which the force acts. A distributed load is one whose area of contact covers, wholly or partially, the area of the supporting surface of the body. Distributed loads are uniform if the intensity is the same for each unit of area covered by the load. When this intensity varies, the distributed load is non-uniform.

Loads may be classified as central, torsional or bending depending upon the effect on the body. A central load is a concentrated load whose line of action passes through the **center of gravity** of the surface under consideration. A distributed load is a central load if the line of action of the **resultant** acts through the center of gravity of the surface. If the central force is at right angles to the surface it is called a direct or axial load. Tensile loads are axial loads which cause an increase in the length of a member. Compressive loads are axial loads which decrease the length of a body. Central forces which act in the plane of the surface under consideration are shearing loads. A torsional load is a force which causes a body such as the **shaft** of a machine to twist about its longitudinal axis. Loads which tend to change the **radius of curvature** of a body are called bending loads. Forces which bend a beam are known as transverse loads. An eccentric load, which is a type of bending load, is a force acting normal to a surface but not passing through the center of gravity of the surface.

A classification of loads which is important to the structural designer, is that which distinguishes between dead and live loads. A permanent load acting on a structure, such as its own weight, is called a dead load. Variable or moving loads are classed as live loads. Snow, wind and merchandise constitute variable loads. Moving loads are made up of the weight of people, vehicular traffic, railroad trains or street cars. The dead weight of traveling **cranes** and their loads must often be considered as live loads when designing the supporting structure. (C.W.C.)

LOAD FACTOR. The ideal electric load, from the standpoint of equipment needed and operating routine, would be one of constant magnitude and steady duration. Such an ideal load is shown in Figure 1 (a). The cost to produce an elementary area of this load curve (i.e., one kilowatt-hour) could be from ½ to ¾ of that

to produce the same unit under the more frequently realized condition illustrated in Figure 1 (b) Hence the problem of variable load is a vital one, for, from

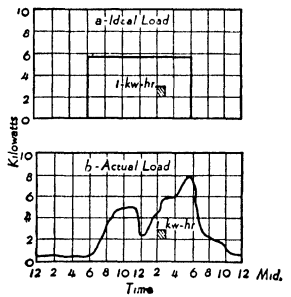


Figure 1.

the industrial viewpoint, the cost of manufactured articles includes an energy charge as an element of no inconsiderable proportion, while from the utility viewpoint, the chief concern is to put each kilowatt-hour on the transmission line at as low a production cost as possible

The general conclusion is that industrial processes and domestic uses impose highly variable demands upon the capacity of a plant The exceptions do not disprove this as a basic operating condition of most generating equipment Even though the characteristics of the demand made by any one user will hardly be understood until his conditions of use are fully investigated, one might suppose, for purposes of illustration, that this has been accomplished Then Figure 2 might represent the domestic demands of two adjacent residences There is, apparently, no great similarity between them, nor would one expect a similarity unless he knew the family life of the two sets of occupants to be similar Furthermore, the next residence might have a still different form of load curve, and so on for still other residences This is all the result of the natural fact of the individual differences of persons However, as the number of customers increases, the effect of individual differences is submerged to the general use conditions of the community, and the resulting load curve is typical

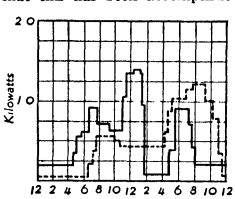


Figure 2
Individual customers' load curves

The variable load problem has injected into the language a number of terms The basic information is the operating data of demanded load plotted against time sequence This is commonly referred to as a load curve and usually appears with kilowatts as the power unit and hours as the time unit, the sequence being the 24 hours beginning with midnight The most important variations of this are the monthly and annual load curves, each of which is the average of the daily load curves over the period named

Some information other than the kilowatt-hour magnitude of energy produced is needed to describe an operating condition Evidently the relation of the peak load to the average in some measure satisfies this requirement. This relationship is expressed in the load factor The daily, monthly, or annual load factor is the average load over the time specified divided by the maximum peak The latter is seldom taken as the maximum instantaneous peak but rather as the maximum 15-minute, half-hour, or even hour-long peak In general, the length of time over which the peak load shall be measured is increased as the period of time in which it might occur is increased from the daily to the monthly or the annual period Load factor should not be confused with power factor, with which it has nothing in common (F T M)

LOAM. Soil.

LOBATA. Ctenophora.

LOBECTOMY. Surgical removal of a lobe of a gland or organ, such as the lung (R S M)

LOBSTER. Crustacea, Decapoda A large marine animal (**Decapoda**) resembling the crayfishes in form The American lobster, *Homarus americanus*, found on the Atlantic Coast from Labrador to North Carolina, attains a length of over twenty inches and a weight of almost thirty pounds, but as a result of large numbers being caught for food they are now rarely taken above one foot long The Norway lobster, *Nephrops norvegicus*, a smaller species with more slender pinchers, is among the marine species known as crayfishes, as also are the spiny lobsters of the warmer latitudes in both Atlantic and Pacific oceans The spiny lobsters, *Palinurus vulgaris*, differ conspicuously from the true lobsters in the absence of the large pinchers Both are important as food

The American lobster is taken in traps (lobster pots) baited with dead animal matter The catch has declined from a peak of 100,000,000 lobsters annually to a small fraction of that figure but measures of protection and propagation are expected to aid in restoring partly their former abundance The similar European lobster has followed the same course (A W L)

LOCKJAW. Tetanus.

LOCOMOTION. The process of moving from place to place, a characteristic power of most animals and a lesser distinction between them and the majority of plants

Locomotion is necessary to animals because their food is organic and in most environments does not reach the animal through external forces Even the **sessile** animals, which may or may not be capable of some locomotion, often accomplish the same end by bringing food within reach through their own activities

In the water the weight of the surrounding medium is so great that the animal may float, and the resistance offered to its body is sufficient to be utilized for propulsion The body is so shaped that resistance is little in the direction of locomotion but great where propulsive effort is expended Projections from the surface which beat against the water like oars or push or pull by undulating are common organs of locomotion here They include **cilia** and **flagella** in one-celled and small multicellular forms, specialized jointed appendages of **arthropods**, and fins and flippers of **vertebrates** Undulation of the body itself is a sufficient means of propulsion in some animals

Some aquatic forms rest on the bottom and the terrestrial animals are forced to rest on some solid support at least intermittently because the air is too light to float them In many of these forms the friction of contact with a solid is utilized by the development of movable supporting appendages which are shifted alternately to change the animal's position This means of locomotion is known as walking Other animals, notably the worms, creep through the action of muscles in the body wall The body is progressively elongated and shortened, parts being thrust ahead and then drawn up to the maximum point of advance In this type of locomotion they are aided by suckers or setae in some cases to grip the supporting surface.

Running may involve no other difference from walking than more rapid movement or it may also involve a change in the order of movement of the appendages and in their position when used, as in the various gaits of a horse. Jumping always differs in that the appendages set farthest back must be powerful enough to project the entire animal through the air. It is highly developed in such insects as the flea beetles and the grasshoppers and in the frogs and kangaroos among the vertebrates. In this class a gallop is no more than a series of leaps.

Locomotion in the terrestrial vertebrates also shows progressive change in the manner of using the appendages. The entire sole of the foot rests on the ground in the more primitive animals, and they are said to be plantigrade. This posture is well adapted to walking but not to running. Animals that need speed are digitigrade, resting on the tips of the toes. This position adds the length of the feet to that of the legs and permits a longer stride. It also adds the springiness incidental to the greater freedom of the ankle joint. The final expression of this position of the leg appears in the unguligrade (**Ungulata**) hoofed animals where only the hoof comes into contact with the ground. Man is plantigrade in walking and at rest but rises to his toes when he runs.

The locomotion of snakes is a highly specialized creeping process in which the ribs serve as the movable appendages and the grip of the body on the ground is provided by the broad scales of the ventral surface which project backward.

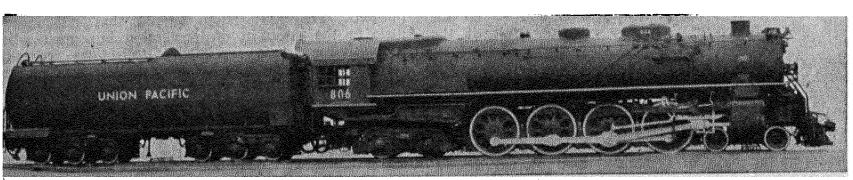
Climbing animals may merely run along branches, aided by sharp claws to provide a secure grip. The sloths, however, have the claws developed as great hooks which suspend them in an inverted position. They walk as well as hang upside down. The primates show the most extreme specialization for a form of locomotion in the trees called brachiation. Their pectoral appendages are arms, adapted for grasping and suspension, and the pelvic appendages are supporting legs. They move by swinging from branch to branch or by shifting from one hold to another, as human beings climb.

Locomotion in the air is a highly specialized process of **flight**. (A.W.L.)

LOCOMOTIVE. The locomotive is a self-propelled vehicle having an excess of power over its own propulsive needs, so that it is enabled to draw a useful load, generally a train of railway cars. While formerly all railway locomotives were steam propelled, the present day witnesses other propulsive media employed in this service, some of which have made large inroads into fields formerly the province of the steam locomotive. Briefly, the types of locomotives encountered at present are: first, **steam engine** driven; second, **electric motor** driven (This refers principally to the electric locomotive obtaining its power from third rail or elevated trolley. While the storage battery locomotive has a definite place in industrial haulage and switching, it is not suited to line service. Many of the lightweight streamlined passenger trains powered by Diesel engines have electric drive); third, **Diesel**, and other **internal combustion engine** driven locomotives. Due to the high **load factor** and uniform operating conditions of rail locomotives, the Diesel engine is particularly well suited for use where internal combustion drive is employed. There is at present a growing tendency on the part of the railroads, stimulated by public interest, to employ specially built Diesel powered train units for high speed passenger runs. Other locomotive types are the **steam turbine** and the **compressed air** locomotives; the former, having enjoyed some measure of success in Sweden, is now being tried in the United States. The latter is a common mine type.

The main function of a locomotive is to exert a draw bar pull at the coupler. This it accomplishes by applying a rotative effort to driving wheels which rest on the track. Since the draw bar pull can not possibly exceed the weight on the drivers multiplied by coefficient of friction between driver and track, it is seen that there is not the same urge for light-weight construction in a locomotive as in the power plant, for example, of the transport airplane. The elements of the locomotive consist, in part, of a frame and running gear, the latter consisting, in part, of a number of wheels called drivers, to which the propulsion is transmitted in the form of a rotation. The reactions developed at the wheel bearing are transmitted through the frame to the coupler. Another element is the source of power. In the common steam locomotive this is an expansion steam engine receiving steam from a **boiler**, and exhausting against atmospheric pressure. By means of a throttle **valve** located on the steam line leading to the engine, and by **valve gear** adjustments, the power developed in the engine cylinder is varied to suit the needs. In the electric locomotive, two or more motors with special windings are so arranged with controllers that their power output may be varied in several steps. They draw their power from a third rail, or overhead trolley. In a Diesel locomotive the engine is built in multi-cylindered form for smoothness of operation, and in order to obtain a high speed design. The engine is **governor** controlled, and operates at constant speed, driving an **electric generator**. This generator is connected through the control arrangement with the driving motors, which are mounted on the locomotive trucks.

Typical of the Diesel drive are the specifications of a recent twelve-car streamlined train. The total locomotive **horsepower** is 3600, this being divided between four 900 horsepower Diesel engines. These engines are 12 cylinder V-type, two-cycle full Diesels, of 8 inch bore and 10 inch stroke, operating at 750 r.p.m. The engines are water-cooled, and connected directly to D.C. generators.



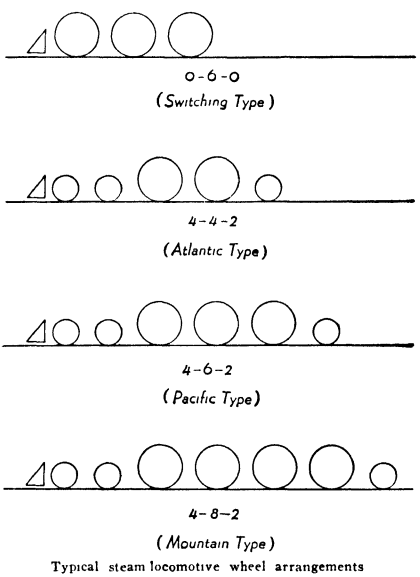
Locomotive.

In the steam locomotive, another essential element is the **boiler** in which the steam is raised. Through many years of evolution, the boiler has become standardized on a horizontal fire tube type, with completely water-cooled **furnace**. The furnace end is placed at the rear of the locomotive, and the products of **combustion** pass forward through the tubes to the smoke box, from whence they are discharged upwards to the atmosphere through a short stack. This type of boiler, in large sizes, has tubes of sufficient size so that **superheater** elements may be installed in them, and the use of superheated steam has greatly improved the per-

formance of the steam locomotive Due to the use of stay-bolt construction to hold the inner and outer shells of the water leg around the furnace, the boiler pressures carried are limited to approximately 250 pounds per square inch The combustion system includes oil firing, hand firing of lump coal on grates, and **stoker** firing of coal **Draft** is obtained by aspirator action of the exhaust discharging into the stack As the locomotive is non-condensing in operation, sufficient supply of water for a run must be carried in the tender tank From the tender tank it is pumped and heated by an **injector**, which is the most common means used to supply feed water to a locomotive boiler

The principal structural material of the steam locomotive is steel There is a great deal of fabrication of plate steel and steel shapes, which are assembled both by welding and riveting In recent years, the heavier portions, including the frames and cylinders, have been made of steel castings Wheels are cast iron, cast steel, or wrought steel, and revolve in plain wick-lubricated **bearings**, or, as is the case on many recent locomotives, in roller bearings.

Locomotives are frequently classified by their wheel arrangements, the method of classification being based upon the position and number of wheels of the leading truck, the drivers, and the trailing truck Some typical wheel arrangements, with corresponding classi-



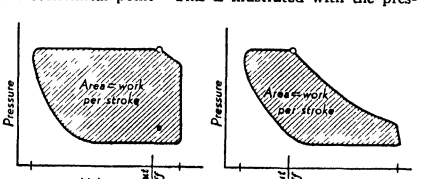
Typical steam locomotive wheel arrangements

fications, are shown in the accompanying figure The **cylinders** are mounted with axis longitudinal, and in line with the center line of the drivers Steam locomotives are two, three, or four cylindered, the most common arrangement being two cylinders Where three cylinders are used, the third cylinder is mounted under the boiler, and between the other two Although compound-expansion locomotives have been built, the common locomotive is a single-expansion type The **connecting rod** which extends from **crosshead** to one of the drivers is enabled to transmit propulsion equally to all drivers by use of the **side rod**, to which the **crank pins** of all drivers are connected The trailing truck under the cab is frequently fitted with a **booster** engine, which is used solely to help get a train started, after which it is disconnected On some locomotives, the booster drives on the leading tender truck

Typical dimensions of a modern steam freight locomotive are boiler pressure, 245 pounds per square inch, cylinders, 25 inch bore by 34 inch stroke, total weight 400,000 pounds, weight on drives, 260,000 pounds, diameter of drivers, 69 inches, draw bar pull, 64,000 pounds

In both freight and passenger service, train schedules have been stepped up in speed In freight service, higher speeds mean less time in transit for perishable goods, and savings such as reducing amount of care needed for livestock in transit, reducing amount of ice needed to refrigerate, etc In passenger service, high speed trains with modern coaches redirected public attention to the railroads, and have succeeded in re-establishing the latter as a personal transportation medium competing with other modern high speed systems As an outgrowth of this trend, several special streamlined locomotives have been built and placed in service While the first of these were Diesel engine powered, several streamlined steam locomotives have now been built The beneficial effects of streamlining do not begin until speeds in excess of 50 miles per hour are made However, the streamlined trains are given schedules calling for high speeds, speeds which may, on occasion, exceed 100 miles an hour

The horsepower capacity in the steam locomotive varies from 1200 to 3000 horsepower, and occasionally is somewhat higher Diesel and steam locomotives must have an equivalent power capacity in order to haul the same trains, however, superior performance has been obtained with Diesel passenger locomotives of lower power when hauling specially built light-weight trains The **boiler efficiency** of a steam locomotive averages from 40% to 50% under load While this may seem rather low compared to the performance of stationary steam generating boilers, the conditions of operation of locomotive boilers require a compromise between efficiency and practicability for motive service The overall efficiency of the steam locomotive is about 4% The power developed by a steam locomotive varies with the speed, and in this respect the Diesel-electric locomotive enjoys an advantage, since it may be built and operated as a constant power locomotive The Diesel engine may be run at full rated power at various train speeds Thus, with a lower maximum power, it may have superior accelerating properties at low speeds For starting purposes, the **valve gear** of the steam locomotive is set so that the steam is cut off from the cylinders relatively late in the stroke This gives considerable more **work** available per revolution than when the cut-off is advanced to a more normal and economical point This is illustrated with the pres-



Cylinder pressure-volume diagrams for two load conditions

sure volume diagram showing conditions in the cylinders at starting and running The **mean effective pressure** may be made nearly equal to full boiler pressure with very late cut-off, however, this operation is so wasteful of steam that it is employed only for starting heavy loads

The complete locomotive includes, in addition to the elements mentioned above, an enclosed cab containing the principal train and locomotive controls conveniently arranged for operation by the engine man Shelter and good vision, important qualities which the cab should offer, are apparently more easily obtained in the Diesel and electric designs than in the steam locomotive having a cab at the rear of the boiler The locomotive must have air brake equipment and control, as well as lighting and various safety devices

The steam locomotive has been evolved and perfected through approximately a century of mechanical progress The design has become standardized, with the result that in spite of size, weight, and power, the steam locomotive is relatively cheap at present With the exception of water-borne carriers, there is no way of transporting goods which costs so little per ton mile carried as the locomotive drawn railway freight. (F T M)

LOCUS OF AN EQUATION. The locus of a point subject to one or more conditions is the set (or totality) of all points satisfying the given condition or conditions

The locus of an **equation** in two **variables** is the set of all points in a plane whose **coordinates** satisfy the given equation and only such points Such a locus is in general a **plane curve**

To simplify the plotting of the graph (or locus) of a given equation,—

(1) the intercepts on the axes should be found,
(2) the symmetry of the locus should be investigated,
(3) the extent of the locus should be investigated,
(4) the existence of horizontal and vertical **asymptotes** should be investigated

Suppose a plane locus is given by its equation in **rectangular coordinates**

To find the X- and Y-intercepts of the locus, put $y = 0$ in the equation and solve for x, and put $x = 0$ and solve for y, respectively

Two points are said to be symmetrical with respect to an axis if this axis is the perpendicular bisector of the segment joining the given points

Two points are said to be symmetrical with respect to a center if this center is the mid-point of the segment joining the given points

A figure or curve is said to be symmetrical with respect to an axis or center if every point on the figure or curve has a symmetrical point (with respect to the axis or center) which also lies on the figure or curve

To test the equation for symmetry

If an equation is unaffected by replacing y by $-y$, the locus is symmetric with respect to the X-axis,

if an equation is unaffected by replacing x by $-x$, the locus is symmetric with respect to the Y-axis,

if an equation is unaffected by changing both x and y into $-x$ and $-y$, respectively, the locus is symmetric with respect to the origin

For an algebraic curve (whose equation is an **algebraic equation** in x and y) the locus is symmetric with respect to the X-axis if no odd powers of y occur in the equation, it is symmetric with respect to the Y-axis if no odd powers of x occur in the equation, it is symmetric with respect to the origin if every term in the equation is of even degree or is of odd degree

The extent of a locus is determined by finding the values of one variable for which the corresponding value or values of the other variable are imaginary or complex Complex coordinates cannot be plotted

An asymptote of a curve is a straight line which the curve approaches closer and closer so that the distance between the curve and the line may be made as small as we please by going out sufficiently far along the curve

To find the horizontal and vertical asymptotes of an algebraic curve, solve the equation of the locus for each variable in terms of the other, let the one variable increase beyond all bounds numerically and find the corresponding limiting value of the other

The locus of an equation in three variables is the set of all points in space whose coordinates satisfy the given equation and only such points Such a locus is in general a surface

The locus of two equations in three variables is in general a curve in space It may be regarded as the intersection curve of the two surfaces represented by the two given equations taken separately

In the discussion of the equation of a **surface**, we should examine the following items

The intercepts of the surface on the coordinate axes should be found by putting the coordinates equal to zero in pairs in the equation of the surface and solving for the remaining coordinate

The traces of the surface on the coordinate planes (intersection curves of the surface with these planes) are found by putting in turn each coordinate equal to zero in the equation, this gives the equations of the curves

Then the curves of intersection of the surface by planes parallel to the coordinate planes are found by putting each coordinate in turn equal to various constant values

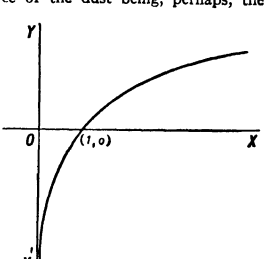
The symmetry of the surface may be investigated by methods analogous to the case of plane curves (L L S)

LOCUST **Grasshopper** **Cicada** The term is more properly applied to the short-horned **grasshoppers** These include the migratory locusts which sometimes appear in Africa, Asia, and the plains of North America as serious crop pests (A W L)

LODE **Ore body.**

LODESTONE **Magnetite; and Magnetism.**

LOESS Loess is a buff-colored, wind-blown deposit of fine silt or marl, usually unstratified, which is often exposed in bluffs with steep to vertical faces Loess is found in the United States in the Mississippi valley from Louisiana to Iowa, and along the course of the Missouri The average thickness of the loess here is about twenty feet, but may range to from fifty to one hundred feet Loess also occurs in central Europe, Mongolia and China where it is said to attain a thickness of three hundred feet The loess of the United States and Europe is believed to be the finer materials first transported and deposited by the waters of the melting ice sheets of the glacial period, and later blown to considerable distances and sometimes deposited in lakes The Asiatic loess seems to be wholly wind transported, the source of the dust being, perhaps, the great deserts of central Asia In the latter case the accumulation of such thick deposits is attributed to the binding power of successive generations of grasses whose former existence is suggested by a network of narrow tubes (R M F)



LOGARITHMIC CURVE Many of the properties of **logarithms** are exhibited graphically by the logarithmic curve The logarithmic curve, whose equation is $y = \log_a x$, is shown in the accompanying figure It is the same as the **exponential curve**, whose equation is

$y = e^x$, except in different position It crosses the X-axis at the point (1,0), is **asymptotic** to the Y-axis as $x \to 0$, and to the right of the point (1,0) it rises more and more slowly

The graph of $y = \log_a x$ (for example, $y = \log_{10} x$) is of the same form as the preceding, except of different **slope** (LLS)

LOGARITHMIC DIFFERENTIATION. Sometimes a **derivative** is found most easily by taking **logarithms** on both sides of the defining functional equation and then differentiating This is called logarithmic differentiation (LLS)

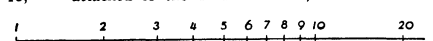
LOGARITHMIC EQUATIONS A logarithmic equation is an **equation** in which the unknown occurs in a **logarithm** Such an equation may often be solved by using the definition of logarithms to reduce the equation to an **exponential** form (LLS)

LOGARITHMIC FUNCTION. If x and y are two **variables** related by the **exponential functional** relation $x = B^y$, where $B > 0, \neq 1$, then y is called a logarithmic function of x, and we write $y = \log_B x$ The logarithmic function is a **transcendental function** It is the **inverse function** to the exponential function (LLS)

LOGARITHMIC PAPER. Logarithmic paper is paper ruled from scales on the two perpendicular axes, in which at least one of the scales is logarithmic In semi-logarithmic paper, the one scale is a uniform scale while the other scale is a **logarithmic scale** In log-log paper, both scales are logarithmic scales (LLS)

LOGARITHMIC SCALE A logarithmic scale is one in which the distance from the origin to any scale mark is proportional to the **logarithm** of the number attached to that mark

Thus, the accompanying figure shows a (common) logarithmic scale with the numbers 1, 2, 3, , 10, attached to the division marks, if we take OI

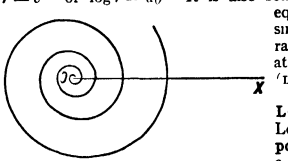


Logarithmic scale

as the unit of length, then the distances OA, OB, OC, etc, are represented by log 2, log 3, log 4, etc, so that $OI = \log 10 = 1$ In going from left to right, the scale marks will become closer and closer together

The logarithmic scale is applied in the **slide-rule** and in **logarithmic paper** (LLS)

LOGARITHMIC SPIRAL This is the spiral curve represented by the equation in **polar coordinates** $r = e^{a\theta}$ or $\log r = a\theta$ It is also sometimes called the equiangular spiral, since it cuts all radii from the origin at a constant angle (LLS.)



Logarithmic spiral

LOGARITHMS Logarithms are **exponents, relative to** a given base Calculations involving **multiplication, division,** raising to **powers** and extraction of **roots** can usually be carried out more quickly and with less labor by the use of logarithms than by direct arithmetic calculation Certain **equations** require the use of logarithms for their solution

The logarithm of a number to a given base is the **exponent** of the **power** of the base which equals the given number, if $N = B^L$, then $L = \log_B N$ The logarithm of a number N to a base B is denoted by $\log_B N$

For any positive base $B \neq 1$, we have

$$\log_B 1 = 0, \quad \log_B B = 1$$

The fundamental laws of logarithms are

1 The logarithm of a product of two or more positive factors is equal to the sum of the logarithms of the factors

$$\log (MN) = \log M + \log N$$

2 The logarithm of the quotient of two positive numbers is equal to the logarithm of the dividend minus the logarithm of the divisor

$$\log (M/N) = \log M - \log N$$

3 The logarithm of a power of a positive number is equal to the logarithm of the number multiplied by the exponent of the power

$$\log M^n = n \log M$$

4 The logarithm of a real positive root of a positive number is equal to the logarithm of the number divided by the index of the root

$$\log \sqrt[n]{M} = \frac{1}{n} \log M$$

Any positive number not equal to 1 can be used as a base of a system of logarithms However, only two particular numbers are in general use as bases, namely 10 and a number denoted by e

The system of logarithms which uses 10 as a base is called the common system (or Briggs' system) and logarithms to the base 10 are called common logarithms This system is especially adapted to the application to numerical calculation and is used principally for such work

The number e is an **irrational** and **transcendental number** defined by the **infinite series**

$$1 + \frac{1}{1!} + \frac{1}{2!} + \frac{1}{3!} + \cdots,$$

or by the **limit**

$$\left(1 + \frac{1}{n}\right)^n,$$

and its approximate value is 2 71828

Logarithms to the base e are called natural logarithms (or sometimes Napierian logarithms, or hyperbolic logarithms) They are particularly adapted to analytical work, but are not of much direct service as a mere aid to computation

The symbol $\ln N$ is frequently used for natural logarithms instead of $\log_e N$

General properties of common logarithms are

A common logarithm in general consists of two parts, an integral part called the characteristic, and a non-integral part, less than 1, usually expressed as a decimal, called the mantissa

The mantissa of the common logarithm of a number is independent of the position of the decimal point in the number, and depends only on the succession of digits that make up the number

The characteristic of the common logarithm of a number is independent of the digits that make up the number but depends entirely on the position of the decimal point in the number

The characteristic of the common logarithm of a given positive number may be found by the following rules

The characteristic of the common logarithm of any positive number greater than 1 is positive and is 1 less than the number of digits in the integral part of the number The characteristic of the common logarithm of a positive number less than 1 is negative and is numerically 1 more than the number of ciphers between the decimal point and the first significant figure in the given number

So-called tables of logarithms contain the mantissas of logarithms of numbers, to a specified number of decimal places Four-place, five-place, six-place seven-

place, eight-place and even fourteen- or more place tables are published and in use A graphic table has also been published which has many features to recommend it

In the use of a table of logarithms, **interpolation** based on a principle of proportional parts is generally required This principle is a small change in the number produces a change in its logarithm which is very nearly proportional to the change in the number

The anti-logarithm of a given logarithm is the number whose logarithm is the given value

The co-logarithm of a number is the logarithm of the reciprocal of the given number and is equal to minus the logarithm

$$\operatorname{colog} N = \log (1/N) = -\log N$$

The co-logarithm is frequently used to simplify logarithmic calculation when quotients are involved

Formulas for change of base of logarithms are the following

$$\log_b N = \log_a N \log_b a,$$
$$\log_a \log_a b = 1,$$
$$\log_e N = \log_{10} N \log_e 10,$$
$$\log_{10} N = \log_e N \log_{10} e,$$
$$\log_e 10 \log_{10} e = 1,$$
$$\log_{10} e \approx 0.434204, \log_e 10 \approx 2.302585,$$
$$\log_e N \approx 2.302585 \log_{10} N,$$
$$\log_{10} N \approx 0.434294 \log_e N$$

The number $\log_{10} e \approx 0.434294$ is called the modulus of the common system of logarithms with respect to the natural system, and the number $\log_e 10 \approx 2.302585$ is called the modulus of the natural system with respect to the common system

The calculation of logarithmic tables is usually based on the use of logarithmic series The basic series is

$$\log_e (1 + x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots,$$

which is **convergent** when $|x| < 1$, but it is too slowly convergent for practical computational purposes It can be transformed into the series

$$\log_e (N+1) = \log_e N + 2\left[\frac{1}{2N+1} - \frac{1}{3}\frac{1}{(2N+1)^3} + \frac{1}{5}\frac{1}{(2N+1)^5} - \cdots\right],$$

which is convergent for all values of N By taking $N = 1, 2, 3,$ successively, the logarithms of integers can be calculated from this series It is only necessary to calculate the logarithms of prime numbers in this way, as logarithms of composite numbers can be found by combination of these

A graphical representation of many of the properties of logarithms is furnished by the **logarithmic curve.** (L L S)

LOGWOOD Haematoxylin. *Haematoxylon campechianum* Leguminosae

LOIN The lower or posterior part of the back, near the hips Usually in the plural (A W L)

LONGITUDE The longitude of a point on the surface of the earth is the angular distance measured along the earth's **equator** from the **meridian** through Greenwich, England, to the local meridian through the point Longitude is measured either east or west from Greenwich through 180° or 12 hours

Since **time** is defined as **hour angle**, the difference between Greenwich time and local time must be equal to the local longitude In case Greenwich time is greater than local time the longitude will be west, if smaller the longitude is east Both the Greenwich and local time must be expressed in the same system, i e. the hour angle of the same object must be considered

The longitude of a celestial object is the coordinate in the ecliptic system of **spherical coordinates** measured along the **ecliptic** from the **vernal equinox** in the direction of the sun's annual motion to the great circle through the pole of the ecliptic and the object.

DETERMINATION OF TERRESTRIAL LONGITUDE

The problem of determination of terrestrial longitude resolves itself into two parts the determination of local time and the determination of the Greenwich time at the same instant

The most accurate method for determination of local time is to observe the instant of passage of a star of known right ascension across the local meridian The **meridian circle** is used for this purpose and is essentially an **altazimuth** instrument accurately fixed in the azimuth of the local meridian By using a large number of stars with accurately known right ascension it is possible to obtain local time with an accuracy of about one thousandth of a second

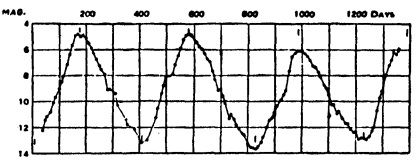
The meridian circle is a fixed instrument and not available for ordinary field work or for navigational purposes For such purposes several different methods for determining local time are available The method most commonly employed is to observe the **altitude** of some celestial object of known **declination** either with an **altazimuth** instrument or with a **sextant** If the **latitude** of the observer is known the **astronomical triangle** is then solved to obtain the hour angle of the observed object If the object observed is a star the **right ascension** of the star added to the computed hour angle will be the sidereal time at the instant of observation In case the altitude of the sun has been measured, the computed hour angle will be the local apparent time

In spite of the fact that methods for measuring the altitude of celestial objects have been known for 2,000 years and the solution of the astronomical triangle understood for nearly half that period, it was not until the 18th century that any method for determining Greenwich time at sea was available for the solution of the longitude problem The first practical method was the employment of the **moon's** motion through the stars as a clock hand The angular distance of the moon from certain bright stars was tabulated in **Ephemerides** for Greenwich time throughout the year The measurement of **lunar distance** to find Greenwich time was far from accurate and it was not until late in the 18th century that the perfection of the **chronometer** made it possible for navigators to carry Greenwich time with them Formerly, the chronometer rate had to be determined while the ship was in port and then the chronometer was treated with great care in order that this rate should remain constant At present time signals are sent out by radio by observatories of the various nations so that navigators may determine the Greenwich time and hence their chronometer corrections with great accuracy In fact the errors introduced by measurement of altitude and determination of dead reckoning latitude, which must be used in the solution of the astronomical triangle, are larger than the errors in the Greenwich time (W K G)

LONG-JAW. Pisces, Teleostei One of the freshwater **herrings**, found in deep water in the Great Lakes (A W L)

LONG PERIOD VARIABLES. Examination of the curve appearing in the article on **variable stars,** indicates that there is a considerable group of variables with periods greater than one hundred days This group of objects is known as the long period variables More than half of the long period variables have periods between 250 and 400 days The accompanying figure

(Light Curve of the Long Period Variable χ Cygni) shows the **light curve** of a long period variable. Examination of the diagram indicates at once that the characteristics of variation do not repeat themselves exactly from cycle to cycle. This irregularity in the shape of the light curve from cycle to cycle is char-



Light curve of the Long Period Variable χ Cygni. (From observations, during the years 1922 to 1925, by the American Association of Variable Star Observers.)

acteristic of all long period variables. All of the long period variables are red stars, most of them being **M spectral class,** with a few in the N, R, and S classes.

There is no adequate explanation for the variability of the long period variables. The pulsation theory, as discussed for the **Cepheid** variables has many attractive features, but on the basis of this theory we should expect the stars to be hottest when they are of smallest diameter and this is exactly contrary to the observed diameters of **Mira.** The similarity between the forms of the light curves of certain long period variables and the **sun spot** curve has frequently been commented upon, and the statement is sometimes made that our sun is a long period variable with period of about eleven years. However, the period is much longer than any known long period variable and, furthermore, the sun is a G type star, so it seems that variability in the sun and in long period variables must be totally different phenomena. (W.K.G.)

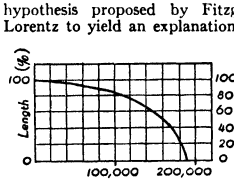
LOOMING. Mirage.

LOON. Aves, Gaviiformes. *Gavia.* Large birds (**Aves**) with short legs, webbed feet, and strong sharp beak. They are powerful swimmers and divers and are called divers as well as loons. (A.W.L.)

LOPHOPHORE. A ridge surrounding the mouth or closely related to it in the phyla **Bryozoa, Brachiopoda,** and **Phoronidea.** It bears the tentacles. (A.W.L.)

LOPOLITH. The term proposed by Grout in 1918 for large concordant **lenticular, igneous** intrusives which differ from **laccoliths** in that the center is depressed so that its upper surface, together with the overlying strata, form a basin instead of a dome. (R.M.F.)

LORENTZ-FITZGERALD CONTRACTION. A hypothesis proposed by Fitzgerald and extended by Lorentz to yield an explanation of the negative result of the **Michelson-Morley experiment.** Fitzgerald suggested that when a body moves through space, it experiences a compression or shrinkage in the direction of the motion. Lorentz showed how such an effect might be expected on the basis of the electromagnetic theory and the electrical constitution of matter. That is, he deduced that when a body moves through space, its dimension parallel to the line of motion should become less by an amount dependent upon its speed. If the speed of the body is v, and that of light is c, then the contraction is in the ratio $\sqrt{1-\frac{v^2}{c^2}}:1$. For the earth moving in its orbit (about 18.5 miles per second), this contraction amounts to about one part in 200,000,000, which, on the diameter of the earth, would be about 2.5 inches. Small as this is, it accounts exactly for Michelson and Morley's result by making the source of light and the mirror draw closer together when the system is moving lengthwise. It is the only satisfactory explanation of that result if we regard light as traveling through a stationary **ether.** Viewed from a different angle and expressed in different terms, this hypothesis is now embodied as one of the basic principles of **relativity.** (L.D.W.)



Graph showing falling off of length with speed. The percentages are of the "static length."

LORICA. A structure enclosing the body in many species of **rotifers.** Formed of thickened integument. Also a shell or test surrounding the body in certain species of **Protozoa.** (A.W.L.)

LORICATA. 1. A group of ciliate (**cilia**) **protozoans** protected by a test. 2. A group of **rotifers** in which the body is protected by a shell. 3. The **Crocodilia,** a division of the reptiles. 4. A suborder of edentate mammals including the **armadillos** and **pangolins.**

A similar name, Loricati, is used for a group of fishes.

The term is now obsolete, in spite of its former wide application, and is rarely met in modern treatises on classification. (A.W.L.)

LORIQUET. Parrot.

LORIS. Mammalia, Primates. Animals of the warmer part of southeastern Asia and the East Indian islands. **Lemurs.** They have large staring eyes and from their very slow movements have also been named slow lemurs. The lorises are forest animals of nocturnal habits. The slender loris is known as *Loris gracilis*; the slow loris is *Nycticebus tardigradus.* (A.W.L.)

LORY. Parrot.

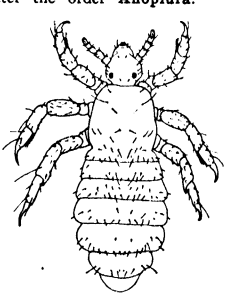
LOSCHMIDT NUMBER. Avogadro's Law.

LOTUS. Water-lilies. Nymphaeaceae.

LOURI. Plantain eater.

LOUSE. Insecta. An external parasitic insect found on warm-blooded animals, both birds and mammals. Two kinds of lice occur, the bird or biting lice and the true or sucking lice. The former make up the order **Mallophaga** and the latter the order **Anoplura.**

As the names suggest, the bird lice have biting mouth parts and the sucking lice have piercing and sucking mouths. Bird lice eat bits of feathers and hair and cuticular scales while true lice suck blood. The true lice and a few species of bird lice live on mammals.



Louse.
The head louse of man.

Three species of true lice, the head louse (*Pediculus humanus capitis*), crab louse, (*Phthirus pubis*), and body louse (*Pediculus humanus corporis*), are parasitic on man. Head lice can usually be removed with a fine-toothed comb and the other species yield to mercurial ointments. The body louse is sometimes dangerous as a carrier of typhus fever.

Many other species of lice infest domestic animals and wild species. (A.W.L.)

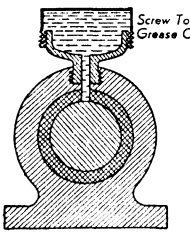
LOUSE FLY. Insecta, Diptera. True **flies** specialized to live as external parasites on birds and mammals. They include the **sheep tick** (*Melophagus ovinus*), **bat ticks**, and **bee lice** as well as certain winged species which are recognizable as flies. Found chiefly on owls and other birds of prey. (A.W.L.)

LOVE BIRD. Parrot.

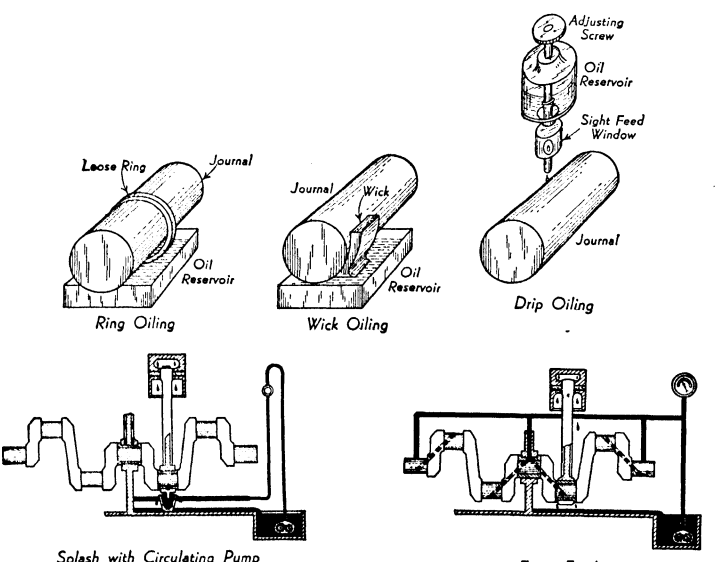
LUBRICATION AND LUBRICANTS. The importance of lubricants to a civilization using **machines** to the extent ours does must be very great since almost every machine has one or more parts which are in motion relative to some other part. The points of contact where this relative motion occurs must be protected from friction of the destructive type, that is to say, solid **friction**, in order, first, to prevent seizure and quick failure of the **bearings**; secondly, to produce efficient operation through the reduction of friction losses; and thirdly, for smoothness, quietness, and coolness of operation. The lubricating action, together with the characteristics of lubricants, will be mentioned following a survey of general classes of lubricated bearings.

The most common form of bearing is occasioned by the necessity of supporting a rotating shaft carrying a load of some description. The portion of the shaft in the bearing is the journal, and the lubrication of journals forms a large and important phase of the subject. Another class of bearing is that between **pistons** and **cylinders**, which, due to the widespread use of the piston-cylinder mechanism, has assumed considerable importance. Furthermore, in this class of lubrication, the conditions of service are the most severe, because of the exposure of the lubricant to the contents of the cylinder, which may be extremely hot, or at high pressure, or corrosive. The instances of friction of plain, flat, sliding surfaces are fewer in number than the others, but not by any means to be considered rare, as many examples, such as cross-heads, slippers, reciprocating carriages, etc., may be mentioned. To the aforementioned groups must be added another, consisting of pivoted type bearings. Illustrated by the conical or collar type step pivot, these are used principally for rather light loads.

Lubrication of these various bearings differs as to type and quality of lubricant and method of applying it. The semi-solid lubricants are applied by smearing directly on the bearing surfaces, or indirectly through the medium of grease cups, pressure guns, etc. The liquid lubricants (oils) are supplied to lubricated surfaces mainly by the following means: Oil sprays which require the bearing to be enclosed in a casing, and some means, such as a pump, for filling that space with a spray of oil; pressure streams in which the oil is supplied to the bearing under pressure, through drilled shafts, or tubing; dip or splash systems, in which periodic and frequent dipping of some part of the bearing into a pool of lubricant provides intermittent oiling of a satisfactory character; ring oiling, wherein a journal is encircled by a loose ring which dips continuously into a reservoir of lubricant (the slow rotation of the ring under the drag of the rotating journal carries oil from the reservoir up to the bearing by surface adhesion to the ring); wick lubrication utilizing capillary attraction provided by a wick dipping at one end into the oil reservoir, and rubbing against the journal at the other; drip lubrication, which varies from the simplicity of occasional oiling manually from an oil can, to automatic lubrication by sight-feed oil cups, which may be adjusted to drip a certain number of drops of oil per minute to the surfaces which are to be lubricated.



Grease Cup



Various methods of lubrication.

Solid friction, which takes place when two clean surfaces move relative to each other with some normal pressure between them, is destructive for all except occasional motions This friction may be due to the **abrasion** between surface molecules of the two parts, or to the varying gravitational pulls between the molecules of the surface layers of the two parts, but is undesirable in any case of a true bearing, although, of course, it has its uses in such a mechanism as a brake Fluid friction is a physical phenomena of a very different sort The ordinary laws of friction do not hold, since the friction of a fluid-lubricated bearing arises from the viscosity of the fluid as long as the fluid completely prevents solid friction Apparently fluid friction, or the friction of a perfectly lubricated bearing (meaning by that one in which the lubricant prevents solid friction), depends on the following factors viscosity of the lubricant, rubbing speed, thickness of the film of lubricant In most bearings there is always a small amount of solid friction, and the above characteristics of perfect lubrication are not fully realized

The properties of a lubricant which are of most importance in determining the success with which it prevents friction in a bearing are its **viscosity**, its "oiliness," and its **surface tension** Other characteristics which influence the qualities of an oil, but which have not the same direct connection with lubrication at the working surface as the above, are, chill point, freedom from **corrosive** impurities, particularly those which corrode metals, **flash point**, ash, and carbon residue

The viscosity is the most important characteristic, since the friction of perfectly lubricated bearings depends upon the viscosity of the lubricant However, the oiliness, which is a factor not fully understood as yet, has been found recently to have perhaps an equally important effect upon this action Oiliness, or "body," of an oil, is not distinguished by such tests as viscosity, specific gravity, and the like It may be that the composition of a layer of oil at the surface between the oil and the lubricated metal is somewhat different from that of the main body of oil It is known that oil is not a unit homogeneous substance, but is a solution of several chemical compounds in one another Probably the surface layer varies by **adsorption** from the rest of the oil film, and also this is probably an extremely thin layer Nevertheless, it can affect the lubrication considerably, and in the lubricant market today are a number of special oils, usually a patented fatty oil, which are to be added to the ordinary mineral lubricating oil, with the claimed results of lower bearing temperatures, lower coefficients of friction, etc. These are either substances tending to increase this "oiliness," or solutions of graphite, the features of which are mentioned later The surface tension of an oil determines the facility with which it wets the bearing surfaces and tends to creep into the area between journal and bearing, cross-head and guide, or the like, when the mechanism is static Thus surface tension determines the ability of a bearing to start with a minimum amount of solid friction, and the success with which a lubricant completely separates the two parts mechanically when the parts are in motion

One way of classifying lubricants is on the physical basis of solid, semi-solid, and liquid; another, as to the origin—mineral, animal, or vegetable Solid lubricants are solids whose molecules have low internal friction Graphite and talc are examples Semi-solid lubricants are the greases, which are made by stirring oil into soap bases, for example, ordinary cup grease is made by stirring oil into a hot soap of lime The liquid lubricants are the oils, consisting of mineral oils refined from crude oil, the animal oils, consisting of fats of animals, such as sperm oil, lard oil, fish oil, etc , and the vegetable oils, such as coconut oil, rape oil, castor oil The mineral oils are classified into those which are made from paraffin base crude oils, such as the Pennsylvania oils, and the asphalt base crude oils (Texas oils). The end product of Pennsylvania oils is wax, and of the Texas oils, asphalt Various ways of refining and mixing the products result in oils of different colors, from the dark cylinder oil to the colorless oils necessary for spindles of spinning machines, and from highly viscous oils suitable for heavy, slow moving machinery, to thin, light viscosity oils suitable for cylinder lubrication Differences in oils produced from petroleum are accounted for by the following controlled features of manufacturing methods filtration, distillation, acid treatment, bleaching, and mixing

Animal oils are obtained by rending or pressing the fatty tissues of the animals, and the resulting product is usually refined and purified Chemical extraction, or hot or cold pressing, obtains the oil from castor bean, rape seeds, and other sources of vegetable oil **Hydro-carbons** (P T M)

LUDIO. Guenon.

LUDWIG'S ANGINA. A very serious, acute infection of the floor of the mouth and neck which is caused usually by the **Streptococcus** The mortality is high The treatment is early proper and adequate surgical drainage Death occurs from **sepsis** or from blocking off of the air passages of the lower throat This latter event may occur very acutely without warning If the swelling becomes alarming an artificial opening is made in the **trachea** through the neck (tracheotomy) (R S M)

LUES Syphilis.

LUMBAGO. Acute pain in the back due to local infection or sprain of back muscles (R S M)

LUMBER Lumber is timber which has been sawed into boards and planks (See also **Wood**) If the logs are cut into quarters, and then sawed across the annual rings, the resulting product is known as quarter-sawed lumber Boards which are sawed tangential to the annual rings are flat sawed, and most lumber is so produced Lumber is known as rough lumber, surfaced lumber, or worked lumber, depending on whether it is rough as it comes from the mill, dressed by a planer, or specially cut to make matched, lapped, or patterned lumber On the basis of quality, lumber is graded into two main divisions, select and common The former class is used mainly for special interior trim, and is more expensive than common lumber, since in select lumber the number, size, and type of defects permissible are restricted There are four grades of select lumber Grade A must be free from defects, grade B allows a few defects or blemishes, grade C allows that small number of defects and blemishes which may be covered by paint, and grade D allows that number of defects and blemishes which do not detract from the finished appearance Grades A and B are suitable for natural finishes, and C and D for painted finishes Grade A lumber is very difficult to obtain Usually it is wanted in small quantities, which can be obtained by cutting out suitable portions of Grade B lumber There are few lumber requirements but which may be satisfactorily executed in Grade B lumber, so when one wishes to have the best it is customary to specify, not A, but "B or better" Common lumber is graded as No. 1 common, No 2 common, etc The grading and selection of lumber can not be exact, and hence there can be no definite demarcation between grades Numbers 1 and 2 common may generally be used for house framing, and other purposes with little or no waste, and this only in the extent the defects permit Most wooden construction is with No. 2 or No 3 common lumber

The common unit of measurement of lumber is the board foot, which is the volume of wood in a board, 12 inches wide, 1 foot long, 1 inch thick It is $\frac{1}{12}$th of a cubic foot However, the purchaser of a board

foot will get 1/12th of a cubic foot only in rough lumber, since it is customary to charge for finished lumber upon the basis of the rough board which was used Thus a piece of 1 inch × 8 inches dressed lumber will usually measure about 7/8 inches × 7¼ inches, but if one contracted for 100 such boards, each 10 feet long, he would be billed with the board feet in the rough lumber before planing In the example quoted, the board feet are 100 × 10 × 2/3 = 667 (1 foot of 1 × 8 board has 2/3 the volume of 1 foot of 1 × 12 board) Standard commercial practice in this country is to market lumber in even lengths, as in 6, 8, 10, 12, 14, and 16 feet Generally the cost per unit is the same for all lengths, but premium may be required for extra long lengths (F T M)

LUMEN. The internal cavity of a hollow organ Usually applied only to tubular organs such as the blood vessels The lumen is also a unit of measurement in photometry, being defined as the quantity of light, or luminous flux, received upon a unit surface, all points of which are at a unit distance from a concentrated source of one spherical candle intensity (A W L)

LUMINESCENCE. Broadly this term refers to the emission of light due to any other cause than high temperature A firefly, for example, illustrates bioluminescence, certain chemical reactions give out light (chemiluminescence), and some electrolytic **rectifiers** are the source of galvanoluminescence Triboluminescence is observed upon vigorously grinding certain solids, notably ordinary sugar

A large variety of substances become luminescent when stimulated or "excited" by suitable radiation or by emissions such as cathode or beta rays This phenomenon is apparently quite complex and is exhibited in various aspects In some cases the light is emitted only so long as the exciting emission is maintained, it is called fluorescence The screen of a **fluoroscope** thus responds to x-rays In other cases the luminescence persists after the excitation is removed and it is then called phosphorescence. Thus zinc sulfide, under certain conditions, glows brightly for a time after exposure to daylight or lamplight, but the luminosity decays rapidly and disappears, usually within a few minutes Some materials exhibit thermoluminescence, that is, they become luminescent, after exposure to excitation, upon being raised to a sufficiently high temperature **Resonance radiation** may be regarded as a type of fluorescence in certain gases

Stokes pointed out that when luminescence is excited by radiation, the frequency of the luminescence is usually less than that of the incident radiation This is of course always true when visible luminescence is excited by ultraviolet, x-rays, or gamma rays

Numerous theories regarding luminescence have been proposed, by Lenard, Kowalski, Perrin, Baly, and others They agree mostly in assuming that the emission of luminescence is due to the removal of electrons from molecules by the energy of the exciting rays and the release of part or all of the energy upon their return The **quantum theory** of radiation and electronic processes has done much in recent years to clarify certain aspects of the phenomena. (L D W)

LUMINOSITY OF A STAR. The intrinsic brightness of a star may be expressed either in terms of its **absolute magnitude** or in terms of the sun's brightness as unity The luminosity of a star is defined as its intrinsic brightness in terms of the brightness of the sun as unity That is to say if our sun were replaced by a star of luminosity 100 the light received by the earth would be 100 times as great (W K C)

LUMINOUS EFFICIENCY. Photometry.

LUMINOUS INTENSITY. Photometry; Candle Power.

LUMMER-BRODHUN SCREEN. Bench Photometers.

LUMP SUCKER Pisces, Teleostei. *Cyclopterus* Coastal fishes (**Pisces**) of the colder seas of the northern hemisphere They have an adhesive organ used to attach them to rocks The body is short and stout (A W L)

LUNAR DISTANCE. For a determination of terrestrial **longitude** the Greenwich **time** must be known Prior to the invention of chronometers and the subsequent development of radio broadcasting of time, the determination of Greenwich time at sea was very complicated. For many centuries it was realized that the position of the **moon** relative to the stars might be considered as a clock hand

Up to 1912 the American **Ephemeris,** and corresponding publications of other nations, published the distance of the center of the moon from the center of the sun, the four brighter **planets,** and certain bright stars, for every three hours of Greenwich time Only those objects were used which were within convenient distance of the moon at the given time All that was necessary for a navigator to determine his Greenwich time at any instant was to measure with his **sextant** the distance between the bright limb of the moon and a tabulated "lunar distance star" Then, after applying necessary corrections, by interpolation from the tables he could find the Greenwich time corresponding to the instant of observation

While this problem is fundamentally very simple in theory, in practice the method will not yield very accurate results In the first place, the published lunar distances were **geocentric** in character and referred to the center of the moon The problem of correcting the observations for **parallax, refraction,** semi-diameter of the moon, etc (known as "clearing the observation") was quite complicated and subject to numerous errors Furthermore, the motions of the moon could not be predicted with accuracy greater than several seconds of arc Finally, it must be realized that the moon is moving, on the average, with a motion of only about 11″ in twenty seconds of time Eleven seconds of arc is about the limit of accuracy of a single sextant observation, and hence twenty seconds of time is about the limit of accuracy of a determination of Greenwich time by the method of lunar distance An error of this magnitude would introduce an error of about five miles in a longitude determination for a ship on the **equator.** (W K C)

LUNAR INTERVAL. Tides.

LUNG Respiratory system.

LUNG BOOK A respiratory organ of **spiders** and some other **arachnids** It consists of many thin plates or leaves in a small chamber on the abdomen which opens by a narrow aperture Air circulating between these leaves supplies oxygen to the blood inside them (A W L)

LUNG FISH. A fish with an air bladder opening from the **pharynx** which can be filled with air gulped through the mouth and serves as a lung Although some members of the other orders are able to breathe air, the term applies specifically to species found only in Australia (*Neoceratodus*), Africa (*Protopterus*), and South America (*Lepidosiren*), constituting the order or subclass Dipnoi The dipnoids live in transient streams and swamps Some species pass the dry season in cells which they form in the muddy bottom as the water dries up They resemble the amphibians in some details of structure (See also **Fossil Fishes**) (A W L)

LUNULE. 1 A crescentic mark in the pattern of any animal 2 A depression in front of the umbo on the shell of some **bivalve** mollusks. (A W L)

LUPANINE. Alkaloids.

LUSTRE. This term is used by mineralogists to describe the appearance of the surface of a mineral, usually a crystal face, in reflected light The principal types of luster are metallic, adamantine, vitreous, resinous, greasy, pearly The degrees of lustre may be defined as splendid, shining, glistening, or dull Schillerization is a peculiar form of sub-metallic luster observed in different directions in certain minerals such as schiller-spar, **diallage, hypersthene,** etc (R M F)

LUTECIUM. Symbol Lu Atomic number 71 Atomic weight 175 0 Type of compound Lu_2O_3 Color of salts Colorless Discovered by Urbain in 1907 A member of the **yttrium** sub-group of the rare earth metals (R K S)

LUTH. Reptilia, Testudinata A large marine **turtle,** *Dermachelys coriacea,* reaching a length of six feet Its **carapace** is formed of bony plates connected together but not joined to the spinal column or ribs Also called the leathery turtle Its flesh is not palatable (A W L)

LYCOPHORE A larval form of tapeworm with ten hooks for locomotion It lodges in **annelids** and **mollusks. Cestoda,** subclass Cestodaria (A W L)

LYCOPIN. Pigments in Plants and **Aminoacids and Proteins.**

LYCOPODIALES. Club mosses The order Lycopodiales contains about 500 species, most of which are included in two genera, *Lycopodium* and *Selaginella* The species of *Lycopodium* are trailing plants often called ground pines, or ground hemlock, as well as club mosses Many of them are common plants of dry open places in the temperate zone The plants have long creeping stems growing on the surface of the ground or several inches beneath it From this prostrate stem short **dichotomously** branched roots extend down into the ground, and erect branches grow upward The stems are covered with many small, pointed, dark green leaves In the more primitive species the reproductive structures or **sporangia** are found in the **axils** of ordinary leaves In other species the sporangia are borne in the axils of modified leaves which are aggregated at the tip of an erect branch, forming a slender cone or strobilus The many **spores** borne within the sporangia are all alike and for this reason *Lycopodium* species are said to be homosporous The spores are disseminated by the wind, and in time develop into gametophytes The **gametophytes** of *Lycopodium* species are extremely small tuberous bodies which grow slowly and reach maturity only if they are invaded by an endophytic **fungus.** Generally the gametophyte or prothallus develops underground In the upper surface of the prothallus both **antheridia** and **archegonia** are found Each antheridium contains many straight, biciliate **sperms.** These swim to the egg, with which one unites, forming a **zygote.** From this the new **sporophyte** develops At first the sporophyte depends on the gametophyte for its food substances Thus it obtains nutriment by means of a special absorbing structure called a suspensor which grows into the tissue of the gametophyte

Lycopodium plants are widely used as material from which to make Christmas wreaths For this purpose the entire plant is often ripped from the ground The spores of *Lycopodium* are also gathered and sold under the name of Lycopodium powder Formerly these spores were used in making explosive mixtures and for flash lights

The genus *Selaginella,* containing some 400 species, is most abundant in the tropics A few species of small plants are found in temperate regions In the tropics there are both terrestrial and epiphytic species The general habit of the plant is much like that of *Lycopodium* The sporangia are formed in the axils of leaves at the tips of the branches, forming terminal strobili or cones At the base of the **sporophylls** there is also a small scale, called a ligule, of unknown function The sporangia are of two kinds, one, a **megasporangium,** containing four large spores, called megaspores, the other a **microsporangium** containing many small spores or microspores Species of *Selaginella* are therefore heterosporous, a character which distinguishes them from *Lycopodium* species The microspores, while still within the sporangial wall, start to develop and become multicellular bodies or microgametophytes In each microgametophyte are formed many biciliate sperms The megaspore also develops without leaving the sporangium Its contents divide and form a mass of cells so great that the wall of the megaspore is ruptured Archegonia are formed in this mass of cells protruding from the cracks in the megaspore wall The eggs within the archegonia are fertilized by the sperms At once development begins and a new sporophyte is formed First formed is the suspensor, a small absorbing organ which pushes into the gametophyte tissue Stem and roots form later Often these structures are well developed while still within the sporangium wall

Several species of *Selaginella* are grown in cultivation because of their delicate appearance Usually they require so much moisture around them that it is difficult to keep them alive in ordinary rooms One xerophytic species, *Selaginella lepidophylla,* is sometimes seen in cultivation The plant, a native of the drier regions of America, when dry forms a tight little ball On receiving sufficient moisture this ball unfolds, forming a flat plant whose much-branched stems spread out on the surface of the ground Large numbers of these plants are gathered and sold under the name of resurrection plants (See also **Paleobotany**) (R M W)

LYCOPSIDA. Lycopsida are **vascular** plants with the following characteristics The **stele** is a solid cylinder, the leaves are small and spirally arranged on the stem, no breaks, or leaf gaps, occur in the central cylinder, and the **sporangia** are borne on the upper surface of the leaves Lycopsida are considered the more primitive types of vascular plants The members of the order Lycopodiales are Lycopsida. (R M W)

LYDITE. Basanite.

LYMPH. A clear fluid which circulates in the tissue spaces of vertebrates and passes into the venous system by way of a tubular **lymphatic system** It is derived from the liquid plasma of the **blood** but is more watery and contains no red corpuscles It serves as an intermediary between the blood itself and the **tissues** of the body

Lymph is found lying free in the serous sac cavities of the body, i e , the **peritoneum, pleura,** and the spaces in the **brain** filled with cerebrospinal fluid, which may also be classified as lymph, although it differs in composition from the fluid found in the lymph vessels

Lymph is derived from the plasma of the blood either by filtration, diffusion, or **osmosis** through the capillary walls or by active secretion of endothelial cells making up capillary walls Its composition is very similar to the blood plasma

The function of lymph is to bring nourishment to the tissue cells and to return waste matter and other toxic material to the blood stream by way of the lymphatic vessels, or directly into the blood stream through the capillary walls Lymph has been compared with the body fluids of invertebrates, commonly designated as **hydrolymph** and **haemolymph.** (A W L, R S M)

LYMPHATIC SYSTEM. A tubular system supplementing the **blood** vascular system of vertebrates It collects fluid, chiefly lymph, from the tissue spaces and returns it to the venous circulation

The smaller tubules of the system resemble **capillaries** and the larger ducts, called lymphatics, are similar

to **veins**, although of more delicate structure in relation to their size. Like veins, they have valves which aid in promoting flow through the movements of the surrounding muscles. They are irregular in diameter, forming reservoirs at some points and dilating in the amphibians, reptiles, and birds to form lymph hearts whose pulsations propel the lymph toward the heart. The smaller vessels converge like blood vessels to form larger trunks. In man the chief vessels are the thoracic duct, and the right lymphatic duct, which empty into the large veins at the sides of the neck Along the course of the lymph vessels are groups of lymph nodes They serve as filters which localize and retard the spread of toxic and infective elements that are being returned to the blood stream. The lymph nodes also serve as centers for formation of **lymphocytes** which form one of the main divisions of blood cells.

Besides returning to the general circulation waste products from the cells the digestive lymphatics absorb nourishment from the products of **digestion** in the intestine, returning these food products to the blood stream. (A.W L., R S.M)

LYMPH GLAND, LYMPH NODES. Lymph.

LYMPHOCYTE. A variety of white **blood** cell or leucocyte which is manufactured by **lymph glands** and **nodes**. They are classified as large and small and together they make up about 25% to 30% of the white blood cells under normal conditions. This relationship is disturbed in disease. (R S M)

LYNX. Mammalia, Carnivora. Moderately large **cats** of the northern hemisphere, characterized by conspicuous ear tufts and a fringe of long fur about the throat. Among the several North American species most are called wildcats or bobcats, and the Canada lynx, *Lynx canadensis*, alone is known as the lynx. Several species of lynx also occur in Europe and Asia. (A W L.)

LYRA (The harp) (Map, page 306). This **constellation**, while small in size, contains a number of most interesting objects for an observer with a telescope, whether the instrument be large or small The constellation is most easily distinguished by the equilateral triangle with the star **Vega** at one of its apexes.

Vega is an interesting star for a variety of reasons. In the first place, it is the brightest star in the northern celestial hemisphere. It lies almost in the direction in which the **sun** and all of the **planets** are moving due to **solar motion**. At present, this star is a long ways from the pole of rotation of the **celestial sphere**, but, due to **precession** this star will be the pole star about 12,000 years hence.

The star Epsilon Lyrae is one of the most famous multiple stars in the entire sky. A field glass will show this star to be double, and a four-inch telescope on a good night will show that each component is also double.

Several other interesting doubles are to be found in the constellation. Also in this constellation is the famous ring **nebula**, which, while not impressive in a small telescope, is a very interesting object in an instrument larger than a six-inch.

In zoology, the term lyra designates a sound-producing or stridulating apparatus of certain **spiders**. It consists of a group of spines projecting over a concavity in the surface to which they are attached. Various other forms of stridulating organs are found associated with the pedipalps and chelicerae of different species of spiders; all consist of structures formed for the production of vibrations. (W.K G , A.W L.)

LYRE BIRD.. Aves, Passeriformes. *Menura.* A large bird (**Aves**) with an ornamental tail in the male sex which simulates the form of a lyre. The several species are Australian. (A.W.L.)

LYRIDS. The Lyrids are **meteor showers** which are observed about April 20 of each year The orbit of the **radiant point** was definitely associated with the orbit of **comet** 1861 I by Weiss. Records of showers from this radiant are found back as far as 687 B C. The report written by the Chinese in 15 B C. indicates that during the Lyrids shower of that year "after the middle of the night, stars fell like rain" Several other accounts of striking showers during April are on record, in particular we find many newspaper accounts of the Lyrid shower of 1803, which was observed over the United States from North Carolina to New Hampshire. The Richmond, Va , *Gazette* of April 23, 1803, gives a long and vivid account of the shower occurring on the morning of April 20, stating that "from one until three those starry meteors seemed to fall from every point of the heavens, in such numbers as to resemble a shower of sky rockets."

A few scattered members of this shower are observed coming from the radiant point in the **constellation** of **Lyra** every year, but there has not been any very striking display since 1803. Since there have been striking showers in the past, the assumption is made that there is a large swarm of meteors at some undetermined point along the orbit, and that we may be treated to another brilliant display during some April in the future. (W.K G.)

LYRIFORM ORGAN. A sensory organ, probably an organ of smell, found in **spiders** These organs occur on most segments of the legs and on the under surface of the body. They consist of a series of slits and are associated with special nerve endings. (A.W.L.)

LYSINE. Aminoacids, Polypeptides, and Proteins.

LYSIS. The gradual decline of the symptoms of disease, referring especially to the gradual abatement of fever. Compare with **crisis**. (R.S M.)

M

M SERIES. X-ray Spectra.

MACAQUE. Mammalia, Primates. **Monkeys** of several Asiatic and one African species They are related to the mangabeys but are stouter and have a slightly longer muzzle. The tail varies from long to rudimentary. These monkeys make up the genus *Macacus*. Among the included species are the bonnet monkey, lion-tailed monkey, pig-tailed monkey, and magot. (A.W.L.)

MACARONI. Wheat.

MACASSAR OIL. Fixed oils.

MACAW. Parrot.

MACE. Nutmeg. *Myristica fragrans.* Myristicaceae.

MACHINES. The term machine applies traditionally in physics to any one of those simple devices—lever, inclined plane, etc.—which might with greater propriety be called "elements of mechanism" These elementary machines fall into two general classes: (1) those dependent upon the vector resolution of forces (inclined plane, wedge, screw, toggle joint), and (2) those in which there is an equilibrium of torques (lever, pulley, wheel-and-axle) Their detailed explanation is to be found in any textbook of high school physics For each of the several types, there is a factor known as the "mechanical advantage," which theoretically represents the ratio of the force exerted by the device to the force acting upon it; though on account of friction and elasticity, the actual ratio of the force may differ somewhat from this theoretical value. For a lever, it is equal to the ratio of the "arms"; for an inclined plane, with the force acting parallel to the plane, it is the cosecant of the angle of inclination, etc. Ordinarily a more practicable measure of the mechanical advantage is the ratio of a small displacement produced by the operator of the machine to the resulting displacement of the load by the machine Thus, if the handle of an automobile jack is moved 1 inch in lifting the car 0 002 inch, the mechanical advantage is 500

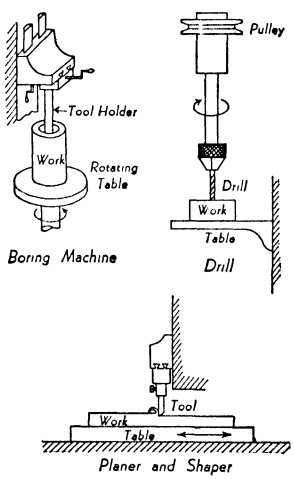
The principles of **efficiency** (ratio of output energy to input energy) are well illustrated by the action of machines No mechanism can operate without loss of energy through friction or otherwise, hence the efficiency of a machine is always less than unity Otherwise, it would be possible to realize **perpetual motion.** (L D W)

MACHINE TOOLS. The various metal-cutting **machines** which are used for forming or finishing metal work by removing a predetermined amount of metal from a rough shape are called machine tools. The classification of the Machine Tool Builders' Association recognizes the following machines:

Boring machines.
Boring and turning mills.
Broaching machines.
Cut-off machines.
Drills.
Gear cutters.
Grinders.
Milling machines.
Hobbing machines.
Planers.
Key seaters.
Rack-cutting machines.
Screw machines
Shapers and slotters.
Tapping machines.
Lathes

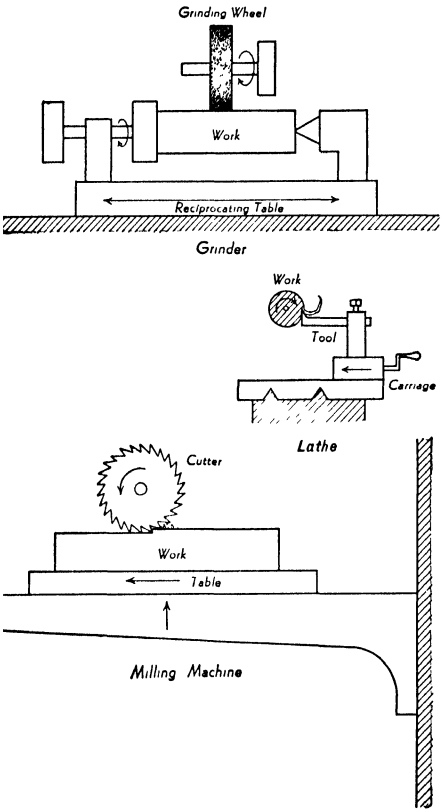
These tool the work in various ways. Most of them employ a cutting action, but not all, for example, grinders and broaching machines. Machine tools may be operated from countershafts which are driven by a central motor, the countershaft containing a cone **pulley** which transmits power to the tool through a cone pulley mounted on the machine. A number of machines so actuated in a machine shop require a number of belts driven from overhead shafting Unit drive employing a motor mounted on or near each machine dispenses with the overhead work, but multiplies the number of drive units that are needed The following brief explanation of the differences between the cutting action of these machine tools may be associated with the accompanying illustrations. Many of the machines mentioned are treated individually in this volume

Boring machines and mills perform a function similar to drills except that boring machines are used for machining large holes, and drills for the smaller ones. In the boring machine, the work is turned, and the tool is held on a head that travels up and down in the hole. The tool head may be moved on its carriage so as to increase the size of the hole. The drill differs in that work is held stationary while the rotating drill is lowered against it. The quill to which the chuck is attached is driven by a pulley, but may slide endwise in the pulley hub, so that the driven pulley does not change its position relative to the driving pulley as the drill penetrates the work.



The planing and shaping operations are used to finish flat surfaces. The machines have reciprocating tables to which the work is fastened. The tool post is on a

carriage which has motion in two directions, one of which lowers the tool against the work and adjusts the depth of cut, and the other, a horizontal motion, moves the tool sidewise over the face of the work These machines cut in one direction only The grinder has three separate motions, one to drive the grind wheel, one to revolve the work as it presses against the grind wheel, and the third to reciprocate the work, so that all parts of it come under the wheel As shown in the diagram, the work is held between centers and rotated These centers are mounted on a carriage which is driven back and forth, so that a shaft, for example, would be ground over its entire length The simplest way to power a grinder is by three separate motor units, but it can be done by countershafts by employing a long drum pulley to drive the work spindle The milling machine uses a cutter which rotates and has a large number of teeth in contrast to the single cutting point of the planer, boring machine, and lathe The milling machine head carries the cutter spindle in fixed journals The work is moved up to it by being held on a table having motion adjustable in three directions, upward for depth of cut, and in two mutually perpendicular directions horizontally, so that the entire surface of the work may be brought under the cutter The lathe is somewhat similar in action to the boring and milling machines, except that it is ordinarily constructed with horizontal action, and the cut is usually taken on the outside of the work In a lathe the work is rotated between centers while a tool held in a tool post which is attached to a carriage is brought against it, causing it to cut the surface The carriage is moved longitudinally along the work, and a cross-feed is provided to move the tool into the work (F T M)



MACKEREL. Pisces, Teleostei Marine fishes (**Pisces**) with compressed spindle-shaped bodies and a widely flaring forked tail The large family Scombridae which they make up includes the important food fishes of moderate size called **mackerels**, *Scomber scombrus*, and a number of moderate to large game and food fishes The latter are the **king fish**, sierra or pintado, *Scomberomorus regalis*, **bonitos**, **albacore**, and tunny, more commonly called the **tuna**, *Thunnus thynnus* One of the smaller genera, *Pneumatophorus*, is called the thimble eye or chub mackerel (A W L)

MACLAURIN'S FORMULA Expansion of **Functions** in **Series**

MACRODASYOIDEA. Gastrotricha

MACRONUCLEUS A large nucleus in the bodies of many one-celled animals, accompanied by one or more small nuclei known as micronuclei The macronucleus is apparently the controlling center for the ordinary activities of the animal It develops under certain conditions from a subdivision of the micronucleus See **Cell** (A W I)

MACROSCOPIC. Derived from the Greek, meaning broad and visual Used by **petrographers** to describe the features of a rock which are large enough to be seen by the naked eye, hence the antithesis of microscopic A better synonym is megascopic, from the Greek, meaning large and visual (R M F)

MACULOSE. A term proposed by Holmes in 1919 to denote a group of spotted **contact-metamorphosed** rocks, including mottled **slates**, **schists**, and **hornfels**, as distinguished from those exhibiting well-defined **foliated** structure (R M F)

MADDER FAMILY. Rubiaceae A family comprising some 4500 species, particularly abundant in tropical regions Some species are found in temperate regions, and a few in Arctic climates The family includes trees, shrubs, and herbs having opposite entire or sometimes toothed leaves with **stipules**, the latter often large and conspicuous The flowers are perfect, regular and **epigynous**, and four- or five-parted Few members of the family are important Species of *Gardenia*, natives of tropical Old World regions, are frequently grown for their fragrant showy flowers *Rubia tinctorium*, the madder plant, was formerly a very important source of the dye madder, also called alizarin Now, however, the dye is prepared synthetically Gambier, *Uncaria Gambir*, a climbing plant native in tropical Asia and the Oceanic Islands, yields quantities of pyrogallol (See **phenol**) **tannin**, extracted with boiling water from the leaves and young shoots This is used in tanning leathers, often mixed with other **tannins** It is also used as an astringent in medicines

Ipecac, *Cephaelis ipecacuanha*, a native of South American tropics, is a shrubby plant, the roots of which are six millimeters thick From the dried roots and the lower part of the stem the drug ipecac is obtained Used in small doses, ipecac is a stimulant, in large doses it is an eliminant, causing vomiting, sweating, and elimination through the kidneys and bowels It is a very efficient means for clearing an overloaded stomach **Quinine** and **coffee** are two other important products from members of this family (R M W)

MADREPORITE A perforated plate on the surface of the body of **echinoderms** The perforations lead into the water vascular system (A W L)

MAD TOM. Pisces, Teleostei **Catfishes** of small size belonging to several species of the genus *Schilbeodes* They occur throughout the Mississippi River system, the Great Lakes region, and the eastern states generally (A W L)

MAFIC Femic.

MAGDALENIAN Paleontology of man.

MAGENTA Dye.

MAGGOT. The soft-bodied **larva** of many species of two-winged **flies** They are often white but some species are brightly colored No organs of locomotion are present Most maggots hatch from the egg in the midst of an abundant food supply of decaying organic matter or living plant or animal tissues and are able to move about sufficiently for their needs by wriggling the body (A W L)

MAGMA. The term for molten material A natural, complex, liquid, high-temperature, **silicate** solution ancestral to all **igneous rocks**, both intrusive and effusive The locus of a magma is within the **lithosphere** (crust) under great pressure and an impenetrable cover which helps the magma to retain its original gases and water vapor in solution The origin of magma is not known but it is generally assumed that separate magma chambers may exist within the lithosphere (R M F)

MAGMATIC STOPING A term proposed by R A Daly in 1906 for a process by which large intrusive rock bodies, such as **batholiths**, might be able to take the space which must have been previously occupied by other rocks This process assumes that the pre-existing rocks are shattered, or stoped, at the roof of the **magma** chamber and sink to lower levels in the magma, where they are melted and assimilated The outer margins of the magma are assumed to be kept molten by the aid of two-phase convection currents as well as by the relatively rapid foundering of the wall rocks and their assimilation in depth When the magma congeals at the top of the chamber so as to show the angular fragments which have been stoped from the walls of the chamber, these fragments are called **xenoliths** (R M F)

MAGNESITE The mineral magnesite is **carbonate** of **magnesium**, $MgCO_3$ It is a hexagonal mineral, but usually found massive It has a **rhombohedral** cleavage, conchoidal fracture, brittle, hardness, 3 5–4 5, specific gravity, 3, luster, vitreous to silky, color, white, gray, yellow, or brown, transparent to opaque Most magnesite is believed to have been derived from the action of carbonated waters upon rocks rich in magnesium Magnesium-bearing waters, on the other hand, may have in some cases acted upon **calcite** or **dolomite** Magnesite deposits are known in Greece, Austria, Norway, India, Australia, and South Africa In the United States magnesite is found in California and Nevada, some of which deposits seem to be of original sedimentary character Magnesite is in demand for the manufacture of refractories and various compounds of magnesium used in medicine or for other purposes (E S C S)

MAGNESIUM. Symbol Mg Atomic number 12 Atomic weight 24 32 Density 1 74 Hardness 2. Melting point 651° C Boiling point 1110° C Isotopes 24 (77 4%), 25 (11 5%), 26 (11 1%)

Magnesium is a silver-white metal, malleable and ductile when heated, unattacked by dry **oxygen**, by water or **alkalis** at room temperature, when heated to about 800° C reacts in air or steam and emits a brilliant white light of high actinic power, reactive with acids including **carbonic** at room temperature, reactive upon heating with **nitrogen**, **phosphorus**, **arsenic**, **sulfur**, **chlorine**, in some cases with such vigor as to constitute a hazard Recognized by Black in 1755, and isolated by Davy in 1808

Magnesium is used in increasing amounts (1) as an alloy with **aluminum** in light, strong construction, e g, **airplanes**, and also used (2) in photographic flashlight powders and signal flares, (3) as a deoxidizer in the casting of metals, (4) as a "getter" in radio tubes, (5) as a reagent in organic chemistry, e g, **Grignard reaction**

Magnesium occurs generally in rocks, especially **limestone** (average 8% MgO) and **igneous rocks** (average 3 5% MgO), as the important mineral **dolomite** (magnesium calcium carbonate mixtures), notably in the Alps, and as **magnesite** (magnesium carbonate, $MgCO_3$), obtained commercially in Austria, Greece, Russia, and the states of California and Washington, in ocean water as the metal second in abundance to **sodium** (about 1 part of magnesium to 10 parts of sodium), in salt deposits, lakes, and brines, notably Stassfurt, Germany, and the state of Michigan, mainly as chloride or sulfate, present in natural hard waters of the earth's surface Magnesium metal is obtained by **electrolysis** of fused magnesium chloride

Acetate magnesium acetate ($Mg(C_2H_3O_2)_2\ 4H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **acetic acid**, and then crystallizing

Arsenates magnesium ammonium arsenate ($MgNH_4AsO_4$), white precipitate, by reaction of soluble magnesium salt solution and **sodium** arsenate in the presence of excess **ammonium** hydroxide, upon igniting yields magnesium pyroarsenate ($Mg_2As_2O_7$), white solid

Borate magnesium borate ($Mg_3(BO_3)_2$ or $Mg(BO_2)_2$), white precipitate, by reaction of soluble magnesium salt solution and **sodium** borate used as a preservative

Boride magnesium boride (Mg_3B_2), brown solid, by reaction of **boron** oxide and magnesium powder ignited

Bromide magnesium bromide ($MgBr_2\ 6H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **hydrobromic acid**, and then crystallizing Is present in many salt brines, and in traces in ocean water, constituting the source of bromine

Carbonates magnesium carbonate, magnesia alba ($MgCO_3$), white solid, insoluble, formed by reaction of soluble magnesium salt solution and **sodium** carbonate or bicarbonate solution Present in carbonate minerals and rocks, **magnesite** (more or less pure magnesium carbonate), **dolomite** (magnesium calcium carbonate mixtures), dolomitic **limestone** When ignited yields magnesium oxide and **carbon dioxide**, when treated with acids yields the corresponding magnesium salt and carbon dioxide, but with **carbonic acid** yields soluble magnesium bicarbonate Used as a heat refractory and insulating material, and as a source of magnesium compounds, magnesium bicarbonate ($Mg(HCO_3)_2$), colorless solution, by reaction of magnesium carbonate and carbonic acid, yields, upon boiling, magnesium carbonate white solid and carbon dioxide, magnesium ammonium carbonate ($MgCO_3\ (NH_4)_2CO_3\ 4H_2O$), white precipitate (soluble in ammonium chloride solution) by reaction of soluble magnesium salt solution and excess ammonium carbonate

Chlorides magnesium chloride ($MgCl_2\ 6H_2O$), white solid, soluble, formed by reaction of magnesium carbonate (or hydroxide, or oxide, or metal) and **hydrochloric acid**, and then crystallizing, loses hydrogen chloride when heated, yielding magnesium oxychloride Used as a dressing and filler for cotton and woolen fabrics, in paper manufacture, in cements, refrigerating brines, in ceramics, and as a source of magnesium for its insoluble magnesium compounds and magnesium metal, anhydrous magnesium chloride ($MgCl_2$), white solid, soluble, formed (1) by heating magnesium chloride crystals in a current of dry **hydrogen chloride**, (2) by heating magnesium ammonium chloride Melting point 712° C Used as the **electrolyte** in manufacture of magnesium metal, magnesium ammonium chloride ($MgCl_2\ NH_4Cl\ 6H_2O$), white solid, soluble, when heated yields anhydrous magnesium chloride residue, magnesium potassium chloride,

carnallite ($MgCl_2 \cdot KCl \cdot 6H_2O$), white solid, soluble, when heated fuses to anhydrous mixture magnesium potassium chloride; magnesium oxychloride, white solid, insoluble, formed (1) by heating magnesium chloride crystals, (2) by mixing magnesium chloride solution and magnesium oxide. Used as a cement when mixed with fillers, such as wood flour, sand powder, marble powder, cork, talc, for flooring.

Chromate: magnesium chromate ($MgCrO_4 \cdot 7H_2O$), yellow solid, soluble, formed by reaction of magnesium carbonate and **chromic** acid solution and then evaporating.

Citrate: magnesium citrate, citrate of magnesia ($Mg_3(C_6H_5O_7)_2 \cdot (4H_2O)$), white solid, soluble, formed by reaction of magnesium carbonate and **citric acid**, and then evaporating. Used in medicine and in effervescent beverages.

Fluoride: magnesium fluoride (MgF_2), white precipitate, by reaction of soluble magnesium salt solution and **sodium** fluoride solution. Used in ceramics.

Fluosilicate: magnesium fluosilicate ($MgSiF_6$), white solid, soluble, formed by reaction of magnesium carbonate and **hydrofluosilicic acid**, and then evaporating. Used in hardeners for concrete, and in ceramics.

Hydroxide: magnesium hydroxide, "milk of magnesia" ($Mg(OH)_2$), white precipitate, by reaction of soluble magnesium salt solution and **sodium** hydroxide solution. Used in medicine as a suspension in water ("milk of magnesia"), and in sugar refining.

Hypophosphite: magnesium hypophosphite ($Mg(H_2PO_2)_2 \cdot 6H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **hypophosphorus** acid, and then evaporating. Used in medicine.

Iodide: magnesium iodide ($MgI_2 \cdot 8H_2O$), white solid, soluble, formed (1) by reaction of magnesium carbonate and **hydriodic acid**, and then evaporating, (2) by heating magnesium metal and iodine. Used in medicine.

Lactate: magnesium lactate ($Mg(C_3H_5O_3)_2 \cdot 3H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **lactic acid**, and then evaporating. Used in medicine.

Nitrate: magnesium nitrate ($Mg(NO_3)_2 \cdot 6H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **nitric acid**, and then evaporating. Used in pyrotechnics.

Nitride: magnesium nitride (Mg_3N_2), yellow solid, with moist air or water yields ammonia and magnesium hydroxide, formed by heating magnesium to a high temperature in **nitrogen** or **ammonia** (**hydrogen** gas evolved), or air (when a quantity of magnesium powder is ignited and then left undisturbed until cool, magnesium nitride is formed in the inner part of the mass).

Oleate: magnesium oleate ($Mg(C_{18}H_{33}O_2)_2$), yellow solid, insoluble, formed by reaction of soluble magnesium salt solution and **sodium** oleate. Used in varnish driers.

Oxalate: magnesium oxalate ($MgC_2O_4 \cdot 2H_2O$), white solid, insoluble, formed by reaction of soluble magnesium salt solution and **ammonium** oxalate solution.

Oxide: magnesium oxide, magnesia, "burnt magnesia" (MgO), white solid, reacts slowly with water to form magnesium hydroxide, absorbs carbon dioxide from the air to form magnesium carbonate, is readily soluble in acids, insoluble in alkalis; formed (1) by heating magnesium carbonate to high temperature (**carbon dioxide** gas evolved), (2) by heating magnesium hydroxide, nitrate, sulfate, or oxalate, (3) by burning magnesium metal in air or **oxygen** (emission of brilliant white light of high actinic power). Used as a heat refractory and insulating material, in compounding rubber, in cosmetics, as a filler for paper; magnesium peroxide (MgO_2), white solid, insoluble, formed by reaction of soluble magnesium salt solution and sodium peroxide. Used in bleaching woolen and silk fabrics, and as antiseptic.

Phosphate: magnesium ammonium phosphate ($MgNH_4PO_4$), white precipitate, by reaction of soluble magnesium salt solution and **sodium** phosphate in the presence of excess ammonium hydroxide, upon igniting yields magnesium pyrophosphate ($Mg_2P_2O_7$), white solid.

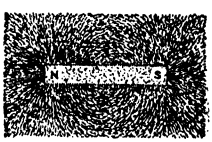
Salicylate: magnesium salicylate ($Mg(C_7H_5O_3)_2 \cdot 4H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **salicylic acid** in water. Used in medicine.

Sulfate: magnesium sulfate, "Epsom Salt" ($MgSO_4 \cdot 7H_2O$), white solid, soluble, formed by reaction of magnesium carbonate and **sulfuric acid**, and then evaporating, removable from natural brines or salt deposits. Used as a source of magnesium for its insoluble compounds, as a dressing and filler for cotton and silk goods, and in dyeing and printing and fireproofing cotton, as sizing for paper, in cosmetics and lotions, and in medicine.

Sulfide: magnesium sulfide (MgS), formed (1) by heating magnesium sulfate and **carbon** to a red heat, (2) by heating magnesium and **sulfur** to ignition (Hazard!).

Tungstate: magnesium tungstate ($MgWO_4$), white precipitate, by the reaction of soluble magnesium salt solution and ammonium **tungstate**. Used as a luminescent paint, and fluorescent x-ray screen. (R.K.S.)

MAGNET. In ancient times it was known that stones containing magnetite (See **Iron**) had qualities which were not the property of other stones. It was found that they would attract iron, and when freely supported would turn so that their axis would take a north-south direction. These lode stones were the earliest magnets, but now are natural curiosities only, since the magnets used in compasses, instruments, magnetos, and all the various array of equipment which embodies a magnetic field produced by a magnet, are artificially constructed of hardened steel, magnetized by a strong magnetic fluid. This type of magnet may be said to be a permanent magnet, in contrast to the **electromagnet**.



Graphical magnetic field of a bar magnet.

A magnet is a body possessing the property of attracting magnetic substances. The so-called permanent magnet should be used where a constant magnetic field is to be produced, since a well-made permanent magnet loses its magnetism very slowly, and then only up to a certain point, after which it is said to be aged. Thereafter it maintains a constant degree of magnetism unless subjected to strong de-magnetizing effects. Manufacturers of permanent magnets for precision instruments artificially age them during the process of manufacture. The permanent magnet is made from crucible steel containing 5% of tungsten, and very small amounts of chromium, manganese, and carbon. Magnetization is accomplished by placing the magnet in a strong field produced by an electromagnet. A bar which has been magnetized is found to have poles. These are centers where magnetic attraction is strongest. If the magnet is free to turn, the pole which points northerly is called a north pole, and the other a south pole. Like poles repel each other with a magnetic force, and unlike poles attract each other. The earth is a large magnet having magnetic poles somewhere near, but not coincident with, the geographic poles. (See **Declination.**) Since unlike poles attract each other, and the north pole of a magnet is taken as that which points northerly, it is the earth's south magnetic pole which lies near the north geographic pole. A magnet, delicately made, and freely suspended, becomes a **compass.** (F.T.M.)

MAGNETIC ANALYSIS. Mass Spectrograph.

MAGNETIC CIRCUIT. A magnet, or a coil of wire carrying a current, is the seat of an influence which extends outward from it and is called a **magnetic field.** The flux from a bar magnet or from a straight electromagnet issues from one end of the magnet or coil, bends

around, and re-enters at the other end This can be exhibited by exploring the region with a compass needle If there is provided an iron frame or ring extending from one pole of the magnet or coil around to the other, and in case of the coil, running clear through it, the magnetic flux is not only concentrated largely in the iron but is much greater in total amount than if the induction is entirely in the air Even a short air-gap in the iron reduces the flux considerably

The analogy of such a magnetic path to an electric circuit is easily seen The magnetic flux corresponds to a current The magnet or coil corresponds to a battery, and provides magnetomotive force just as a battery supplies electromotive force The amount of flux produced by a given magnetomotive force depends upon the dimensions and material of the "magnetic circuit," e g , the length and cross-section of the iron ring followed by the flux and the permeability of the iron, just as the dimensions and material of the electric conductor determine its resistance. This attribute of the magnetic circuit (corresponding to resistance) is called its reluctance

These ideas are expressed quantitatively for the purpose of practical calculations The magnetomotive force $\mathfrak{M}$ is commonly given in "ampere-turns" Thus, a coil of 50 turns carrying a current of 4 amperes has a magnetomotive force of 200 ampere-turns Another unit of magnetomotive force sometimes used is the "gilbert," equal to $5/2\pi$ or 0 794 ampere-turn The flux ϕ is expressed in lines or "maxwells" Just as the resistance of an electric circuit is defined as the ratio of the electromotive force to the current, so the measure of the reluctance $\mathfrak{R}$ of a magnetic circuit is the ratio of the magnetomotive force to the flux We then have the relation

$$\phi = \frac{\mathfrak{M}}{\mathfrak{R}},$$

a sort of magnetic Ohm's law, known as Bosanquet's law

There are approximate formulas, used in electrical engineering, for calculating $\mathfrak{M}$ and $\mathfrak{R}$, and hence ϕ, from the specifications of a coil, its core, air gaps, etc Such formulae are extensively used in designing transformers, generators, motors, etc (See **Electromagnet**) (L D W)

MAGNETIC DAMPING. Lenz's Law

MAGNETIC FIELD The region surrounding a **magnet** or an **electric current** is endowed with peculiar properties, the most familiar manifestation of which is the **torque** experienced by a small magnet, such as a compass needle, when placed in such a region For any point of the field, there is only one direction in which the small magnet will come into stable equilibrium, and when this takes place, the direction in which the north pole of the magnet points is called the direction of the field Upon exploring a magnetic field by moving the small magnet about in it, it is found that the field direction in general follows curved lines of force If the field is due to the current in a conductor, these lines form completely closed curves enclosing the conductor, if due to a magnet, they apparently enter the iron at the south pole and emerge at the north pole, inferring that they complete themselves through the iron as they do through a coreless, current-carrying helix

In any magnetic field there is at each point a certain magnetic intensity, a vector whose direction is that of the field If one pole of a very long, slender bar magnet of unit pole strength is inserted into the field, that pole is acted upon by a force which, expressed in dynes, is a measure of the magnetic intensity The unit magnetic intensity is the **oersted** (formerly the **gauss**) An instrument used for measuring the intensity is called a **magnetometer.** (See **Magnetic Flux**)

Just as there is an **electric potential** at every point of an electric field, a **magnetic potential** exists at every point of a magnetic field The difference in the magnetic potential at two points is measured by the work necessary to move a unit magnetic pole against the field from one point to the other This difference is sometimes called a magnetomotive force, in analogy to **electromotive force** (See **Fields of Force.**)

The lines of magnetic intensity around a current-carrying wire are circular, having the plane of the circle perpendicular to the axis of the wire Such magnetic fields are thought of as whorls of magnetomotive force encircling the wire The direction of the whorls of force is determined by the "right-hand rule" When the wire is grasped by the right hand, the fingers encircling the wire, and the thumb pointing along the wire in the direction of the current, the fingers encircle the wire in the direction of the lines of force This rule is used to determine in which direction the north pole would lie in a helix or solonoid of wire, for, instead of having a straight wire encircled by magnetic whorls, the wire itself is bent into a circular form by being wound in a solonoid or helix The lines of force will then produce an axial magnetic field, so that one end of the solonoid is equivalent to a north pole, the other to a south pole (L D W, F T M)

MAGNETIC FLUX The magnetic flux through any closed figure, such as a circle, a rectangle, or a loop of wire, is the product of the area of the figure by the average component of magnetic induction (See **Magnetism**) normal to that area Thus, if a rectangle 5 centimeters $\times$ 8 centimeters is placed in a region where there is a uniform magnetic induction of 2500 **gauss,** and at an angle of 30° with the lines of induction, the magnetic flux through it is 2500 gauss $\times$ 40 centimeters^2 $\times$ sin 30° = 50,000 gauss-centimeters^2 or "maxwells" The magnitude of this quantity is often conventionally represented by imagining the lines of induction to be so spaced that the number of them through a given area is equal to the number of gauss-centimeters^2 or maxwells of flux through that area The flux in the above example would be commonly expressed as 50,000 "lines" When a coil has several (n) turns and each turn has approximately the same flux (ϕ) through it, the effect is the same as for a single loop with the flux $n\phi$ through it This product, which is called the "linkage," is expressed in "maxwell-turns" or "line-turns"

The magnetic flux or the linkage through a loop or a coil may be measured by putting into the circuit a ballistic (undamped) galvanometer and then suddenly removing the flux (or the coil) If the resistance of the whole circuit and the constant of the galvanometer are known, the flux may be calculated from the "throw" of the galvanometer (L D W)

MAGNETIC INDUCTION Magnetism; Gauss

MAGNETIC INTENSITY. Magnetic Field, Oersted

MAGNETIC MOMENT. Magnetism.

MAGNETIC PENDULUM A bar magnet poised on a pivot or suspended by a thread in a magnetic field having a horizontal component will, if disturbed and released, oscillate in a horizontal plane as a magnetic pendulum This arrangement is commonly employed in the **magnetometer** method of measuring the earth's magnetic field intensity, or in comparing field intensities in different localities The period of oscillation of such a pendulum depends upon the magnetic moment M of the magnet, the horizontal component H of the magnetic field intensity, the **moment of inertia** I of magnet and supports with respect to the oscillation axis, and (if a suspending fiber is used) the torsion coefficient K of the fiber For small amplitudes the period is

$$T = 2\pi\sqrt{\frac{I}{MH + K}}$$

With a pivoted magnet, $K = 0$, while if the bar is unmagnetized, $M = 0$, and the formula degenerates into

that for a **torsion pendulum** The moment of inertia I may be determined experimentally in the same manner as with a torsion pendulum, but using $MH + K$ in place of K In order to find K alone, the magnet is replaced by a non-magnetic bar having the same moment of inertia, and the torsion pendulum method applied (L D W)

MAGNETIC POLE. **Magnet; Magnetism.**

MAGNETIC POTENTIAL. **Potential; Magnetic Field.**

MAGNETIC RESONANCE ACCELERATOR. **Cyclotron.**

MAGNETIC STORMS. **Terrestrial Magnetism.**

MAGNETISM. Centuries ago, minerals were discovered which exhibited strong attraction for iron and served as compass needles These "lodestones" are in fact iron ores, usually Fe_3O_4 It was found that a steel bar stroked with such a natural magnet becomes itself a magnet with poles dependent upon the direction of stroking With care the poles may be strongly localized in limited regions, almost points, and the forces between poles are then found to obey **Coulomb's law** of inverse squares Two unit poles at a distance of 1 centimeter in a vacuum attract or repel each other with a force of 1 dyne When placed in a **magnetic field**, a bipolar magnet experiences a torque proportional to the field intensity and to the sine of the angle between the axis of the magnet (line joining poles) and the field direction The maximum torque per unit field intensity (which obtains when the magnet and the field are at right angles) is the magnetic moment of the magnet

When a substance having magnetic properties is placed in a magnetic field, the field intensity gives rise to a magnetizing force H within the body, and the substance acquires a certain magnetization I depending upon H and upon the susceptibility of I/H of the substance The resulting magnetic induction, $B = H + 4\pi I$, is a quantity much used in magnetic theory If the field intensity is gradually built up from zero, the induction may be represented by a curve with H and B as coordinates As magnetization proceeds, the curve approaches a straight line inclined at 45° (if B and H are on same scale), which means that I approaches a steady value, a condition called saturation The ratio B/H is at any stage the magnetic permeability of the substance If now the field is diminished, it is found that a certain reverse intensity OC, called the coercive force, is usually required to reduce the induction to zero This is due to **hysteresis** Some alloys of iron show extraordinary peculiarities, for example, permalloy (22% iron, 78% nickel) has enormous initial permeability, while perminvar (iron, nickel and cobalt) has almost constant permeability for different fields, so that the graph OS is practically straight (See typical hysteresis curve on page 607)

Substances may exhibit magnetic properties not only in different degrees, but in radically different ways There are three fairly distinct classifications, paramagnetic, ferromagnetic, and diamagnetic substances The many paramagnetic substances, and the small group of ferromagnetic substances (iron, nickel, cobalt, gadolinum, and some alloys), both have positive susceptibility (I increases with H), but their magnetization curves are different and the phenomena are attributed to quite different causes Any ferromagnetic substance becomes paramagnetic at a sufficiently high temperature (See **Curie-Weiss Law**) With diamagnetic substances, such as copper, silver, and bismuth, the susceptibility is negative and the permeability slightly less than 1, so that their magnetization curves lie in the fourth quadrant

The physical nature of magnetism has been the subject of much speculation and research It appears now that paramagnetism is probably due to the orbital motion of electrons in the atom, there being an excess of electrons revolving one way over those revolving the other, that in ferromagnetic substances large groups called "domains," made up of atoms having parallel magnetic moments, act together when the substance is magnetized and somehow add enormously to the induction, and that diamagnetism arises from the **precession**, in the applied field, of atoms which are not even paramagnetic, but which thus give rise to a feeble magnetization opposed to the field The magnetic moments of paramagnetic atoms appear to be made up of very small units called magnetons, and the processes causing changes in magnetization take place in accordance with **quantum** conditions (See also **Barkhausen Effect, Barnett Effect, Heusler's Alloys, Magnetic Circuit, Magnetic Flux, Magnetostriction, Electromagnetism**) (L D W)

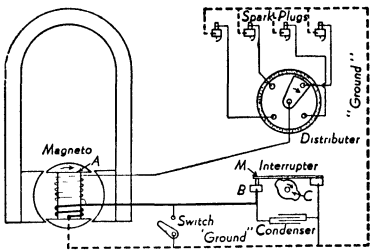
MAGNETITE or MAGNETIC IRON-ORE (LODE STONE). The mineral magnetite, ferroferric oxide, Fe_3O_4, is **isometric**, commonly occurring in **octahedrons, dodecahedrons**, and massive, granular, laminated, etc It is brittle with an uneven fracture, cleavage is not distinct, but with pressure an octahedral **parting** may develop, hardness, 5 5–6 5, specific gravity, 5 18, luster, metallic to dull, color, **iron** black, **streak**, black It is opaque and strongly magnetic, when possessing polarity is known as lode stone Magnetite is a common mineral in the **igneous rocks**, especially those of the ferromagnesian varieties, and is found in many **metamorphic** types It is associated with **corundum** in **emery** In northern Sweden are what may be the largest magnetite deposits in the world, believed to have been formed by segregation in the **magma** Magnetite is also found in Norway, in the Urals, Italy, Switzerland, Australia and Brazil In the United States the Pre-Cambrian rocks of the Adirondacks contain large beds of magnetite This mineral is found also in New Jersey, Arkansas, Utah, and in Canada in Quebec and Ontario The lode stone or natural magnet is found in Siberia, the Harz Mountains, the Island of Elba, and at Magnet Cove, Arkansas The name magnetite is said to be derived from the district of Magnesia, near Macedonia There is, however, a fable that it was named for a shepherd, Magnes, whose iron-bound staff and shoes with iron nails stuck to the ground in which magnetite was present

This mineral is an important ore of iron, containing 72% **of** metallic iron (E S C S)

MAGNETO. The magneto is a device for producing alternating currents of high **voltage** properly synchronized and distributed to the spark plugs of an engine operating on the **Otto cycle** principle (See **Ignition System**) The same function may generally be admirably performed by the coil and battery circuit, but the compactness and light weight of the magneto as a single unit, coupled with its reliability, have caused it to be widely used for ignition The magneto is, however, no longer used with that most familiar example of the Otto engine, the automobile, because various electrical requirements of the automotive vehicle, other than ignition, have made the coil and battery more attractive The magneto may not produce any electrical energy for starting, lighting, etc Its function is solely that of ignition Today it is found on stationary and portable engines, tractors, motor boats, and on airplane engines, where its proved reliability is respected

In reality, the magneto is a **generator**, and is usually combined with an **induction coil, interrupter**, and **distributor**, all consolidated in one small compact unit whose largest dimension is rarely over six inches, even for a multicylindered engine The figure on the following page illustrates the elements of the magneto Between the pole pieces of a permanent horseshoe magnet, a core is caused to rotate by being connected by gear or chain to the engine crankshaft A common arrangement is for this rotor to revolve at crankshaft speed The primary circuit, condenser, and interrupter are built in, and revolve with the **armature** The cam action is obtained

through static cams bearing against the rotating interrupter arm Thus the primary circuit is complete within the rotor, and needs no brush to carry it to the frame



Typical wiring diagram of high tension magneto

of the magneto One end of the secondary circuit is grounded to the primary, and the other is led off from the rotor through a ring and brush arrangement This high-voltage circuit connects with the distributor, which is driven at half engine speed by two-to-one gearing to the rotor The magneto so described is a shuttle type Another important type is the inductor magneto, different in that instead of rotating the armature coils between the poles of a stationary magnet, the magnet itself is caused to rotate between shoe pieces which are the ends of the armature core (F T M)

MAGNETOMETER. An apparatus used for measuring moderate magnetic field intensities, or sometimes the magnetic moments of magnets, frequently both The standard laboratory equipment is set up in two ways, giving two results from which may be calculated both the magnetic field intensity (or rather, its horizontal component H) and the magnetic moment M of a short bar magnet forming part of the equipment The terrestrial magnetic intensity is usually measured in this way, and Gauss employed this method in verifying the magnetic inverse-square law

In the first arrangement, the magnet is used as a **magnetic pendulum,** whose **moment of inertia** I is known and whose period of oscillation T is measured It is usually suspended by a fiber of known torsion coefficient K, in some cases K is small enough to be neglected From the magnetic pendulum formula we obtain the product

$$MH = \frac{4\pi^2 I}{T^2} - K \qquad (1)$$

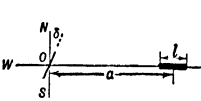


Diagram of magnetometer, δ is the deflection of the needle at O, due to magnet in the "end-on" position at distance a

The magnet is then arranged to deflect a small compass needle The needle is at O, the magnet at a considerable distance a from it, and commonly east or west of and aligned upon it (see figure) If the length of the magnet is l, the deflection δ of the needle is given by

$$\tan \delta = \frac{M}{H} \frac{32a}{(4a^2 - l^2)^2},$$

from which

$$\frac{M}{H} = \frac{(4a^2 - l^2)^2}{32a} \tan \delta \qquad (2)$$

The second members of (1) and (2) contain only measurable quantities, and are therefore known Hence, by multiplying (1) and (2) we get M^2, and by dividing (1) and (2) we get H^2, from those results M and H follow Instruments embodying these principles are regularly used by the U S Coast and Geodetic Survey. (L D W)

MAGNETOMOTIVE FORCE; Magnetic Circuit.

MAGNETON. Magnetism.

MAGNETO-OPTICAL ROTATION. Some substances are in themselves optically active, that is, they rotate the polarization plane of **polarized light** passed through them In 1845 Faraday discovered that glass and other substances devoid of this property acquire it when placed in a strong magnetic field This is the so-called Faraday effect The light must traverse the substance along the lines of force The direction of the rotation is reversed if the field is reversed, but is the same with respect to the observer whether the light is going or coming, so that a beam passing one way and reflected back has its rotation thereby doubled (which is not the case with natural activity) Some substances produce right-handed, some left-handed rotation in light traveling in the direction of the field In any case, except for ferromagnetic substances, the rotation per unit thickness is for a given wave length proportional to the field intensity, its value per centimeter per oersted intensity being called the Verdet constant Some typical values of the constant, with sodium light, are flint glass, 0 061', water, 0 013', air, 0 000007' For ferromagnetic substances the rotation is proportional to the magnetization (See **Magnetism**) rather than to the intensity, as shown by Kundt The rotation increases with diminishing wave length

Another type of magnetic rotation was observed by Kerr in 1877 A beam of plane-polarized light vibrating either in or perpendicular to the plane of incidence has its polarization plane rotated upon reflection from the polished pole-piece of a strong magnet The polarization is at the same time rendered slightly elliptical (L D W)

MAGNETOSTRICTION. The term literally implies magnetic contraction, but is generally understood to include a number of closely allied phenomena relating to ferromagnetic substances under magnetic influence

(1) When an iron rod is subjected to a gradually increasing longitudinal magnetic field, it at first increases slightly in length (Joule effect) and later the length diminishes, when the magnetic intensity has reached about 250 oersteds, the rod has returned to its original length, and further increase of intensity causes it to contract (Villari reversal point) Nickel contracts rapidly at first and then remains nearly constant, while some iron-nickel alloys lengthen without reversal The following phenomena are also recognized (2) The Guillemin effect the tendency of a bent ferromagnetic rod to straighten in a longitudinal field (3) The Wiedemann effect the twisting of a rod carrying an electric current when subjected to a magnetic field (4) The Villari effect a change of magnetic induction within an iron rod under longitudinal stress (inverse Joule effect)

Magnetostriction has been put to practical use in the magnetostrictive resonator, essentially an iron rod maintained in longitudinal elastic vibration by a high-frequency current in a helix wound upon it, and used, through the joint operation of the Joule and Villari effects, to control the frequency of the current, somewhat after the manner of the familiar **piezo-electric** (crystal) **resonator** (I D W)

MAGNIFYING POWER Crudely defined, the magnifying power of an optical instrument is the ratio of the apparent size of an object as seen through the instrument to the apparent size of the same object as seen without the instrument To define "apparent size of an object" in terms which will permit of rigorous discussion requires certain assumptions We may define the apparent size of an object as the angle which the object subtends at the eye, or as the size of the image which the lens of the eye forms of the object on the retina of the eye (retinal image) Using this definition we shall find that the apparent size of the rising moon is actually

less than that of the moon when up on the meridian in spite of the fact that the rising moon always "looks" much larger than when it is up away from objects with which direct comparison can be made

Even with the assumption of apparent size defined as above, the significance of the term magnifying power depends upon the type of instrument which is under consideration For a **telescope,** used to view distant objects, the magnifying power may be directly defined as the ratio of the size of the retinal image obtained with the instrument to the size of the retinal image obtained without any optical aid When a positive **eyepiece** is used the magnifying power may be shown to be directly equal to the ratio of the focal length of the object glass of the telescope to the focal length of the eyepiece For example, a telescope with an object glass of 10 feet focal length will have a magnifying power of 60 when used with a positive eyepiece of 2-inch focal length It should be noted that changing the eyepiece will change the magnifying power of the telescope, e g , if an eyepiece with one-half inch focal length were used with the above telescope, the magnifying power would be 240 Hence, the question regarding the magnifying power of a telescope with interchangeable eyepieces is meaningless unless the particular eyepiece is specified for the particular telescope In telescopes, binoculars, field glasses, etc , purchased from dealers in optical supplies, usually the eyepieces are not interchangeable and the magnifying power specified by the maker depends upon the lenses supplied with the instrument In case negative eyepieces are used with a telescope a so-called "effective focal length" must be known for the eyepiece before the magnifying power can be calculated

In the case of a **microscope,** either simple or compound, the magnifying power is usually defined as the ratio of the retinal image obtained for a given object while using the microscope to the retinal image that would be obtained of the same object without the instrument with the object at a standard distance from the eye, usually 250 mm For a compound microscope the magnifying power is approximately equal to 250 times the length of the tube, divided by the product of the focal lengths of the objective and eyepiece, the three lengths all expressed in millimeters The magnification effected by a projection instrument, such as an enlarging camera or a stereopticon, is logically expressed as the ratio of the diameter of the real image formed on the screen to the diameter of the object itself If the focal length of the projecting lens is f and its distance from the screen is d, this magnetification is approximately equal to $\frac{(d-f)}{f}$ (W K G, L D W)

MAGNITUDE. Stellar Magnitude.

MAGPIE Aves, Passeriformes Moderately large long-tailed birds (**Aves**) related to the crows The common North American species, *Pica pica,* ranges from Alaska to Arizona and eastward into Iowa It is a black and white bird The yellow-billed magpie, *P nuttalli,* flies only in California The European and Asiatic species of magpies are more brightly colored

The magpies build very large untidy nests and are noted for their curiosity, adaptability, and noisiness (A W L)

MAHOGANY. *Swietenia mahogani* and other species. Meliaceae The name mahogany belongs properly to a group of trees which are found in Central America and the West Indies, and to a few related species growing in tropical Africa These, species of the genus *Swietenia,* are large trees with **pinnately** compound leaves like those of ash trees and small flowers in **panicles** in the leaf **axils** The term mahogany is also frequently and mistakenly applied to many dark red woods not mahogany.

The trees grow in a variety of habitats, often in most inaccessible places, so that it is very difficult to get the cut logs to the market Mahogany is usually classified according to the region from which it comes, as Cuban Mahogany, Honduras Mahogany, etc

The first mahogany to appear in Europe was brought in as ballast in a ship, the heavy logs being very suitable for that purpose In port it was necessary to remove these in order to get in more cargo So it was offered to English woodworkers At first it was rejected as too hard to work and of little use, being heavy and dark-colored Gradually it found favor, until it became a highly prized wood for fine furniture making The first mahogany used in cabinet work was Spanish mahogany, *Swietenia mahogani* For a long time mahogany from San Domingo held first rank and was eagerly sought after It was a very hard dark wood which could be given a very high polish, and was very durable The supply is now nearly exhausted Cuban mahogany is another variety which gives a dark red wood, and which finishes with a very fine glossy surface In this, as in some other varieties, the wood is frequently marked with very small white pores of chalk-like substance With age the wood of these varieties gradually darkens, it does not, however, lose its beautiful smooth finish Other species of *Swietenia* are shipped from Panama, from Mexico, and from South American countries

The heavy logs of mahogany are removed from their native forests and shipped to American or foreign markets In some varieties the logs are short and thick, often they are not perfect, having cracks or imperfections caused by branching Some of the larger logs may be hewn square before removing from the forest, making them lighter and easier to handle Specially valuable are those logs which when cut show a wavy grain or other irregularities Even more valuable are blocks of mahogany which come from a large forking of the stem, from these the beautifully grained crotch mahogany is obtained This is usually cut into thin **veneers** In drying, mahogany shrinks very little, and once dry, is very durable, twisting or warping very little

African mahogany is becoming increasingly valuable It is obtained from large trees of the genera *Khaya* and *Entandrophragma,* both members of the same family as mahogany, and yielding woods very similar to it Often appearing as mahogany are certain species of the genus *Cedrela,* which includes Spanish **Cedar,** native trees of Central and South America Many entirely unrelated woods, such as birch, maple, and even softwoods like whitewood, are frequently stained to simulate mahogany True mahogany need not be stained (R M W)

MAHSEER, MAHASIR. Pisces, Teleostei A large fresh-water fish (**Pisces**) (*Barbus mosa*), of the Oriental region, related to the carps It attains a length of six feet (A W L)

MAIDENHAIR TREE. *Ginkgo biloba* Ginkgoales The maidenhair tree is the sole surviving member of an order of **Gymnosperms** which in **Mesozoic** times was very abundant and widely distributed Doubt exists whether the tree grows wild in any region today, though many people state that it does on the mountain slopes of China It has been cultivated in the temple gardens of China and Japan for centuries In late years it has been widely planted in the New World

The tree often has a tall slender pyramidal shape when young, others, and especially older specimens, are wide-spreading The branches are of two kinds a long shoot which grows rapidly in length and which is composed mostly of woody tissue; and short shoots or spurs which elongate very slowly These short shoots have a large pith, a thick **cortex** and very little wood A short shoot may sometimes (especially in the case of injury to the long **shoot**) become a long shoot The leaves of the **ginkgo tree** are somewhat variable in shape Those on the long shoot are wedge-shaped and deeply notched,

those of the short shoot broadly wedge-shaped and little or not at all notched It is to the leaves that the tree owes its common name, Maidenhair tree, since their shape suggests that of the maidenhair fern The trees are **dioecious**, the two types of flowers being borne on different trees The male **strobilus** is composed of many **sporophylls**, each with two **sporangia**. The female flowers are also numerous Each consists of a long slender **peduncle** or stalk bearing two **ovules**. In most cases one of those aborts early The pollen grains, which consist of three small disk-shaped cells and one relatively large one, are carried to the ovule by the wind There it forms a pollen tube which digests its way through the tissue surrounding the **gametophyte**. A pollen tube which has nearly reached the gametophyte contains two large **sperms**, each of which has a spiral coil of cilia at its anterior end One of these sperms passes to one of the large eggs contained in the female gametophyte, and joins with it The nucleus of the sperm unites with that of the egg, which is then said to be fertilized The ovule containing the fertilized egg enlarges When mature it is about an inch in diameter and green Its outer covering is fleshy and has a curious rancid odor which is very noticeable when the fruit is crushed Within this fleshy coat is a dry covering surrounding the gametophyte and the embryo plant The seeds germinate readily, forming a long tap root and a short erect shoot Young plants are rather susceptible to low temperatures, requiring some protection in the northern states (R M W)

MALACHITE. The mineral malachite is a **basic carbonate** of **copper** corresponding to the formula $CuCO_3$ $Cu(OH)_2$ It is **monoclinic**, crystals tending to be acicular, but usually found massive It is a brittle mineral, hardness, 3 5–4, specific gravity, 3 9–4 03, luster, vitreous to silky or dull, color, green, streak, green, translucent to opaque Malachite is an alternation product found associated with other copper bearing minerals It is a rather common mineral and is found quite widely distributed Large quantities have been found in the Ural Mts , it is also found in Germany, France, England, the Belgian Congo, Rhodesia, and Australia In the United States beautiful radiated masses of fibrous crystals have been found in Berks County, Pennsylvania It has been found in Tennessee at Ducktown, and in Arizona, Nevada and Utah Malachite besides being an ore of copper has been used for various ornamental purposes The word malachite is derived from the Greek meaning, *a mallow*, because of its green color (E S C S)

MALACOLITE Diopside.

MALACOSTRACA. Crustacea.

MALARIA A disease caused by a **protozoon** parasite transmitted by the bite of an infected anopheline mosquito The disease occurs in endemic and epidemic forms and is very common in the tropical countries Probably no other disease has disabled and killed as many people throughout the world as malaria Except in some of the Southern states, malaria is quite rare in the United States and is much less encountered than formerly due to eradication of mosquito propagation by means of drainage of breeding swamps and the use of oil in killing the breeding mosquitos and their larvae Other important measures involve screening, segregation of human malarial carriers, and prevention of infection of mosquitos from the carriers by the usual means

Malarial parasites in an infected person are found within the red **blood** corpuscles and are seen as pigmented small bodies (See Plate C, facing page 149) They infect monkeys, fish, birds, and cattle as well as man, who serves as the intermediate host and in whom the parasite causes symptoms In the mosquito, which serves as the definite host, the sexual cycle of the parasite takes place

The names of the men associated with the discovery of the parasite and its development in man and the mosquito are Laveran, Golgi, Ross, Grassi, Bastianelli and many others

Malarial parasites occur in several forms The intermittent forms of fever, characterized by regularly recurring paroxysms of fever and chill are classed as (1) Tertian in which the tertian malarial parasite causes paroxysms of fever at regular intervals, each twenty-four hours, (2) Quartan in which another form of parasite causes paroxysms on the fourth day

The paroxysms occurring with the different forms of the parasite correspond to the evolution of the parasite's cycle in man The tertian form occurs most commonly in temperate regions; the quartan is most common in India

An irregular form of fever occurs and is known as the Estivo-autumnal forms It occurs in the tropics and in temperate zones This type of parasite has an irregular cycle of development so that the paroxysms occur at irregular intervals Infection with this parasite resembles typhoid fever

There are several other forms of malarial fevers (1) *Pernicious malaria* The symptoms may be predominantly cerebral accompanied by delirium and coma which usually results fatally, or gasterointestinal with vomiting, diarrhea and suppression of urine which also usually results in a fatal outcome, (2) *Black Water Fever* A very serious form of fever in which a toxic substance dissolves the red blood corpuscles resulting in the passage of dark-colored scanty urine Why this form occurs is not definitely known, but it is thought to be the result of the production of toxins in repeated malarial attacks, lowered bodily resistance, individual sensitivity and the taking of quinine Fortunately, this frequently fatal form is rare

Complete cure of all forms of malaria is difficult and sometimes impossible because of the danger from carriers It has been known to be transferred to another party by means of transfusions and in drug addicts where a common unsterilized needle has been used Latent malarial infection occurs without causing any symptoms of the disease

In the treatment of malaria **quinine** is a specific remedy for destruction of the parasites in the body Various derivatives of quinine are used in special forms of malaria or in those patients with whom quinine disagrees (R S M)

MALEIC ACID Acids, Carboxylic.

MALEO Aves, Gallıformes A peculiar bird (**Aves**) of Celebes and neighboring East Indian islands The head and neck are covered with naked red skin and the crown bears a black prominence resembling a helmet The plumage is mostly black but that of the breast and belly is salmon colored The large eggs are buried in hot sand (A W L)

MALIC ACID AND MALATES Malic acid, hydroxysuccinic acid (H_2 $C_4H_4O_5$ or COOH CH_2 CHOH COOH) is a white solid, melting point 133° C , decomposes at 150° C , soluble in water, alcohol, or ether **Calcium** malate, on account of its solubility characteristics, is of importance in the separation and recovery of malic acid Calcium malate plus dilute **sulfuric acid** yields malic acid plus calcium sulfate and the latter may be separated by **filtration** Malic acid may be obtained by evaporation of the filtrate

Ester Ethyl malate $\begin{matrix} CH_2 & COOC_2H_5 \\ | & \\ CHOH & COOC_2H_5 \end{matrix}$ boiling point 253° C Malic acid may be obtained (1) from some natural products, e g , the free acid in the juice of unripe apples and gooseberries, often in conjunction with citric or **tartaric acid**; potassium hydrogen malate is present in rhubarb and currants, calcium malate in sugar "sand" by evaporation of the sap of the sugar maple, (2) by synthesis Malic acid is a dibasic acid, that is, two

series of **salts** and **esters** are known On sublimation at 200° F , it is converted into fumaric acid Malic acid is used in medicine and in the production of various salts and esters (R K S)

MALIGNANT. An infection or diseased condition that is especially virulent and rapidly grows worse Malignant tumor or malignancy are terms for cancer (R S M)

MALIGNITE This rock is best described as a **nepheline syenite** with larger proportions of **iron** and **magnesia** than is usual in **alkali** rocks It has received its name from the type locality on the Maligne River, Province of Ontario, Canada (E S C S)

MALINGERER One who pretends sickness deliberately (R S M)

MALKOHA. Aves, Cuculiformes A **cuckoo** of Ceylon

MALLEABILITY. Metals, Physical Properties of.

MALLEABLE CAST IRON. Malleability is understood, in most cases, to be that property which makes it possible to hammer, press, roll, etc , a metal to some finished shape However, in the case of malleable cast **iron,** the malleable product denotes a casting which is much stronger and possesses shock resisting qualities to a much greater extent than gray cast iron A malleable iron casting is produced from an iron casting which in the untreated state is hard and brittle This casting is caused to have as large a silicon content as possible, since it has been found that this element promotes the change from the hard casting to the malleable form during the heat treatment

The malleabilizing of iron castings is the conversion of cementite **carbon** into a finely dispersed graphite form, although a part of malleabilizing may result from burning out of the surface layer of the carbon by heating the casting in the presence of the oxidizing agent The hard castings are annealed to the malleable form by packing them in an annealing box surrounded by an oxidizing agent Crushed iron oxide and mill scale have been used for this packing, but the malleable product may be produced even if an inert packing, such as sand, be used However, since some increase in strength is obtained by packing in an active material, castings are so treated After packing, the boxes are placed in an annealing furnace, and held at a temperature of about 800° Centigrade for 3 to 5 days, after which they are slowly cooled, and are malleable There are two types of product —white heart and black heart malleable iron The latter is made by conducting the annealing operation at a higher temperature and shorter period of time than for the white heart, and it is more satisfactory when large, thick castings are to be annealed (F T M)

MALLOPHAGA The **bird lice** or biting lice, constituting a small order of insects They have flattened bodies with many spines directed backward, short legs, and biting mouths Wings are lacking Most species live as external parasites on birds but a few are found on mammals (A W L)

MALLOW FAMILY Malvaceae The plants of this family include herbs, shrubs and trees (the latter tropical), and are rich in mucilaginous substance The leaves are alternate, and in most cases **palmately** lobed and veined, with small deciduous **stipules.** The flowers are regular and perfect, often large and showy, and variously borne They have five (or rarely, fewer) more or less united **sepals,** five petals, and numerous **stamens,** which characterized the family by having their filaments joined to form a tube which surrounds the **styles.**

The most important member of this family is the **cotton** plant, whose fibers outrank in commercial importance all others Okra, *Hibiscus esculentus,* a native of tropical Africa, is another member of importance It is a coarse annual plant with large veiny leaves and showy axillary flowers The slender five-ribbed pods are used in soups, or when young, are cooked and used in salads Okra has also been used as a source of fibers for paper manufacture Another member of some importance is *Althaea officinalis,* the Marsh Mallow The underground rootstock of this plant is not only rich in mucilage, but is also used medicinally in ground form, the bark being removed before grinding

Many members of the family are grown as ornamental plants, among them being the Hollyhock, *Althaea rosea,* the so-called flowering maples, *Abutilon* sp , species of *Malva,* the true Mallows, and the Rose of Sharon, *Hibiscus syriacus,* which becomes a large bush or even a small tree, with showy pink or white flowers (R M W)

MALONIC ACID Alcohols and Ethers.

MALPHIGIAN TUBULES Small tubules closed at one end and connected with the alimentary tract at the other They occur in the spiders and other **arachnids, centipedes** and millipedes, and **insects,** and function as excretory organs The tubules vary greatly in form and number in different species (A W L)

MALT. Barley

MALTA FEVER. (Undulant fever, Brucellosis) A specific fever found in man, cattle, goats and other animals, caused by organisms called *Brucella melitensis* and *Bacillus abortus* Human infection usually occurs from the drinking of unpasteurized milk from infected animals or from handling infected animals The infection in animals causes abortion

Infection in man gives a varied picture The onset may be acute or gradual Fever may be slight and of intermittent nature, persisting for weeks or months Weakness, malaise, gastro-intestinal symptoms, are the rule The mortality is low but recurrences and relapses are quite common

Pasteurization or boiling of milk is a sure preventive In some districts 20% of cattle are infected

There is no specific treatment although **serum** and **vaccine** therapy may be tried Otherwise the disease is treated with the same measures as are used in any general systemic infection (R S M)

MALTOSE. Carbohydrates.

MALUS'S LAW. A law applying to the intensity of **polarized light** as affected by the polarizing apparatus If a beam of plane-polarized light is passed through a **Nicol prism,** for example, the intensity (flux density) of the emergent beam falls off, as the prism is rotated, from a maximum value when the transmission plane of the prism coincides with the plane of vibration of the light to zero when it is at right angles to that direction The intensity varies as the square of the cosine of the angle through which the prism has been thus rotated The same law applies to the effect of a glass reflector, reflecting always at the polarizing angle, as the plane of reflection is rotated around the stationary, polarized incident beam (L D W)

MAMMALIA. Animals characterized by warm blood and hairy vestiture The young of most species develop in the body of the mother and all are nourished by milk secreted by special glands The teeth are of four kinds, incisors, canines, premolars and molars (**Dentition**) A class of the phylum **Chordata,** including the creatures popularly called animals without further qualifications

The mammals are one of the dominant forms of animal life The most important domestic species belong in this class and man himself is a mammal, hence their economic importance cannot be overemphasized They are the source of most of the animal products used by man and include also some harmful species of predators and rodents

The classification of the mammals is briefly as follows·

Subclass Prototheria Egg-laying mammals
Order **Monotremata** The duck-bill (**Platypus**) and spiny anteater (**Echidna**) of the Australian region
Subclass Eutheria Young developed at least partly in the body of the mother
Division Didelphia Pouched mammals Young born in an early stage of development and carried in a pouch on the abdomen of the female until able to walk
Order **Marsupialia** **Kangaroos** and **wallabies, opossum, koala**, and others
Division Monodelphia Placental mammals Young connected with the body of the mother throughout embryonic development by a special structure called the **placenta**
Section **Unguiculata.** Clawed animals
Order **Insectivora** Small furry animals, mostly nocturnal They eat insects and smaller animals and some vegetable matter **Shrews, moles** etc
Order **Dermoptera** The flying **lemurs** of the Oriental region
Order **Chiroptera** Winged mammals The **bats.**
Order **Carnivora** The flesh-eating species, with large canine teeth and sharp edged molars **Lion** and **tiger, weasels, bears, skunks, seals, walruses**, etc
Order **Rodentia** Gnawing animals Incisor teeth like chisels **Rabbits, squirrels, rats, mice, porcupines**, etc
Order **Edentata** Toothless or with imperfect teeth The **sloths, armadillos** and **ant bears**
Order **Pholidota** Scaly anteaters or **pangolins**
Order **Tubulidentata** The **aardvarks**
Section **Primates** With nails instead of claws or hoofs Appendages often differentiated as arms and legs Thumb and great toe opposable to the other digits or anatomically similar to such appendages
Order **Primates** The **monkeys, baboons, apes,** man, and other related species
Section **Ungulata** The hoofed animals and related forms with heavy nails on the appendages
Order **Artiodactyla** The even-toed ungulates The axis of the foot is through two digits **Swine, cattle, sheep, deer, camels** and other species
Order **Perissodactyla** Odd-toed ungulates Axis through the middle digit of the foot **Horses, rhinoceroses, tapirs** and related species
Order **Proboscidea** **Elephants.** Nose and upper lip prolonged to form a trunk or proboscis
Order **Sirenia** Aquatic species **Dugongs** and **manatees**
Order **Hyracoidea** Small animals resembling rodents The hyraces or **conies**
Section **Cetacea** Highly specialized marine animals
Order **Odontoceti.** The toothed **whales** Sperm whales, **porpoises, dolphins,** and related forms
Order **Mystacoceti** Species with baleen or whalebone in place of teeth Right whales, rorquals, and baleen whales (A W L)

MAMMARY GLAND A large gland which secretes milk for the nourishment of the young of **mammals.** Mammary glands are structurally related to the sweat glands They are normally functional only in the female although they develop as rudiments in the male sex In most species the ducts of the glands open on a prominence, the teat or nipple, from which the young suck the milk, but in egg-laying mammals the milk is merely licked from the surface upon which it exudes and in some of the pouched mammals the young are temporarily attached to the teats within the pouch by an oral sucker and the milk is discharged into their mouths (A W L)

MAMMARY ORGAN An organ developed in some of the **bryozoans** which nourishes the embryos during their attachment to the parent (A W L)

MAN **Paleontology of Man.**

MANAKIN. Aves, Passeriformes Brightly colored birds (**Aves**) of Central and tropical South America. **Chatterers** (A W L)

MANATEE, MANATI. Mammalia, Sirenia Completely aquatic animals with a horizontally flattened oval tail, no hind limbs, and fore limbs developed as flippers They are superficially similar to the whales but differ in many details of structure and are apparently derived from different ancestral stock They live only in shallow coastal waters and estuaries and eat aquatic plants Also called sea cows

The several species of the genus *Manatus* are distributed on both shores of the Atlantic and in the Oriental and Australian regions *M latirostris* is found in Florida (A W L)

MANDIBLE. A structure associated with the mouth and used for biting, or if used differently, evolved from a biting organ The term is applied to the pair of biting organs derived from jointed appendages in the **arthropods,** and in the sucking mouths of some **insects** to the slender piercing structures which have been shown to have the same origin It is also used for the lower jaw of **vertebrates** and for a prominent bone of that jaw which makes up the entire structure in the mammals but is associated with other bones in the jaws of fishes (**Pisces**), **amphibians** and **reptiles.** The two parts of the beak in birds are known as the upper and lower mandibles (A W L)

MANDIBULAR GROOVE A groove in the **carapace** of some **crustaceans** just behind the **mandible.** It may accompany the **cervical groove,** in which case it is located farther forward (A W L)

MANDRILL Mammalia, Primates A peculiarly ugly species of African **baboon,** *Papio maimon* (A W L)

MANGABEY Mammalia, Primates *Cercocebus* An African **monkey** of a small group of species also called the white-eyelid monkeys They are slender animals with a fairly long muzzle and long tail Related to the macaques (A W L)

MANGANESE. Symbol Mn Atomic number 25 Atomic weight 54 93 Density 7 2 Hardness 5 Melting point 1260° C Boiling point 1900° C

Manganese is a silver-white metal, not notably hard (becomes hard on alloying with **carbon**), brittle, capable of taking a brilliant polish but readily oxidized upon heating, reacts with water upon boiling, soluble in dilute acids Discovered by Scheele in 1774

Manganese occurs chiefly as **pyrolusite** (manganese dioxide (MnO_2)) in the Caucasus Mountains of Russia, India, Brazil, the Gold Coast of Africa, and United States (1) Treating pyrolusite in a **blast furnace** with **iron** ores and **carbon** furnishes ferro-manganese (78% Mn) and speigeleisen (12%–33% Mn), both used in the production of steel (2) Pure manganese may be obtained by ignition of the oxide with **aluminum** powder Small percentages of manganese are added to steel as a deoxidizer, and large percentages, say 12%, produce a very tough steel (3) When pyrolusite is heated with **sodium** carbonate and nitrate, sodium manganate is formed, which is then extracted with water This is the substance from which manganese compounds are commonly obtained

Acetate Manganese acetate ($Mn(C_2H_3O_2)_2 \cdot H_2O$), pale pink crystals, soluble

Chlorides Manganese chloride, manganous chloride, manganese dichloride ($MnCl_2 \cdot 4H_2O$), rose-red crystals, soluble to practically colorless solution by reaction of

hydrochloric acid on manganese oxides, hydroxide, carbonate, sulfide and subsequent crystallizations, manganese tetrachloride, manganese perchloride ($MnCl_4$), green solid

Dithionate· Manganese dithionate (MnS_2O_6), by reaction of manganese dioxide suspension in **sulfurous acid.** With **sodium** carbonate yields sodium dithionate solution and manganese carbonate precipitate

Hydroxide Manganese hydroxide, manganous hydroxide ($Mn(OH)_2$), white precipitate but rapidly turning brown in the air by oxidation to manganic hydroxide, formed by reaction of manganese salt solution and **sodium** hydroxide solution, manganic hydroxide ($Mn(OH)_3$), brown solid

Manganates· Sodium manganate (Na_2MnO_4) and potassium manganate (K_2MnO_4), green soluble solids, formed (1) by oxidation of other forms of manganese by heating with **sodium** carbonate and nitrate, and (2) regulated reduction of permanganate Manganate solution is readily oxidized to permangate in the presence of acid

Nitrate· Manganese nitrate, manganous nitrate ($Mn(No_3)_2\ 6H_2O$), rose-red crystals, soluble to practically colorless solution

Oxides Manganese monoxide, manganous oxide (MnO), grayish-green solid, formed by heating of manganese **oxalate,** hydroxide or carbonate in the absence of air, (2) by reduction of higher manganese oxides by heating with **hydrogen;** manganese sesquioxide, manganic oxide, (Mn_2O_3), brownish-black solid, by heating manganese dioxide at 700° C , trimanganese tetroxide, mangano-manganic oxide (Mn_3O_4), brownish-black solid, by heating any oxide of manganese at 1000° C , manganese dioxide, manganese "peroxide" (MnO_2), black solid, by heating manganese nitrate to 200° C , used as pyrolusite in dry cell batteries, and to color glass and ceramic ware, also in the preparation of a dryer for paint and varnish oils, and in the chemical laboratory for the preparation of **chlorine** from **hydrochloric acid;** manganese heptoxide (Mn_2O_7), red oil, dangerously explosive, formed by reaction of potassium permanganate and concentrated sulfuric acid

Permanganates Sodium permanganate ($NaMnO_4$) and potassium permanganate ($KMnO_4$), purple-black soluble solids, the latter readily crystallized, formed by oxidation of acidified manganate solution Permanganate solution, purple, is readily reduced to manganous in the presence of acid, e g , by the reaction of ferrous salt

Sulfate· Manganese sulfate, manganous sulfate ($MnSO_4\ 4H_2O$), pink solid, soluble to practically colorless solution

Sulfide Manganese sulfide, manganous sulfide (MnS), pink precipitate by reaction of manganous salt solution and **ammonium** sulfide solution (R K S)

MANGANITE. The mineral manganite is a hydrous **oxide** of **manganese** corresponding to the formula MnO(OH), it occurs in prismatic **orthorhombic** crystals, sometimes in massive columnar forms It is a brittle mineral, hardness 4, specific gravity 4 2–4 4, luster, submetallic, color, steel gray to iron black, streak, red brown to almost black, opaque Manganite is of secondary origin and it may itself alter to **pyrolusite** It is usually associated with other manganese minerals It is found in the Harz Mts , Germany, Sweden, Corwall and Cumberland, England, and in the United States in Michigan It is an ore of manganese (E S C S)

MANGEL-WURZEL. **Beet.**

MANGO. **Mangifera indica.** Anacardiaceae The mango is a long-lived tree, often developing a massive trunk, and widely spreading branches Its **lanceolate** leaves are evergreen and about four inches long The flowers are numerous, small, pink and borne in **racemes.** The ovoid fruits, 1-5 inches in **diameter,** are one-seeded berries having a thick rough greenish rind and a pleasantly aromatic orange-colored flesh esteemed by many. This fruit is eaten fresh or in salads Unfortunately, fruits frequently occur which are not at all agreeable, because of the fibrous nature of the flesh and the unpleasant sour taste

Reproduction is either by seedlings, which do not always come true, or by grafting The tree is extensively cultivated in tropical regions, and is now grown in Florida, southern California, and tropical America. For successful growth hot moist weather is necessary, followed by a short dry period for successful ripening of the fruit (R M W)

MANGOSTEEN. **Garcinia.** Guttiferae

MANGROVE *Rhizophora mangle* Rhizophoraceae The mangrove is a moderate-sized tree which grows on low, often submerged, coastal lands It is found, for instance, in all tropical American coasts The leaves of the plant are opposite, entire, dark green, and rather tough The flowers are borne in small clusters and are perfect, with four **sepals,** four pale yellow linear petals, four to twelve **stamens** and single two-celled inferior **ovary** Only one **ovule** develops The seed usually germinates while the fruit is still attached to the tree A long thick **hypocotyl** grows from the fruit, and attains a length of five to ten inches and a diameter less than three-quarters of an inch Eventually an **abscission layer** develops, so that the fruit, in which the young seedling is well advanced in germination, falls to the soft muddy ground, in which the new tree will grow Because the lower part of the hypocotyl is heaviest, it strikes the ground first and so sinks into a position most favorable for further growth Should it fail to penetrate into the mud, the upper and lighter portion of the germinated fruit causes it to float until a favorable environment is reached In a favorable location the hypocotyl puts out many roots, which anchor the young plant, then the **epicotyl** quickly grows It is characteristic of the mangrove that from the stem and branches there grow out arching prop roots which soon form an intricate mass in which is deposited silt and all sorts of debris floating in the water Because of this the mangrove causes a gradual building up of the land around it, until eventually the black slimy mud in which it grows gives place to a low coastal land which gradually becomes usable by man

In addition to its land-forming function, the mangrove has other uses The wood is dark red or reddish-brown, fine-grained, and hard, it is used in charcoal making The bark contains **tannin** and so is employed in tanning hides From the young shoots a reddish dye may be obtained, which, however, is of little value. (R M W)

MAN-HOLE. A man-hole is a means of ingress and egress to a region, ordinarily and normally not occupied by humans, but occasionally necessitating inspection or repair by them Sewers, tanks, boiler drums, and many other structures are equipped with one or more man-holes which are often only of sufficient size to permit a man to crawl through with considerable difficulty. Normally these openings are closed by man-hole covers. (F T M)

MANIA. Insanity with excitement or exaltation as opposed to insanity with depression or melancholia It is characterized by violence, extreme excitement, hallucinations, delusions, requiring restraint to protect the patient as well as others (R S M)

MANIC-DEPRESSIVE INSANITY. A kind of insanity characterized by recurrent states of marked depression, elation, or both This may occur in separate distinct attacks, may be marked by definite cyclic

attacks or may occur as simple mania or melancholia in recurrent or periodic forms

Cause of this form of insanity has never been reduced to physical ailments, although they may be predisposing factors The fundamental cause is a constitutional emotional instability which is quite likely to be inherited This constitutional factor may remain dormant or unobserved until some physical ailment, injury, difficult personal problem, as loss of money, thwarted love, or grief brings on the first attack

The symptoms of the depressive phase may occur first, as consistent, transient or continuous sadness, melancholia, loneliness and lack of ambition, gradually increasing until the patient sees his future and past through a distorted medium

The elation phase is marked by excessive activity, mental and physical Orientation is usually retained There is lack of inhibition in speech, impulses and in primitive and sexual reactions Lying and dramatization of events are quite common The excitement may be extreme, resembling delirium **Hallucinations** may occur in the severe form with loss of sense of time and surroundings The physical condition usually seems unimpaired during the attack, the patient being able to keep up excessive activity for weeks with only a few hours of sleep

Circular insanity is a form in which depression or elation follows the other without any break in the cycle

The prognosis of this insanity is good, if complications are not present and the disorder is not of a marked form The longer the attack, in general, the poorer the prognosis There is always a tendency toward occurrence of further attacks This is more apt to be the case in older people

Suicide is particularly apt to take place with these patients and it is more likely to occur in a patient who is beginning to show improvement It is less likely to be attempted while in a depressive phase (R S M)

MANIFOLD, ENGINE. With particular attention to the **internal combustion engine** in the multi-cylindered form, the manifold is that part which distributes a common fuel-air mixture uniformly to each of the several **cylinders,** or which gathers up the exhaust gases after they issue from the cylinders, and combines them into one exhaust stream Since the great majority of internal combustion engines are multi-cylindered, and further, since the purpose of multi-cylinders is to provide more uniform flow of power, the manifolds must be well chosen and correctly patterned, or else they will tend to offset the advantage of the multi-cylinder arrangement

Considering problems of manifolding from the standpoint of gasoline engines, in which they are most difficult, the condition which the manifold must meet is that of equal distribution of fuel and air to the different cylinders without permitting any segregation of the heavier fuel particles, and without creating much pressure drop by friction The inlet manifold is attached at its discharge end to the inlet ports of the cylinders, and at its other end to the outlet of the carbureter A carbureter does not perfectly vaporize and mix a fuel with air so that an equal distribution of the volume and the fluid passing through the manifold is not necessarily an equal distribution of the fuel to the separate cylinders because of the inertia of the heavier fuel particles, therefore bends have to be carefully laid out, and any factors which might tend to deflect the stream unevenly into one limb of the manifold should be eliminated Inlet manifolds may be either updraft or downdraft, depending on the relative location of carbureter and cylinders It is much simpler to maintain uniform mixture in a downward moving stream than in the upward Many manifolds are provided with what is known as a hot spot, which is a portion of the manifold upon which the heavier gasoline particles will strike, and which by the heat it contains will immediately vaporize these heavier particles In an ordinary T-shaped manifold, the hot spot should be placed at the top of the vertical stem, where it will form a target for the ascending droplets of gasoline While shape of the inlet manifold is a matter of great importance, the material of it is not, since the inlet manifold is kept cool by the inflowing mixture It should be tight and smooth internally

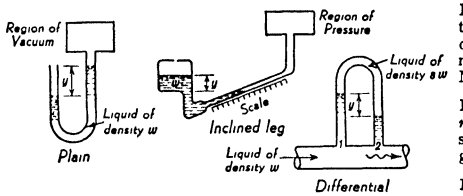
The exhaust manifold conveys a stream of heated gas which may, at times, cause it to reach red-hot temperatures, and it must be constructed of a material capable of resisting such conditions, and be provided with some means of expanding and contracting with variation of temperature Some large engine exhaust manifolds are water-jacketed The ideal exhaust manifold has a separate lead from each cylinder, each lead being streamlined into a common stack or exhaust pipe at some distance from the cylinder If this is not possible, the manifold should be divided into sections so that two cylinders will not exhaust into the same section simultaneously Where the noise of the exhaust is not objectionable, or is less objectionable than the back pressure created by the exhaust manifold, exhaust may either be freed directly from the ports, or from short, straight exhaust stacks discharging directly to the atmosphere (F T M)

MANILA HEMP. *Musa textilis* Musaceae The Manila Hemp plant is a perennial herb having an underground **rhizome** from which the very large leaves rise directly The apparent stem, which may be as much as twenty feet in height, is composed of the tightly overlapping, broad, leafstalks The flower stem grows up through the center of the column formed by the leaf-bases and bears inconspicuous flowers covered by reddish bracts The fruit is green, banana-like and filled with numerous seeds The native home of the plant is the Philippine Islands

To obtain the fibers the so-called stem of leaf-bases is cut down and at once cut in long narrow strips By drawing these over a dull knife the fibers are cleaned of most of the non-fibrous substance surrounding them, leaving uniform strands six to ten feet or more long The fibers are white to buff-colored and lustrous, coarse and very strong They are extremely durable, little affected by water, and hence much used for making cables, hawsers and marine cordage The finer strands may be spun into thread and from that coarse cloths woven Manila waste and worn-out manila products are used in making a very tough paper known as manila paper The plant is extensively cultivated, especially in the Philippine Islands The cultivated plant yields a better grade of fiber Another name given to the fiber is **abaca.** (R M W)

MANOMETER Pressures which are so small that the Bourdon tube **pressure gage** is not accurate, are conveniently measured by a liquid manometer This instrument is one which balances fluid heads in a glass tube so that readings may be taken by comparing the registry of menisci on a scale mounted alongside the tube In its simple form, it consists of a U-tube, one end of which is open to the atmosphere, and the other to the region where the pressure is to be measured If the pressure is different from atmospheric, the liquid with which the manometer is partially filled will stand higher in one leg of the tube than the other As shown in the illustration accompanying, the manometer is connected to a vacuum, the balancing head on the low-pressure leg Since the other leg is open, the pressure head y is either the vacuum or the gage pressure The magnitude is yw pounds per square foot when y is measured in feet and w in pounds per cubic foot To make the instrument more sensitive, one leg may be inclined at a large angle to the other so that a given

vertical displacement of the meniscus will travel a considerably larger distance along the scale Of course in this type the other leg must be of enlarged cross-



Manometers

section so that its level will not vary appreciably as the meniscus travels along the scale The scale can be calibrated to read any desired pressure units

Very small pressure differences are measured by differential manometers, a simple form of which is shown Suppose that a liquid of specific weight w is flowing along a pipe and it is desired to measure the friction loss between points 1 and 2 An inverted U-tube is connected, having its upper portion filled with a non-miscible liquid of specific weight sw The difference of pressures at points 1 and 2 will then be $wy\ (1-s)$ Very small differences of pressure may thus be indicated by a readable displacement y if s approaches unity, that is, if the two liquids are nearly of the same density (F T M)

MANTIS. Insecta Orthoptera A large insect of predacious habits The body is moderately broad and bears four wings The first segment of the thorax is long and rather slender, adding to the reach of the powerful raptorial front legs The head is prominent and has large eyes

From the fancied supplant air of these voracious insects as they await their prey with the forelegs uplifted they are called praying mantises, and their owlish expression has given them the rarer name of soothsayers The common species is *Mantis religiosa* (A W L)

MANTIS FLY. Insecta, Neuroptera Small predacious insects superficially like the **mantis** in form They make up the family Mantispidae and are also called mantispas (A W I)

MANTISSA OF A COMMON LOGARITHM. Logarithms.

MANTIS SHRIMP. Crustacea, Hoplocarida Moderately large marine **crustaceans** with a pair of powerful grasping appendages formed like those of the mantis They are named for their superficial resemblance to the shrimps on one hand and to the mantis on the other (A W I)

MANTLE 1 A fold of the dorsal body wall of **mollusks** It secretes the shell, forms a respiratory chamber, and in some species encloses the body 2 The wall of the body of **tunicates**, beneath the enclosing tunic 3 Folds of tissue forming a dorsal and a ventral flap which secrete the shell in the **brachiopods.** (A W L)

MANTLE ROCK (REGOLITH). The term mantle rock is applied to all of the loose unconsolidated material which is found at the surface of the earth and covers, more or less completely, the solid rock beneath

Regolith is derived from the Greek word meaning a *cover* and *stone*, is essentially synonymous with mantle rock (R M F)

MANUBRIUM 1 A projection at the axis of the body of a **medusa** on which the mouth opens In some species the reproductive bodies (**gonads**) develop in the manubrium 2 A handle-like process, such as the uppermost piece of the **sternum.** (A W L)

MANUCODE Aves, Passeriformes A name applied to a few smaller **birds of paradise** of several islands of the Australian region Derived from the generic name *Manucodiata* which is in turn a corruption of a Malay name (A W L)

MANUL. Mammalia, Carnivora A wild **cat,** *Felis manul,* of Siberia, Mongolia and Tibet It is about the size of the domestic cat and varies from buff to silver gray in color Also called Pallas' cat (A W L)

MAP. A drawing which describes portions of the earth's surface is called a map Since there are many different purposes for which maps are used, different kinds of maps are made For example, there are the topographic maps, land subdivision maps, general geographic maps, geologic maps, etc The features which are expressed on a map will vary with the degree of specialization of use of the map, even to the point of excluding all features except those which are to be emphasized For example, railway maps show little other than the line of the railway and the towns along its route Since the surface of the earth is in three dimensions, it is necessary to use some special method of showing the altitude of the surface Otherwise the drawing would be capable of showing only breadth and length of an area A topographic map is one on which the altitude is shown by some conventional means, usually contour lines or hachures Other features of the landscape, such as bluffs, woodland, streams, marshes, may be included on the topographic map by generally accepted symbols The standard symbols of the U S Geological Survey are more often used than any others (See **Contour.**)

A map may be oriented or interlocked with adjacent plats by giving the direction of either true or magnetic north on the map, or by placing thereon some of the meridians and parallels of the earth The former method is suitable to maps of small areas, the latter for depicting the larger areas, states, and countries Maps of large areas must show the surface of a sphere, as that is the shape of the earth It is not possible to represent accurately a spherical surface on a flat surface, therefore some approximation, or some method of representation which is correct in some, but not all respects, must be employed in mapping large areas so that the effect of curvature is not neglected (See **Map Projections and Charts.**) (F T M)

MAPLE SUGAR Sugar.

MAP PROJECTIONS Different principles of projection have been employed in the endeavor to show the spherical surface of the earth correctly on a flat surface The three principal projections are the **gnomonic,** the **mercator,** and the **polyconic** The mercator projection is the development of the surface of the earth as a cylinder which is tangent to the earth at the equator The points on the earth's surface are projected upon the cylinder in such a way that a line connecting two points, and crossing the meridians at the same angle would appear as a straight line Distortion is present in the polar regions, and absent in the equatorial regions The meridians and parallels of latitude are straight lines forming a system of rectangles. This system of projection is probably the most frequently employed, since distortion in high latitudes is of little importance except for the infrequent purposes of polar navigation

The polyconic projection is based upon a development of the earth's surface as a system of cones, or frusta of cones, each having a parallel as its base, and the vertex at a point where the axis of the earth intersects the tangent at that parallel There is but little dis-

tortion in this system of projection, however, the parallels and meridians are curved There is not a great deal of difference between mercator and polyconic projections in the equatorial regions

The gnomonic projection has a plane of projection which is tangent to the earth at a given point, and the projections are as viewed from the point to the center of the earth This projection is little used except for navigation in high latitudes

The U S Department of Commerce uses also another type of projection for maps, known as the Lambert projection In this system, all angles between intersecting lines or curves are preserved, and the meridians and parallels cross at right angles Small areas of the earth's surface retain the original form, and the scales along the meridian and parallel are the same, though not necessarily absolute (F T M)

MARAL. Mammalia, Artiodactyla A Persian **deer** of the red deer group, *Cervus elephas maral* (A W L)

MARASMUS. A disease of infancy characterized by gradual and progressive loss of weight and slow wasting It is due to a failure of assimilation owing to imperfect digestion, improper food, unhygienic surroundings and feeble constitutional make-up The disease is severe and often fatal (R S M)

MARBLE. Technically speaking this term should only be applied to metamorphosed, recrystallized **limestones** and **dolomites** It is generally used as a trade term, however, for any crystalline **calcium** carbonate rock of pleasing pattern and color when cut and polished Some marbles are almost pure white, as in the case of the best statuary marble, but various impurities produce marbles of all colors, shades and patterns In the northern Appalachians there is a great belt of marbles which, in Vermont, have been developed into one of the greatest marble producing regions in the world Here are quarried and mined a variety of marbles which compete with the Italian **travertines** and **breccias.** Including the more common stone, which is bluish gray, are such decorative types as red, verd antique, black, green and pink Other producing states are Alabama, Massachusetts, North Carolina, Maryland and Virginia The amount of marble produced in the United States in 1933 was equivalent in value to $6,236,508 (R M F)

MARCASITE. The mineral marcasite, sometimes called white iron pyrites, is, like ordinary **pyrites,** disulfide of **iron** corresponding to the same formula, FeS_2 Marcasite, however, crystallizes in the **orthorhombic** system often yielding serrate, spear shaped **twins,** hence the name "cock's comb pyrites" It is a brittle mineral, hardness, 6-6 5, specific gravity, 4 85–4 90, luster, metallic, color, light bronze yellow, streak, grayish black, opaque Marcasite alters very easily and may disintegrate with the formation of sulfuric acid and iron sulfate Fossils replaced by marcasite are therefore often destroyed after being placed in collections Marcasite is found in numerous places in Europe, Czechoslovakia, France, England, etc , in Mexico, and in the United States in the lead districts of Illinois, Wisconsin and Missouri The name marcasite is believed to be of Arabic origin and formerly was applied to common pyrite (E S C S)

MARE The female of the **horse** and related species with the exception of the asses Females of these animals are called jennets (A W L)

MARGAY. Mammalia, Carnivora A wild **cat** of moderate size It is reddish marked with black spots Mexico to Paraguay (A W L)

MARIALITE. Wernerite.

MARIHUANA Hemp

MARINE BIOLOGY. The study of all living things found in the ocean and their interrelations

The masses of water in the oceans are so great that all human knowledge of the living things within them must be a very small part of their story Most investigations have been conducted in the shallower waters near the shores Specially equipped ships have occasionally conducted extensive towing operations in deep as well as shallow waters but this work is hampered by the great expense involved and discloses only such forms of deep sea animals as can be taken in relatively small nets The recent use of the bathysphere by Beebe and Barton for direct observation down to a half-mile depth has shown that large fishes also occur in the abysses

Many marine laboratories have been established primarily for the study of marine biology Among them the station at Naples is famous In the United States stations are located at Woods Hole in Massachusetts, Cold Spring Harbor on Long Island, Friday Harbor on Puget Sound and in other favorable places The Bermuda Biological Station for Research, formally opened in 1932, is one of the most favorably located institutions for all oceanographic work (A W L)

MARJORAM. Mint Family.

MARKHOR. Mammalia, Artiodactyla A wild **goat,** *Capra falconeri,* of the Himalayas It is a large and variable species with long horns, spirally twisted although in variable forms (A W L)

MARL. Marl is a loose earthy deposit of **calcium** or **magnesium** carbonate mixed with clay in varying proportions It is usually gray but the color may be affected by the presence of other substances, such as **iron** oxides Marls are believed to have accumulated in fresh water basins as they are frequently found carrying shells of fresh water **mollusca,** then called shell marl If sand is present in any quantity it is then called sandy marl There are considerable deposits of marl in the **Tertiary** formations of the Atlantic and Gulf States. (E S C S)

MARLIN. 1 Pisces, Teleostei Large marine game fishes (**Pisces**) taken in the warmer waters of the Atlantic Related to the swordfishes and sailfishes 2 Aves, Charadriiformes The marbled **godwit** (A W L)

MARMOSET. Mammalia, Primates Small **monkeys** of Central and South America They have only thirty-two teeth, four less than the other American monkeys, and the thumb is not opposable to the fingers All digits but the great toe bear claws instead of nails They constitute the family Hapalidae

Most of these monkeys are called marmosets but the common Brazilian species, *Hapale jacchus,* is also known as the ouistiti and the group of long-tusked marmosets, *Mystax,* are called tamarins One species, *Midas oedipus,* of the Isthmus of Panama, bears the French name pinché (A W L)

MARMOT. Mammalia, Rodentia Stout-bodied burrowing animals of moderately large size The common **woodchuck** or groundhog, *Marmota monax,* is a familiar North American species, and in the western states others occur, one of them, *M caligata,* known as the whistler In Europe and Asia the bobac, *M bobac,* alpine marmot, *M marmota,* golden marmot, and several other species occur The fur is sparse and rather coarse but it is used to a limited extent The flesh is edible. (A W L)

MARS. (cf planetary tables, page 865) Mars, the "ruddy planet," is the fourth **planet** in order of distance from the sun It has been observed from remote antiquity since its ruddy color and relatively rapid motion among the stars make it a very conspicuous object.

Within the past fifty years there has been a great deal of speculation relative to the possibility of there being intelligent life on this planet, and, for this reason, there has probably been more printers' ink expended in pseudo-scientific articles about conditions on Mars than on any other astronomical object, with the possible exceptions of the sun and moon

Since the **orbit** of Mars lies entirely outside of the orbit of the earth, the planet can never be seen in the crescent **phase** However, at **quadrature**, Mars does present a distinctly gibbous phase condition as seen with a telescope

Mars is best observed at **opposition**, for during this **configuration** it is on the **meridian** at midnight The distance from the earth at an average opposition is about 78,200,000 kilometers (48 600,000 miles), but at a "favorable opposition" (i e , with the earth at **aphelion** and Mars at **perihelion**) this distance is reduced to 55,700,000 kilometers (34,600,000 miles) These favorable oppositions occur at intervals of from 15 to 17 years, the last one being in 1924

The question regarding the possible habitability of Mars, or of any other planet, may be said to hinge upon two questions, not mutually exclusive the **temperature** of the surface, and the existence and character of an **atmosphere** The temperature of the surface of Mars has been a vexing one for a long time, but has apparently been definitely settled by the brilliant research both at the Lowell and Mt Wilson observatories Using independent methods, both agree that the temperature of the planet's surface is approximately 283° K (50° F) at the equatorial regions at noon –a condition well adapted for life as we know it on the earth The question regarding the atmosphere of Mars cannot be said to be as definitely settled as the surface temperature The **surface gravity** of the planet is such that the planet could retain an atmosphere of oxygen, nitrogen, and other heavy gases, and probably water vapor as well, but could not hold the light gases such as hydrogen and helium The clarity with which the surface features of the planet can be observed and the absence of any definite cloud effects seem to indicate conclusively that there is very much less atmosphere than we have on the earth At the Mt Wilson Observatory, using the most powerful instruments and most delicate tests, it has been shown that the amount of oxygen over the planet's surface cannot exceed a thousandth part of that over the surface of the earth, and that the planet's atmosphere and surface must be exceedingly dry

Through even a moderately large telescope Mars is a very beautiful object, with a number of large and permanent surface markings clearly visible From the motion of these surface markings the rotation period of the planet has been definitely determined as about 24 5 hours It has also been determined that the planet's equator is inclined to the planet of the orbit of the planet at about 24° Both of these figures indicate that the day and night conditions and **seasonal** changes on Mars are comparable with those on the earth, with the exception, however, that the Martian year is about twice as long as the corresponding period on the earth

The greater portion of the surface of Mars is reddish in appearance, but there are large and well-defined greenish gray areas, and brilliant white caps at the polar regions The reddish areas do not show any seasonal changes, and are believed to be desert areas, possibly similar in character to regions on the earth such as Sahara The dark areas, unfortunately known as seas, show definite seasonal variation in color, having a more strikingly greenish tint during the summer than in the winter The seasonal changes of these dark areas have been ascribed by many reliable authorities as due to some form of vegetation and there seems to be no need for rejecting this possibility, in spite of the low oxygen content of the atmosphere and scarcity of water The changes in appearance of the polar caps with season is most striking During the winter season in the northern Martian hemisphere the polar cap is extremely prominent, while no cap whatsoever appears at the south pole As spring approaches in the north the north cap shrinks and the south cap grows until the north cap entirely disappears It has long been believed that the polar caps are composed of snow, but whether this is actually frozen water or of some other form of frozen gas is not definitely known

The question regarding the fine details on the surface of Mars, in particular the so-called canals, is still a puzzling one In 1877 and again in 1879 Schiaparelli announced the discovery of a number of fine dark lines crossing the surface of the planet During the next fifty years a great many observers searched for the canals with varying degrees of success Schiaparelli, Lowell, E C Pickering, and a number of other observers saw the canals and were able to construct detailed maps of them On the other hand, Barnard and a number of other excellent observers were never able to see any trace of the canals All of the observers who have been able to see the canals agree that they show great variations in visibility and also that they show seasonal variations Even taking this into account, it is difficult to understand why Barnard, one of the most skillful of observers, and working with the best instrumental equipment in the world, should never be able to see the canals at all To date the canals have never been photographed, and until their reality is proved beyond serious doubt, it is futile to speculate regarding their origin or purpose

Mars has two **satellites**, both discovered by Hall in Washington in 1877 They are both very small and relatively close to the surface of the planet The inner one is so close that it revolves about the planet in about 7 5 hours, about one-third of the rotation period of the planet, and hence rises slowly in the west and sets in the east, contrary to all other celestial objects observed from Mars This is the only case on record in the solar system where a satellite has a period of revolution shorter than the rotation period of the planet. (W K G)

MARSH GAS Methane

MARSHMALLOW Mallow Family.

MARSH TEST. Arsenic.

MARSUPIALIA. The pouched mammals, including the kangaroos, opossums, and many less familiar forms. The order is characterized by the presence of a marsupium or pouch on the abdomen of the female in which the young complete their development They are born in a very early stage With the exception of the opossums of the Americas, all marsupials occur in the Australian region

The principal forms in this order are the **kangaroos** and **wallabies, phalangers, wombats, bandicoots, dasyures, pouched mole**, and **opossums** (A W L)

MARSUPIAL MOLE. Mammalia, Marsupialia A pouched burrowing animal, *Notoryctes typhlops*, found in a very limited part of Australia It is about the size of the true moles and resembles them in the soft fur, the rudimentary eyes, the enormously developed claws, and the lack of external ears Also called the pouched mole (A W L)

MARSUPIUM. A pouch formed of a fold of skin on the abdomen of the female The teats open into this pouch and the young, born in a very early stage of development, are transferred to it They adhere to the teats by a temporary sucker and the milk is discharged into their mouths (A W L)

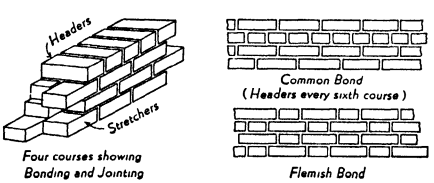
MARTEN Mammalia, Carnivora Slender animals with short legs and a moderately long bushy tail Related to the weasels but larger The several species live in the northern hemisphere

Some of the most valuable furs marketed are those of martens, and all species bear fur of fine quality The sable of northern Asia, *Martes zibellina*, and the marten of northern North America, *M americana*, produce the most valuable fur, although that of the fisher is also good The fisher, *M pennanti*, formerly ranged over most of North America, but is now found only in the wilder northern areas It is also called the pekan and the American marten is sometimes known as the American sable (A W L)

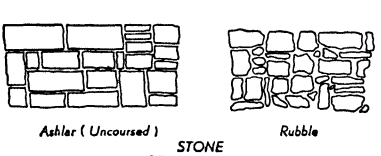
MARTIN. Aves, Passeriformes Any of several species of **swallows,** represented on all continents except Australia They have the short beak and wide mouth of the swallows and either a forked or a square tail They nest about houses, on cliffs, and in burrows and hollow trees North America has one species, the purple martin, *Progne subis* The male is glossy blue-black and the female somewhat duller These birds commonly nest in the cornices of buildings or in bird houses, where they live in colonies (A W L)

MASK. A peculiar hinged appendage associated with the mouth of the immature **dragon fly** It can be extended to catch the animal's prey A modified **labium.** (A W L)

MASONRY. Masonry is a term applied to structures composed of individual units laid in and bound together by mortar The common materials of masonry construction are brick, stone, and tile Masonry is one of the most durable and permanent types of construction, since the materials which enter into it are but little affected by the elements However, the quality of masonry construction depends on the mortar, and caliber of workmanship employed in its construction Masonry is used chiefly in the walls of buildings, retaining walls, **piers,** buttresses, **arches, foundations,** and monuments Brick masonry is used more frequently than any other type Brick walls may be either solid or veneered Veneered construction has strength imparted by a framework of wood or a rough masonry wall composed of concrete or tile blocks, over which is placed a layer of bricks which give weatherproofing and a finished appearance to the wall The veneered wall is often superior to a solid brick wall Solid brick masonry is made of two or more layers of brick with the bricks running longitudinally, bound together with bricks running transverse to the wall These brick arrangements are known respectively as stretchers and headers The method of alternating stretchers and headers gives rise to different bonds, such as the common bond, the English bond, and the Flemish bond There is not a great deal of difference between these bonds from the utilitarian standpoint, but the appearance of the finished wall is somewhat different, and these bonds have been developed to suit different tastes



BRICK



STONE Masonry

Blocks of cinder concrete, or of ordinary concrete, and blocks of hollow tile, are known as building blocks They are much larger in size than the ordinary bricks, and lay up much faster in the wall Furthermore, cinder and tile masonry have but little water absorption compared to solid brick masonry While these blocks are used alone for commercial walls such as factories, garages, etc, their use in the best grade of construction is limited to backing up brick veneer and to interior partitions and cellar walls

Stone which is worked into the masonry may be dressed or rough Stone masonry wherein the stones are dressed to flat surfaces, is known as ashlar masonry Stone masonry with irregularly shaped stones is rubble masonry Both ashlar and rubble masonry may, by the selection of stones, be laid in course, but a great deal of stone masonry is uncoursed

The strength of masonry walls is dependent upon the bond between the building material and the mortar, but not entirely so, since the complete filling of the space between adjacent bricks or stones with a mortar which hardens so interlocks the units that a strong masonry wall would be obtained even with no adhesion between mortar and brick The irregularities of stone surfaces, and the artificially made grooves or recesses of building blocks, aid this interlocking action (F T M)

MASS Few terms are used in physics with greater frequency and assurance than "mass of a body," and few are more difficult to define Mass is often confused with weight, a mistake not helped by the use of the same names for the units of mass and of weight (e g, gram) What appears to be the only inseparable attribute of mass is **inertia;** and, indeed, for the purposes of dynamics, inertia may be taken as the measure of mass One body has twice as much mass as another body if it offers twice as much force in opposition to the same acceleration, no matter where the two bodies may be in the universe The **relativity** theory teaches, however, that the inertia of a body, and hence its mass, is dependent upon its motion If in any state we consider the body at rest, and call its mass in that state m_0 (the "rest mass"), then when the body is given a velocity v with respect to that state, the mass becomes $m = m_0(1 - v^2/c^2)^{-\frac{1}{2}}$, in which c is the velocity of light, so that at a speed of about 160,000 miles per second, the mass of a body would be doubled The concept of the "electromagnetic mass" of electric charges was developed by Maxwell (See **Electromagnetic Field**) (L D W)

MASS ACTION, LAW OF Equilibrium

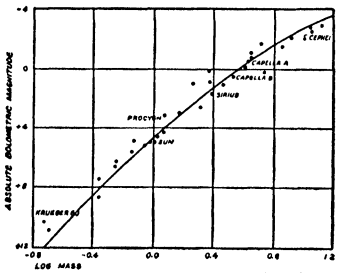
MASSASAUGA. Reptilia, Sauria A small **rattlesnake,** *Sistrurus catenatus,* found throughout the eastern half of the United States and south into Texas and Mexico in low swampy ground It does not attain a length of three feet and is consequently less dangerous than the larger rattlers, but like all others of the group it is poisonous (A W L)

MASS CURVE. Impounding Reservoir.

MASS, LAW OF CONSERVATION OF. Matter can not be created nor destroyed This law holds within the experimental error of the most precise **chemical reactions.** However, matter is believed to be converted into energy according to the Einstein equation (energy equals mass times the velocity of light squared) in many of the atomic disintegrations (**Radioactivity.**) (R K S)

MASS-LUMINOSITY RELATION. From purely theoretical reasoning, based upon the hypothesis that the

material of which a **star** is constructed follows the gas laws, Eddington was able to show that there should be a relationship between the mass and the total radiation from a star The details of the theory are far too complex to be included here, but it should be emphasized that the conclusions are based upon purely theoretical reasoning and not upon a statistical study of previously determined masses and **absolute magnitudes.** The results obtained from the theory are graphically



Mass luminosity curve (From a diagram by Eddington)

represented by the curve shown in the accompanying figure The curve was calculated from pure theory and the plotted points represent stars with observationally determined masses and luminosities The agreement between theory and observation is remarkably close for **giant and dwarf stars** of all **spectral classes.** The only class of stars for which the theory completely fails to agree with observational results is the abnormal group known as the **white dwarfs.** (W K G)

MASS POTENTIAL. Potential.

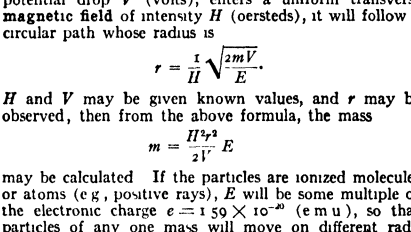
MASS SPECTROGRAPH Any type of apparatus for sorting streams of electrified particles in accordance with their different **masses** by means of deflecting fields If a particle of mass m (grams) carrying a charge E (e m u) and moving with the **kinetic energy** EV corresponding to its passage through an accelerating potential drop V (volts), enters a uniform transverse **magnetic field** of intensity H (oersteds), it will follow a circular path whose radius is

$$r = \frac{1}{H}\sqrt{\frac{2mV}{E}}.$$

H and V may be given known values, and r may be observed, then from the above formula, the mass

$$m = \frac{H^2r^2}{2V}E$$

may be calculated If the particles are ionized molecules or atoms (e g, positive rays), E will be some multiple of the electronic charge $e = 1.59 \times 10^{-20}$ (e m u), so that particles of any one mass will move on different radii according as they happen to be singly, doubly, , multiply ionized, while all singly ionized particles moving on different radii will be known to have masses in



The particles follow semicircular paths and make spots where they strike the plate

proportion to r^2 The figure shows, in purely schematic form, one type of apparatus arranged for this purpose (In the Aston spectrograph the particles pass through both an electric and a magnetic field, the separation produced by the one being offset by a convergence due to the other, in which case V need not be known) By means of such "magnetic analysis," much has been learned concerning the actual masses of atoms and other particles, and the **isotopes** of elements (L D W)

MASTAX. The chewing or grinding apparatus of the alimentary tract of **rotifers** It is an expanded chamber with muscular walls in which chitinous jaws or trophi work together to break up the food (A W L)

MASTECTOMY. Surgical removal of the breast This is usually done for **cancer.** Simple mastectomy is removal of the breast alone Radical mastectomy is removal of the breast, the underlying breast muscles and the lymph glands in the axilla This latter operation is the one most frequently done to obtain a cure when breast cancer is present (R S M)

MASTIC. Resins.

MASTIGOPHORA. One-celled animals whose bodies bear one or more **flagella** as organs of locomotion. A class of the phylum **Protozoa**

This group contains a large number of species, some of great economic importance Many of them contain chlorophyll and so carry on a type of metabolism like that of green plants They may be green in color or blue, yellow, brown or red, due to other pigments associated with the green chlorophyll Many species are colonial and some show a division of labor within the colony which foreshadows true multicellular organization A few of the colonial species have collared cells like the sponges

The **trypanosomes** which cause African **sleeping sickness** and various diseases of animals and the Leishmanias which cause kala azar and Oriental sore are the most important species economically

The classification of the group is as follows

Subclass **Phytomastigina** Usually with chlorophyll, living as plants
- Order **Chrysomonadida.** Very small One or two flagella Color yellow to brown, rarely green or bluish Sometimes form pseudopodia
- Order **Cryptomonadida.** No pseudopodia Color varied
- Order **Dinoflagellida** Marine and some fresh water forms Body enclosed in a cellulose sheath, often beautifully sculptured
- Order **Phytomonadida.** Small rounded green species Many colonial
- Order **Euglenoidida.** Usually elongate, with one or more flagella in a pit at the anterior end With or without green color Sometimes with a pigment spot (stigma) near the anterior end
- Order **Chloromonadida.** A few rare green species without a stigma

Subclass Zoomastigina Without pigment bodies Free living and parasitic species
- Order **Pantostomatida.** With pseudopodia and flagella
- Order **Protomonadida** One of three flagella Sometimes form pseudopodia Mostly parasitic **Trypanosomes** and others
- Order **Polymastigida.** Three to eight flagella Mostly minute, living in the alimentary tract of animals
- Order **Hypermastigida** With numerous flagella Living in the alimentary tract of insects **(Soptera.)** (A W L)

MASTITIS Chronic or acute infection of the breast. (R S M)

MASTODON. Fossil Mammals.

MASTOIDITIS. Infection of the bony cells of the mastoid process behind the ear It usually results from an extension of the infection from the middle ear Mastoid involvement of some degree probably occurs with all acute middle ear infections Thus it is evident that many early cases of mastoiditis recover without operation Usually when the ear infection has been virulent and prolonged, mastoiditis becomes sufficiently acute to demand operative procedure When mastoiditis is present there is usually a larger amount of pus draining from the ear than occurs with simple ear infections There is often, but not always, a rise in temperature Dull aching pain present in the mastoid region is significant, as is tenderness over the mastoid region X-ray is usually helpful for diagnosis of doubtful cases Early operation on the mastoid has almost a certain chance of quick recovery, absence of complications, and restoration of normal hearing (R S M)

MASTURBATION. Producing an orgasm in oneself by the hand or some other mechanical friction of the genital organs It is more common than supposed, occurs in both sexes and often is quite common in childhood The habit does not produce physical disorders or injury but does have an injurious mental effect largely produced by the consciousness that one is doing wrong Often, especially in childhood, it begins from local irritation or infection In others it begins as an accidental occurrence and later develops In still other individuals it is learned or acquired from others (R S M)

MASURIUM. Atomic number· 43 A chemical element discovered by Noddack, Tacke and Berg in 1925 (R K S)

MATE *Ilex paraguayensis* Aquifoliaceae Maté is a drink made from the leaves of a small evergreen tree found in the forests of Paraguay and southern Brazil The branches of the tree are cut off and dried, after which the leaves are broken off, dried more thoroughly and ground to a powder The drink is prepared by pouring boiling water over the powder, and has a pleasant mild odor and taste As yet it has not gained great popularity as a beverage in the United States South American natives consume great quantities, using a curious instrument for the purpose,—a tube at the lower end of which is a flattened spoon-shaped part with a perforated top Through this instrument, called a bombilla, mate is sucked up (R M W)

MATERIALS HANDLING Conveyor; Elevator; Hoist, Dredge, Crane, Cableway.

MATING. The process of securing a consort of the opposite sex for the purpose of reproduction

Among some animals sexual union seems to follow the meeting of the sexes without preliminaries while among others a period of more or less elaborate courtship precedes the actual choice of mates and sexual union Under the simpler conditions the sexes must be together at the time when their reproductive cells are ripe, but this results usually from the normal course of development, aided in some cases by special behavior such as the swarming of marine **annelids.** When sexually mature these worms respond to the same conditions by vigorous activity which brings them, in some cases, to the surface waters in great numbers at twilight Here their mating takes place

Birds and mammals offer many examples of special courtship As a rule the male is active in the process and the female receives his attentions, which may involve no more than close personal interest and may include a great variety of display Birds often sing at their best during this period and often go through strange evolutions to display the beauties of their plumage Displays such as that of the **prairie chicken** combine vocal efforts, such as they are, with display of plumage and mimic combat with other males, and in many species both of birds and of mammals combat between males is a prominent feature of the mating period

The acceptance of a mate by the female is followed by their physical union, or **copulation,** and in many cases by mutual preparation for the care of the young Some species, however, including the **wrens,** include nest building in mating activities The male provides one or more nests as a practical accompaniment for his abundant song while he seeks a wife (A W L)

MATRICES. A matrix is an ordered set of mn elements a_{ij} arranged in a rectangular array, having m rows and n columns The notation commonly used is

$$A \equiv \begin{Vmatrix} a_{11} & a_{12} & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & a_{2n} \\ & & & \\ a_{m1} & a_{m2} & & a_{mn} \end{Vmatrix} \text{ or } \begin{pmatrix} a_{11} & a_{12} & \cdot & a_{1n} \\ a_{21} & a_{22} & \cdot & a_{2n} \\ & & & \\ a_{m1} & a_{m2} & & a_{mn} \end{pmatrix}$$

If $m = n$, the matrix is called a square matrix of order n.

Any two matrices A and B of the same number of rows and of columns are said to be equal if and only if $a_{ij} = b_{ij}$ for every i and j

If the matrix is square, from the elements of this matrix a **determinant** can be formed, which is called the determinant of the matrix From the elements of a rectangular matrix, by striking out rows or columns or both, determinants can be formed

A matrix A is said to be of rank r if there exists at least one determinant of A of order r which is not zero, while all determinants of A of order higher than r are zero

The idea of the rank of a matrix is of importance in stating the conditions under which a **system of linear equations** has a solution (L L S)

MATRIX MECHANICS Quantum Mechanics.

MATTERHORN. Cirque.

MAVIS. Aves, Passeriformes The European song **thrush,** *Turdus philomelus,* a bird that resembles the wood thrush of North America (A W L)

MAW WORM. Nemathelminthes, Nematoda A large roundworm parasitic in the intestine of the horse When present in large numbers its attack is serious A member of the genus *Ascaris* which contains the **eelworm** and other species of similar habits (A W L)

MAXILLA. 1 A bone of complex shape that forms the greater part of the upper jaw in the **vertebrates.** 2 One of a pair of jointed appendages developed as mouth parts in the **arthropods.** They lie behind the **mandibles.** The typical maxilla consists of a basal segment, the cardo, bearing a second segment, the stipes, from which two parts arise On the outside the **palpifer** serves as the attachment for a sensory palpus consisting of several joints Mesially the **stipes** bears the subgalea, from which arises the galea, of one or two segments, and a cutting or chewing part called the lacinia The entire structure may be greatly modified In the **butterflies,** for example, the maxillae are developed into long flexible structures which fit together to form a tubular proboscis (A W L)

MAXILLARY GLAND. An excretory organ of **crustaceans.** Its duct opens at the base of the **maxilla.** (A W L)

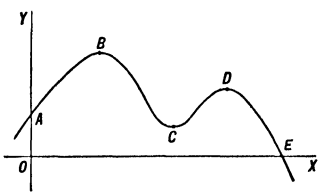
MAXILLIPED. A jointed appendage of the body region of **arthropods,** modified to serve as an accessory mouth part The term is applied to one to three pairs of the thoracic appendages of some **crustaceans** and to the poison claws of the **centipedes.** (A W L)

MAXIMA AND MINIMA. Maxima and minima of **functions** of one variable·

If, as x increases and passes through a value x_1, a function $f(x)$ ceases to increase and begins to decrease,

then $f(x)$ is said to have a maximum at $x = x_1$ and $f(x_1)$ is called a maximum value of the function, if $f(x)$ ceases to decrease and begins to increase, then $f(x)$ is said to have a minimum at $x = x_1$ and $f(x_1)$ is called a minimum value of the function

A maximum value of a function as just defined is not necessarily the greatest value of the function, nor is a minimum the least value Maxima and minima should properly be called relative maxima and minima Together they are often called extremes of the function



For the graph of the function, the points corresponding to the maximum and minimum values are called turning points of the curve Thus, in the accompanying figure, the points B and D are maximum points and C is a minimum point of the graph

In the case of both maxima and minima, the value of the first derivative at $x = x_1$, $f'(x_1)$, is either 0 or ∞

If, as x passes through x_1, increasing, $f'(x)$ changes sign from + to —, then $f(x_1)$ is a maximum, if from — to +, $f(x_1)$ is a minimum If $f'(x)$ does not change sign in passing through x_1, then $f(x_1)$ is neither a maximum nor a minimum

If at $x = x_1$ we have $f'(x_1) = 0$ and if also $f''(x_1)$ is negative, then $f(x_1)$ is a maximum, but if $f''(x_1)$ is positive, then $f(x_1)$ is a minimum

Hence, to determine maxima and minima of a function $f(x)$

First find all the real values x_1 of x for which $f'(x)$ is 0 or ∞, these are called critical values To test the critical values, to find which give maxima and which minima, we may use either of the following two methods

(1) If $f'(x)$ changes sign from + to — as x passes through a critical value x_1, increasing, then $f(x_1)$ is a maximum, but if $f'(x)$ changes from — to +, $f(x_1)$ is a minimum

(2) If $f''(x_1)$ is negative, then $f(x_1)$ is a maximum, but if $f''(x_1)$ is positive, then $f(x_1)$ is a minimum

At a maximum or minimum, $x = x_1$, we must have $f'(x_1) = 0$ (or ∞), but it may happen that $f''(x_1)$ is also 0 In this case the preceding tests fail

If $f'(x_1) = 0$ and $f''(x_1) = 0$, and if also $f'''(x_1) = 0$ and $f^{(4)}(x_1) < 0$, then $f(x_1)$ is a maximum, but if $f'''(x_1) = 0$ and $f^{(4)}(x_1) > 0$, then $f(x_1)$ is a minimum

For the general case

Suppose that $f'(x_1) = 0$, $f''(x_1) = 0$, $f'''(x_1) = 0$, , $f^{(k-1)}(x_1) = 0$, but $f^{(k)}(x_1) \neq 0$, then if k is odd, $f(x_1)$ is neither a maximum nor a minimum, but if k is even, then $f(x_1)$ is a maximum if $f^{(k)}(x_1) < 0$, and a minimum if $f^{(k)}(x_1) > 0$

Maxima and minima of functions of several variables

A function $f(x, y)$ is said to have a maximum value at a point (a, b) if $f(a, b)$ is its greatest value in some region about (a, b), i e , if $f(a + h, b + k) - f(a, b) < 0$ for all values of h, k (except 0, 0) which are numerically less than some positive number d In like manner, $f(x, y)$ is said to have a minimum value at (a, b) if $f(a + h, b + k) - f(a, b) < 0$ for all values of h, k (except 0, 0) such that $|h| < d$, $|k| < d$

A function $f(x, y)$ can have a maximum or minimum only at points where $\frac{\partial f}{\partial x} = 0$ and $\frac{\partial f}{\partial y} = 0$

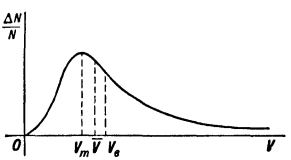
If at a point (a, b), we have $\frac{\partial f}{\partial x} = 0$ and $\frac{\partial f}{\partial y} = 0$, and if also $\left(\frac{\partial^2 f}{\partial x \partial y}\right)^2 - \frac{\partial^2 f}{\partial x^2} \frac{\partial^2 f}{\partial y^2} < 0$, then $f(a, b)$ will be a maximum if $\frac{\partial^2 f}{\partial x^2} < 0$ and $\frac{\partial^2 f}{\partial y^2} < 0$, and will be a minimum if $\frac{\partial^2 f}{\partial x^2} > 0$ and $\frac{\partial^2 f}{\partial y^2} > 0$

For maxima and minima of functions of three variables, there are similar conditions (L L S)

MAXWELL-BOLTZMANN LAW. Equipartition of Energy.

MAXWELL COLOR TRIANGLE. Color.

MAXWELL DISTRIBUTION LAW. A law expressing the relative numbers of **molecules** in a gas which have various given speeds, or various given kinetic energies, of thermal agitation at any instant In its usual forms, it is limited by certain simplifying conditions, viz, uniformity of temperature, absence of turbulence or convection currents, negligible effect of gravity, and purity of the gas (molecules all of equal mass) The



Graph of the Maxwell distribution law

law may be expressed in various terms For example, if N is the total number of molecules, the proportion of them having speeds confined to the interval Δv between $v - \frac{1}{2}\Delta v$ and $v + \frac{1}{2}\Delta v$ (and hence having v centimeters per second as their representative speed), is

$$\frac{\Delta N}{N} = \frac{4h^3 \Delta v}{\sqrt{\pi}} v^2 e^{-h^2 v^2} \qquad (1)$$

h is a constant which may be shown to be equal to

$$h = 6\,034 \times 10^7 \sqrt{\frac{m}{T}}, \qquad (2)$$

in which T is the absolute temperature and m is the mass of one molecule in grams From (1) it is easily deduced that the modal (most frequent) speed of the molecules is

$$v_m = \frac{1}{h}, \qquad (3)$$

the mean speed is

$$\bar{v} = \frac{2}{\sqrt{\pi} h}; \qquad (4)$$

and the effective speed (corresponding to average kinetic energy) is

$$v_e = \sqrt{\frac{3}{2}} \frac{1}{h}. \qquad (5)$$

This last quantity, and hence h, can be calculated from the density and the pressure of the gas (See **Kinetic Theory.**) (L D W)

MAXWELL'S EQUATIONS. A set of four classic formulae of the **electromagnetic** theory They deal with certain **vector** quantities pertaining to any point of a region under varying electric and magnetic influence If the point is in empty space, the equations are somewhat simplified, in general, provision must be made for the presence of dielectrics, conductors, or magnetizable bodies In these equations, H is magnetic intensity, B is magnetic induction, E is electric intensity, D is electric displacement, ρ is electric space density, u is conduction current density, t is time, c is the **electromagnetic constant.** The "curl" and the "divergence" of a

function are well known operators of **vector analysis.** The equations, in this notation, are

$$\text{curl } H = \frac{1}{c}\frac{\partial D}{\partial t} + \frac{4\pi u}{c}, \quad (1)$$

$$\text{div } B = 0, \quad (2)$$

$$\text{curl } E = -\frac{1}{c}\frac{\partial B}{\partial t}, \quad (3)$$

$$\text{div } D = 4\pi\rho \quad (4)$$

(L D W)

MAYFISH. Pisces, Teleostei A species of **killifish,** *Fundulus majalis,* found in shallow bays from Massachusetts to Florida (A W L)

MAYFLOWER. Heath Family.

MAY FLY. Ephemerida.

McBURNEY'S INCISION. One of the most frequently used incisions for removal of the **appendix.** Since no muscles are cut across and no nerves are cut, there is very little danger of post-operative **hernia** Its disadvantage is that one must be sure of the diagnosis as the incision is so small, a general exploration of the abdominal cavity cannot be done The incision is made in the right lower portion of the abdomen running obliquely inward The incisions through the muscular layers are in the direction of the muscular fibers (R S M)

McBURNEY'S POINT. A point on the abdomen situated about two inches in on a line drawn from the right bony prominence of the **ilium** (hip bone) through the naval This point corresponds to the most frequent location of the appendix, and is the point of maximum tenderness when the infected **appendix** is in this location (R S M)

McLEOD GAGE. Pressure Gages.

MEADOW-BROWN. Insecta, Lepidoptera **Butterflies** of dull gray-brown color marked with eye-like spots, in some species set in a yellow patch on the fore wings Family Satyridae (A W L)

MEADOWLARK. Aves, Passeriformes A common North American bird (**Aves**) more closely related to the blackbirds and orioles than to the true larks The eastern meadowlark, *Sturnella magna,* is less attractive than the western, *S neglecta,* which has a brief but glorious song Both have the characteristic yellow breast with a black chevron at the throat (A W L)

MEAGRE Pisces, Teleostei Fishes of numerous species of fishes (**Pisces**), widely distributed in the oceans and to a limited extent in fresh water Most are of moderate size but one species of the Old World reaches a length of six feet Excellent food fishes (A W L)

MEALY BUG. Insecta, Homoptera Small active scale **insects.** The body is covered with a granular white secretion

Mealy bugs are important greenhouse pests Spraying with whale-oil soap (1 pound per gallon of warm water) is recommended for resistant plants and with fir-tree oil (1 part to 20 parts water) for ferns and orchids (A W L)

MEAN EFFECTIVE PRESSURE. Effective pressure acting against a **piston** face and transmitted into a thrust in the piston rod is at any instant the difference between the pressures on the two sides of the piston In the **steam engine, gasoline engine, air compressor,** and other piston and cylinder mechanisms, this effective pressure varies throughout the stroke The average of the effective pressure is known as the mean effective pressure It may be predicted by means of equations and empirical constants, and also found experimentally by the use of the **indicator.** The mean effective pressure is represented by the average height of the diagram drawn by an indicator (F T M)

MEAN FREE PATH. Kinetic Theory.

MEAN SUN. The mean, or average, sun is a purely fictitious object used as a reference point for measuring mean or civil time by the rotation of the earth The term mean sun comes from the fact that the day as determined by use of it, i e, the mean solar day, is very nearly equivalent in length to the average of the lengths of the different apparent solar days throughout the year

The apparent motion of the true sun through the stars is produced by the actual motion of the earth in an elliptical orbit about the sun, the plane of which is inclined to the plane of the **equator.** To remove the irregularity in the apparent motion of the sun due to the **elliptical motion** of the earth a fictitious object is assumed to move in the plane of the **ecliptic** with constant angular velocity which passes through **perihelion** coincident with the true sun The mean sun is a fictitious object assumed to be moving in the plane of the equator with constant angular velocity passing through the **vernal equinox** coincident with the fictitious object just defined (W K G)

MEAN VALUES OF FUNCTIONS. The mean value of a function $f(x)$ over an interval (a,b) is defined by

$$\frac{\int_a^b f(x)dx}{b-a}.$$

The mean value of a function $f(x, y)$ over an area S is defined by

$$\frac{\iint_S f(x,y)dS}{S}$$

The mean value of a function $f(x, y, z)$ over a region V of space is defined by

$$\frac{\iiint_V f(x,y,z)dV}{V} \quad (L L S)$$

MEAN VALUE THEOREM FOR DERIVATIVES. Let $f(x)$ be a **function** which has a finite **derivative** at all points of the interval (a,b) Then there exists a value ξ of x between a and b such that

$$f(b) - f(a) = f'(\xi)(b-a) \quad (L L S)$$

MEAN VALUE THEOREMS FOR INTEGRALS. The first law of the mean for **integrals** is

$$\int_a^b f(x)dx = (b-a)f(\xi),$$

where $a \leqq \xi \leqq b$

The second law of the mean for integrals may be written

$$\int_a^b f(x)\phi(x)dx = \phi(a)\int_a^\xi f(x)dx,$$

where $a \leqq \xi \leqq b$, provided $f(x)$ is **continuous,** and $\phi(x)$ is continuous and is also a positive monotonic decreasing function in the interval (a,b), and

$$\int_a^b f(x)\phi(x)dx = \phi(a)\int_a^\xi f(x)dx + \phi(b)\int_\xi^b f(x)dx,$$

where $a \leqq \xi \leqq b$, provided $f(x)$ and $\phi(x)$ are continuous functions, and $\phi(x)$ is a monotonic decreasing function in the interval (a,b) without being always positive

There are similar formulas for the case when $\phi(x)$ is an increasing function (L L S)

MEASURING WORM. Insecta, Lepidoptera A **caterpillar** which loops the body by drawing the hind legs up close to the front legs as it crawls. The move-

ment is associated with the lack of most of the legs near the middle of the body Caterpillars of the family Geometridae and a few species of Noctuidae are of this type (A W L)

MECHANICAL ADVANTAGE. Machines.

MECHANICAL EFFICIENCY. An **efficiency**, including only the effect of losses arising from mechanical sources, mainly **friction**, would be mechanical efficiency A **machine** such as a **hoist** has an efficiency expressible only as the mechanical efficiency A **steam engine** has not only a mechanical efficiency which measures the friction in windage losses, but a thermal efficiency which is an entirely different quantity The mechanical efficiency of a hoist is the output divided by the input The former is the weight lifted multiplied by the height through which it is lifted The input is the pull exerted on the hoist, multiplied by the distance through which that pull acts The mechanical efficiency of a steam engine is the ratio of net horsepower available at the pulley to horsepower developed by the steam in the cylinder The mechanical efficiency of a pump is the ratio of power expended on the water to that which the motivating source supplies to the pump These are a few examples of mechanical efficiency, and might be multiplied endlessly since any moving machine incurs friction losses, and consequently has a mechanical efficiency of less than 100% (F T M)

MECHANICAL EQUIVALENT OF HEAT. It was in 1840 that Dr James P Joule began his classic researches on the quantitative relationship between **heat** and **work.** Rumford and Davy had established the fact that heat is a form of energy, it remained to determine how many **foot pounds** are equivalent to one **British thermal unit** In the arrangement adopted by Joule, a heavy weight, in descending, was caused to drive a mechanism for "churning" water in a calorimeter The energy furnished by the weight in its descent, with correction for friction losses, was then equated to the heat indicated by the rise in temperature of the agitated water, with the usual calorimeter corrections, the result indicated that one British thermal unit equals about 774 foot-pounds of energy Translated into c g s units, this meant that there are 41,600,000 ergs to the calorie, and when we consider that the most elaborately precise modern electrical methods give, as the present accepted value of "J," 41,852,000 ergs per calorie or about 778 foot-pounds per British thermal unit, it is clear that Joule's experimental skill must have been of a high order

It has been customary, in writing thermodynamic equations involving both thermal and mechanical energy terms, to include the factor J in the former in order to reduce them to the same denomination, but the tendency at present is to express quantities of heat directly in ergs or joules, thereby avoiding the necessity of this factor (See **Thermodynamics.**) (L D W)

MECHANICAL EQUIVALENT OF LIGHT. Since any radiation is a flux of energy, it should be possible to express the emission of **light** in equivalent power units Great precision in such measurements is hardly possible, because of the difficulty of separating the visible sharply from the invisible components of radiant energy One procedure is to enclose a lamp, whose total power input (and hence its total output) is known, in a jacket of transparent material which strongly absorbs throughout both the infrared and the ultraviolet, so that only the visible radiation comes through The absorbed energy is deduced calorimetrically from the rise in temperature of the jacket, while the luminous intensity is obtained photometrically in the usual way The dynamical power corresponding to the light is the difference between the total power output of the lamp and the power absorbed by the jacket Measurements of this type carried out by Ives in 1926 with lamps giving white light gave an equivalent to 0.0016 watt per lumen. (Since the visibility of light varies greatly with the color, being a maximum near the middle of the visible spectrum, the lumen would represent more power for blue light than for average light or for white) The "light-source efficiency" of a good lamp is of the order of 10 lumens per watt input power, which is thus equivalent to 0 016 watt per watt or only 1 6 per cent It is therefore evident that there is still room for much progress in lighting economy (L D W)

MECHANICAL POWER TRANSMISSION. Belts, Gearing, Gear Train, Bearings, Lubrication, Friction Gearing, Speed Changers and Reducers, Coupling, Mechanical Efficiency, Screw Gearing, Shaft, Universal Joint, Worm Gear.

MECHANICS. Mechanics is that science which deals with the effects of forces upon bodies at rest or in motion The laws and phenomena of gases and liquids and solid bodies have a part in this subject, and it is one of the basic studies of engineering, physics and astronomy It is customary to subdivide mechanics into the study of liquids (**hydraulics, hydrodynamics** and **hydrostatics**), the study of the action of gases (**pneumatics**), and the study of rigid or elastic particles or bodies of solid materials It is to the latter field that the term mechanics is frequently restricted For convenience it is further subdivided into **statics, kinematics,** and **kinetics,** each of which is treated in this book Statics deals with bodies at rest, in equilibrium under the action of forces or of torques, kinematics deals with abstract motion and kinetics treats of the effect of forces or of torques upon the motions of material bodies Modern usage favors the term **dynamics,** reserving mechanics for the more practical phases of the field (machinery, building, etc) (F T M)

MECOPTERA. **Insects** with four narrow wings with numerous veins The head is prolonged downward in a beak bearing biting mouth parts at the tip The relatively few species inhabit moist woods and are not commonly known

This order includes two chief forms, the **scorpion flies** and a group of slender long-legged insects usually known by their generic name, *Bittacus* In the former the tip of the abdomen is modified so that it resembles that of a scorpion slightly *Bittacus* has the general appearance of the crane flies but for its four wings, and is chiefly remarkable for the grasping joints at the tips of the legs (A W L)

MEDIAL MORAINE If one or more tributary **glaciers** coalesce with the main glacier the **lateral moraines** unite to form trains of debris on the surface of the glacier at or near its center, these are called medial moraines (R M F)

MEDIASTINUM. The space in the **chest** between the **lungs,** around and above the heart, bounded in front by the anterior wall chest and in back by the posterior chest and spine The space contains many blood vessels, nerves, and lymph glands which may be involved in infections or cancerous disorders Surgically it is difficult of access because the greater part of the space is filled with large blood vessels and the heart (R S M)

MEDINA WORM. Guinea worm.

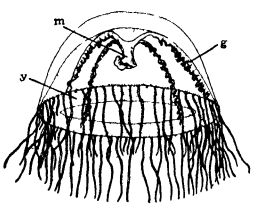
MEDIOSILICIC. A term proposed by Clarke, in 1911, to describe **igneous rocks** whose **silica** content is between 52% and 66% (R M F)

MEDULLA. 1 An axial structure found in some hairs 2 The central portion of the **adrenal glands** 3 The medulla oblongata, the posterior region of the vertebrate **brain** (A W L)

MEDUSA, HYDROMEDUSA. A form of **coelenterate** in which the body is shortened on its principal axis and broadened, sometimes greatly, in contrast with the **hydroid** or **polyp** It varies from bell-shaped to a thin disk, scarcely convex above and only slightly concave below The upper or aboral surface is called the exumbrella and the lower surface, on which the mouth opens, the subumbrella The latter may be partly closed by a membrane extending inward from the margin This structure is called the velum The digestive cavity consists of a central chamber, the stomach, and radiating canals which extend toward the margin These canals may be simple or branching and few or many The margin of the disk bears tentacles and sensory organs

In the class Hydrozoa medusae are the sexual individuals of many species, alternating in the life cycle with asexual **polyps**, but in the Scyphozoa or **jellyfishes** proper the medusa alone is well developed (A W L)

MEDUSOID The **medusa** of certain **coelenterates** of the class **Hydrozoa** A hydromedusa Medusoids differ from the free-swimming jellyfishes to which the term medusa is applied in the usual presence of the velum and in the simpler digestive cavity The term is also applied in some cases to the young medusae budded from the larval **polyp** stage of the **jellyfishes.** (A W L)



Medusoid

MEERKAT Mammalia, Carnivora A South African animal of the civet family, related to the **mongooses** The name is sometimes applied to the penciled mongoose (A W L)

MEERSCHAUM Sepiolite.

MEGAGAMETE Gamete.

MEGALONYX Pleistocene.

MEGANUCLEUS. Macronucleus.

MEGAPODE Aves, Galliformes Dull-colored birds (**Aves**) of the Pacific islands, from the Philippines to Australia They have strong legs and feet and resemble turkeys slightly The eggs are deposited in mounds of decaying vegetation, which generates the heat necessary for incubation The family includes the **brush turkeys** of the Australian region and the **maleo** in addition to the true megapodes (A W L)

MEGASCLERES The large spicules in **sponges** They form the chief support of the body wall (A W L)

MEGASCOPIC Macroscopic.

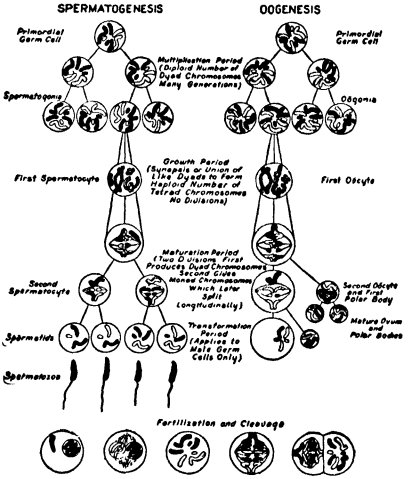
MEGATHERIA. Pleistocene.

MEIGEN'S REACTION. The use of a solution of **cobalt** nitrate as a stain and reagent for determining the difference between **aragonite** and **calcite** Aragonite, when boiled in the solution, is tinted lilac, which remains visible in thin section Calcite and **dolomite** may be colored blue, but the color does not show in thin section (R M F)

MEIONITE. Wernerite.

MEIOSIS. A process of **cell division** accompanied by the reduction of the chromosomes from the diploid condition in which two of a kind occur in the same cell to the haploid, with only one of a kind In a great majority of animals the **cells** of the body are diploid and the reduction occurs in the process of maturation, which culminates in the formation of the sexual reproductive cells (gametes)

The **germ cells** in the **gonads** of the male (spermatogonia) subdivide repeatedly by **mitosis** and the resulting cells may undergo meiotic division The foundation of the process is the same as that of mitosis but the behavior of the chromosomes differs The similar chromosomes pair in a process of synapsis as the primary spermatocyte develops from the spermatogonium, and each chromosome of the pair splits so that a group of four parts called a tetrad results Without further change two maturation divisions ensue, the primary spermatocyte splitting to form two secondary spermatocytes and each of these dividing into two spermatids, which develop into spermatozoa Each of the four cells contains one of the four members of each tetrad of the original cell, and thus bears representative halves of only one-half of the original chromosomes.



Diagrams of spermatogenesis, oogenesis, and fertilization. Chromosomes derived from female are shown in solid color, those from male in outline Sex chromosomes are shown with roughened contours The diploid complex consists of a double series, both as to size and shape, with the exception that the male has only one sex chromosome Note that it is always derived from his mother (Courtesy of E Carothers, 1931)

In the formation of egg cells the chromosomes behave in the same way, but in the first maturation division the primary oocyte gives rise to a large secondary oocyte containing most of the cytoplasm and a small polocyte or polar body containing almost none The second maturation division of the secondary oocyte is similar, and in some cases the first polar body also divides equally to form two The net result is then one ovum and three polar bodies from each oogonium The polar bodies disintegrate

The union of the two kinds of gametes in the process of **fertilization** restores the diploid number of chromosomes (A.W.L)

MELANCHOLIA. A form of insanity, characterized by great depression and a marked emotional tension with little mental or physical activity The disease is of unknown cause and may be a fixed state or consist of recurrent attacks. (R S M)

MELANISM. A condition of unusually dark pigmentation Melanism is conspicuously shown in occasional aberrant individuals of certain **butterflies** whose wings are usually colored yellow or red-brown over most of their area Melanic (melanistic, melanotic) individuals have the normal black markings extended into the lighter areas or in extreme cases have these areas entirely obscured The black leopard is a melanic phase of the spotted leopard and the black fox is related in the same way to the red fox (A W L)

MELANOCRATIC. The term proposed by W C Brogger for eruptive igneous rocks containing more than 50% of **femmic** minerals Derived from the Greek, meaning black (R M F)

MELAPHYRE An old general term proposed by Brongiart, in 1813, for altered **amygdaloidal andesites** and **basalts** (R M F)

MELON. *Cucumis melo* **Gourd Family**

MELTING POINT With the exception of certain glassy or resinous substances devoid of crystal structure and some that are chemically unstable, every pure substance has a more or less well defined melting point (or freezing point) under any given pressure By this is meant a temperature at which the solid and the liquid phases of the substance may exist together in equilibrium, without either phase changing into the other Thus, at atmospheric pressure, a mixture of ice and water kept at 0° C will not change in relative proportions unless heat is applied or withdrawn, and the temperature of the mixture will remain constant so long as both phases are present Applying heat will merely melt some of the ice, withdrawing it will freeze some of the water The melting point is in general affected by pressure, for some substances it is lowered by increased pressure, for some it is raised, according to whether the liquid or the solid phase has the greater density The melting points of substances in an impure state (mixture or solution) are often profoundly modified by the presence of the impurity, thus solder, a mixture of lead and tin, has a much lower melting point than either pure metal The **freezing point law** and the properties of **solutions** give further information on this aspect of the subject

MELTING POINTS OF SOME ELEMENTS

Aluminum	657° C	Platinum	1755° C
Copper	1084° C	Silver	960° C
Gold	1063° C	Sulfur	445° C
Iron	1535° C	Tin	232° C
Lead	327° C	Zinc	419° C
Mercury	−40° C		

(L D W)

MEMBRANELLE A thin projection adjacent to the mouth of most ciliate **protozoans**, formed of fused cilia (A W L)

MENHADEN. Pisces, Teleostei An abundant marine fish (Pisces), *Brevoortia tyrannus*, related to the herrings Massachusetts to Florida Edible and also used for oil and fertilizer Also called mossbunker, bug fish and fat back (A W L)

MENISCUS In physiology, this term denotes a crescent-shaped piece of cartilage in a joint The medial and lateral meniscus are two flat pieces of cartilage on either side of the knee joint between the femur and the tibia They serve as cushions between the long surfaces At times they become injured or torn loose from their attachments This causes considerable pain and interference with function, with accumulation of fluid in the knee joint In such a case, operation is performed and the injured meniscus is removed No interference with function follows such a procedure (R S M)

MENORRHAGIA. Abnormally increased flow of blood during **menstruation** (R S M)

MENSES. Menstruation. (R S M)

MENSTRUATION. The monthly discharge of blood from the **uterus** that begins with puberty and continues until the menopause It is absent during pregnancy, after removal of the uterus or ovaries, and after exposure of the ovaries to sufficient radiation from x-ray or radium It may cease during severe illnesses and emotional disturbances

The primitive explanation of menstruation (and this explanation is still believed by many uninformed people) was that of periodic purging of the woman's body of poison The Greek word for menstruation was the same as that for catharsis

It has been believed in the past that menstruation was caused by a **hormone** The discovery by Fraenkel in 1903 of the corpus luteal hormone substantiated this belief With the discovery of the follicular or estrogenic hormone of the ovary and the pituitary hormones, a more adequate explanation of the menstrual cycle could be given (See **Sex Hormones**) In brief, two hormones from the **ovary,** acting in sequence, are directly responsible for the changes that take place in the uterus during the twenty-eight day cycle The production of these ovarian hormones is controlled by hormones secreted by the **pituitary gland.**

Immediately following menstruation, follicles mature in the ovary, from one of which the egg cell or ovum will be freed During the growth of the follicles a hormone is secreted into the blood stream This follicular hormone is called by various names—estrogenic hormone, female sex hormone, theelin, folliculin, estrin, etc Excess of this hormone is secreted into the urine This particular hormone is responsible for growth or regeneration of the lining of the uterus, helping to prepare it for reception of the ovum if pregnancy is to take place The follicular hormone is produced by the ovary after stimulation of this gland by a hormone secreted by the pituitary gland

Ovulation or escape of the ripe **ovum** from the ovary occurs between the tenth and seventeenth day of the menstrual cycle (the cycle beginning on the first day of menstrual flow, extending to the beginning of the next period—an average duration of twenty-eight days) Following ovulation a new development begins in the collapsed follicle and the follicle becomes the corpus luteum During development of the corpus luteum the follicular hormone is still produced, but, in addition a second hormone is secreted This is called progesterone (progestin, corpus luteal hormone) and it causes the lining of the uterus to change from a vascular to a secreting type of mucosa, further preparing the uterus for implantation of the fertilized ovum If the ovum is not fertilized (if pregnancy does not take place) the corpus luteum degenerates and the production of the follicular and luteal hormone ceases

The withdrawal of these hormones is believed to cause the onset of menstrual bleeding (the sloughing away of the lining of the uterus)

Menstruation and likewise, pregnancy, cannot take place without the pituitary or ovarian sex hormones

All of the phenomena of menstruation cannot be explained solely on a hormone basis It is supposed that a sexual center in the brain—unknown as yet—may stimulate or inhibit the pituitary production of gonad-stimulating hormones Such a condition would tie up the endocrines with the nervous system There is much evidence that the two systems are closely related Certain tumor formation about the floor of the third ventricle of the brain may cause disturbances of hormone production from the pituitary gland The relation is also brought out by the effect of fear and other psychic

factors on menstruation, and also by the fact that certain menopausal symptoms seem to involve nerve pathways

The periodicity of the menstrual cycle is characteristic Eighty percent of normal women have a cycle of twenty-eight days between periods The cycle may be longer or shorter Under abnormal conditions great variation may be seen.

The average duration of flow is from three to five days and the amount of blood lost varies from two to eight ounces The menstrual discharge consists of blood, mucous cellular debris and bacteria Menstrual blood does not clot

The average age of onset of menstruation is 13 9 years and is influenced by physical health, temperament, and environment and to a less extent by race and climate Menstruation ceases with the change of life which usually occurs in the majority of women at forty-seven years

In the healthy woman when there is no endocrine disturbance, and no infection or abnormality of the generative system, menstruation should not be accompanied by dysmenorrhea (pain, headache or vomiting during a part or all of the period) It is quite normal for lassitude, a feeling of heaviness in the pelvis, irritability, depression, frequency of urination, painful swelling of the breasts, to be present (R.S M)

MENTHOL. Alcohols and Ethers.

MENTHONE. Aldehydes, Ketones, and Related Compounds.

MENTUM. 1 **Labium.** 2 The chin

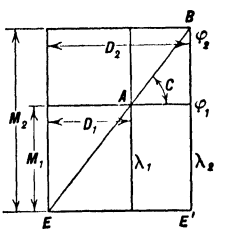
MERCAPTANS. Thioalcohols and Related Compounds.

MERCATOR PROJECTION. The Mercator method of projecting the surface of the earth on a plane was invented by Gerard Mercator, who lived in Flanders during the latter part of the 17th Century At the present time, ninety percent of the chart work of the deep sea navigator is done on the Mercator Chart To realize the general outline of the method, say that we have a terrestrial globe and wish to peel off the surface One method of procedure would be to make cuts through the surface along **meridians** of **longitude** and remove the sectors of the surface thus obtained If the material of which the surface was constructed was of sufficient elasticity, these segments could be placed on a plane with a small amount of stretching The segments would be tangent along the equator, but would separate as the poles were approached, thus forming a discontinuous map To make the map continuous requires stretching the segments along parallels of **latitude,** the stretching increasing as higher latitudes are reached This east-west stretching will introduce distortion in the shape of objects, e g , a circular object would be distorted into an ellipse To maintain the shape of objects the same amount of stretching must be introduced in the north-south direction in any latitude, as is necessary in the east-west direction in that latitude to make the segments tangent The final result is that objects retain their true shape, but there is considerable alteration in the relative sizes of surface features in different latitudes

On the completed Mercator Chart meridians of longitude and parallels of latitude appear as perpendicular straight lines The meridians are equally spaced, but the distance between successive parallels becomes greater and greater as we proceed away from the equator This distance becomes so great that Mercator projection is not used beyond 70° latitude The actual computation of the distances of the successive parallels from the equator, taking into account the ellipticity of the earth, is a complicated mathematical task The results of the computation have been tabulated in a number of places (e g , Bowditch—American Practical Navigator, and similar publications) being generally known as the meridional parts

The great advantages of the Mercator Chart over all others are that meridians and parallels are perpendicular straight lines, and also **rhumb lines** are straight lines Problems in **dead reckoning** may be solved graphically on the mercator chart using straight lines to indicate the courses of the vessel To facilitate such problems and avoid the marking up of actual charts Mercator plotting sheets are published by the different governments, which show meridians and parallels drawn on the proper relative Mercator scale (W K G)

MERCATOR SAILING. In case the distance run by a ship does not exceed 300 **nautical miles** the various problems of **dead reckoning** and the **sailings** may be solved without sensible error by methods which assume that the surface of the earth is a plane The distances run by modern steam ships and aircraft during a single day frequently exceed this limit and the true shape of the earth's surface must be taken into consideration The method of solving the various problems connected with **course** and distance in such cases is usually one which depends for its theory upon the **Mercator projection** and is known as Mercator Sailing



Mercator sailing

In the accompanying figure we have the representation of the general problem, drawn on a section of a mercator chart The vessel is proceeding from A in **latitude** φ_1 and **longitude** λ_1, to B, in latitude φ_2 and longitude λ_2 The course is extended to cross the **equator,** EE' in the point E The angle C is approximately the **rhumb line** course between the two points M_1 and M_2 represent the stretched distances of the parallels φ_1 and φ_2 from the equator, the values being taken from tables of meridional parts D_1 and D_2 represent the difference of longitude of the points A and B from the point of equator crossing of the extended course

Now call $M_2 - M_1 = m$ and $D_2 - D_1 = \delta\lambda$ (the longitude difference between A and B) and we have at once from the figure $\delta\lambda = m \tan C$ The value of C thus computed, taking into account the mercator stretching, is frequently referred to as the mercator course between A and B The distance along AB is a stretched distance and, if calculated from the above figure, or obtained graphically, would be greater than the distance actually traveled between A and B To avoid this discrepancy the distance is computed by the methods of **plane sailing,** solving the plane triangle using the mercator course as computed above for the vertex angle and the difference of latitude as one leg The so-called mercator distance is obtained as $d = (\varphi_2 - \varphi_1)$ secant C, the value of $(\varphi_2 - \varphi_1)$, the difference of latitude, being expressed in minutes of arc which is practically identical with nautical miles (W K C)

MERCURY. Mercury is the name of a **planet,** and of a chemical **element.** They will be discussed in that order in this article

The planet Mercury (c f planetary tables, page 865) is the closest planet to the sun of those thus far discovered It has been known from remote antiquity and there are recorded observations of it as far back as the third century B C Mercury is so close to the sun that at its maximum **elongation** it is less than 30° away, as seen from the earth, with the result that it will never rise more than two hours before the sun, nor be above the horizon in the evening more than two hours after sunset in the latitudes of the United States The early astronomers failed to recognize the planet as the same object when seen east and west of the sun, it being

known as Apollo when seen west of the sun in the early morning, and as Mercury when seen east of the sun in the evening

As well as being the closest planet to the sun the **orbit** of Mercury is the most eccentric of all planetary orbits This high eccentricity, coupled with the proximity of the sun, give to the planet a velocity of more than 36 miles per second when at perihelion, a value more than twice as great as that for the earth After orbits had been computed on the basis of the Newtonian and Keplerian laws and all **perturbations** applied for the gravitational effects of all known planets, there still remained a progressive motion of the longitude of **perihelion.** For many years this unexplained perturbation was attributed to the attractions of an unknown planet between Mercury and the sun The search for this intra-mercurial planet, provisionally called Vulcan, formed a part of many **eclipse** programs during the past century The application of the theory of **relativity** to the orbit calculations for Mercury removed this hitherto unexplained perturbation and was one of the early triumphs of the theory

Because of the fact that Mercury is always very low in the sky during darkness it must be observed with a telescope in the daytime to obtain reliable results regarding surface characteristics Only very few observers have ever been able to distinguish any surface markings on the planet and the different reports are quite conflicting The general consensus of opinion seems to be that these markings do not change their apparent positions, a result which can only be explained on the hypothesis that the planet is rotating about the sun in the same period as it revolves, as is the case with the **moon** relative to the earth

The physical conditions of the surface of Mercury are quite comparable with those on the moon The surface gravity and reflecting power of both the moon and Mercury are very comparable and these results have led to the conclusion that Mercury is without atmosphere and hence barren of life as we know it on the earth Observations of the temperature of the sunlit surface of Mercury give a value of over 600° K (621° F), a temperature comparable with that of molten lead

When inferior **conjunction** occurs with the sun close to one of the nodes of the apparent path of the planet, the planet will pass between the earth and the sun This phenomenon, known as a transit of Mercury, occurs about 13 times in each century, the next one coming on November 11, 1940, and partially visible in the United States Transits of Mercury formerly were used as a method for determination of **solar parallax,** but this method for determining the value of this important constant has been superseded by other methods At the time of a transit of Mercury the planet appears as a very small dot visible only with a telescope, and moving slowly across the disk of the sun

The chemical element mercury Symbol Hg (hydrargyrum) Atomic number 80 Atomic weight 200 61 Density 13 546 at 20° C Melting point —38 87° C. Boiling point 356 90° C Isotopes (page 239)

Mercury or quicksilver is a silver-white liquid metal—the only metal that is liquid at ordinary temperatures (the melting point of gallium is 29 75° C), forms alloys, called amalgams, with most metals, but not with **iron** or **platinum;** does not wet glass but forms a convex surface when in a glass container, is slightly volatile at ordinary temperatures and a health hazard due to its poisonous effect, slowly tarnishes in moist air, upon heating in **air** or **oxygen,** somewhat below its boiling temperature of 357° C, forms mercuric oxide slowly, as in the classical experiment by Lavoisier on the composition of air, may be purified by distillation and condensation (health hazard); unattacked by dilute **hydrochloric** or **sulfuric acid,** but dissolved by dilute or concentrated **nitric acid** with the formation of mercurous and mercuric nitrates, respectively, and by hot concentrated **sulfuric acid** with the formation of both mercurous and mercuric sulfates, unattacked by **alkalis.** Discovery ancient

Mercury is used (1) in scientific apparatus on account of its remarkable range of properties, (2) in the preparation of dental and other amalgams, (3) recently, in some industrial **boilers** instead of steam, (4) in the manufacture of fulminate of mercury **explosive,** vermilion (mercuric sulfide) pigment, and other mercury compounds, (5) in the amalgamation process for the recovery of **gold** and **silver,** (6) in medicine Mercury occurs infrequently as free metal, but chiefly as the red colored sulfide (cinnabar, HgS) in Spain (the Amaden mine has been continuously worked for over 2,500 years and furnishes all of Spain's production), Italy, California, Oregon The ore is roasted with air and the exit gases passed through a condensing system where the mercury is collected

Bromides mercurous bromide ($HgBr$), pale yellow precipitate, formed by reaction of mercurous salt solution and **potassium** bromide solution, sublimes at 345° C, mercuric bromide ($HgBr_2$), white, sparingly soluble precipitate, formed by reaction of mercuric salt solution and potassium bromide solution Melting point of mercuric bromide 237° C

Chlorides mercurous chloride, "calomel" ($HgCl$), white precipitate, formed by reaction of mercurous salt solution and **sodium, potassium** or **ammonium** chloride solutions or **hydrochloric acid** Melting point of mercurous chloride 302° C Turned black by ammonium hydroxide, mercuric chloride, "corrosive sublimate" ($HgCl_2$), formed by heating mercuric sulfate and **sodium** chloride whereupon mercuric chloride, melting point 277° C, sublimes Used in medicine, mercurammonium chloride, "infusible white precipitate" (NH_2HgCl), by adding ammonium hydroxide to mercuric chloride solution, mercurodiammonium chloride, "fusible white precipitate" ($HgCl_2\ 2NH_3$), formed by adding mercuric chloride slowly to a hot mixture of **ammonium** hydroxide and ammonium chloride

Chromates mercurous chromate (Hg_2CrO_4), red precipitate, formed by reaction of mercurous salt solution and **potassium** chromate solution, mercuric chromate ($HgCrO_4$), red precipitate, formed by reaction of mercuric salt solution and potassium chromate solution

Cyanide mercuric cyanide ($Hg(CN)_2$), white solid, soluble—the only soluble cyanide of the heavy metals—slightly ionized and giving no precipitate with sodium hydroxide Used in the manufacture of cyanogen gas

Fulminate mercuric fulminate ($Hg(CNO)_2$), dark brown powder, formed by the reaction of mercury, **alcohol** and concentrated **nitric acid.** Used to detonate explosives of various types in military, industrial, and sporting practice

Iodides mercurous iodide (HgI), greenish-yellow precipitate, formed by reaction of mercurous salt solution and **potassium** iodide solution, melting point of mercurous iodide 290° C with decomposition, mercuric iodide (HgI_2), pale yellow turning to red precipitate, formed by reaction of mercuric salt solution and potassium iodide solution, melting point of mercuric iodide 250° C, potassium mercuriiodide (K_2HgI_4), yellow crystals, formed by addition of excess of potassium iodide to mercuric iodide and crystallization of the mixture Used in the presence of **sodium** hydroxide as an important reagent (Nessler's) for **ammonia,** with which it forms the "iodide of Millon's base" ($HgO(NH_2)HgI$), yellow to brown precipitate

Nitrates mercurous nitrate ($HgNO_3\ H_2O$), white crystals, formed by reaction of mercury metal in excess and dilute **nitric acid,** and crystallization, mercuric nitrate ($Hg(NO_3)_2\ \frac{1}{2}H_2O$), white crystals, formed by reaction of mercury metal with excess of concentrated nitric acid, and crystallization

Oxides· mercurous oxide (Hg_2O), black precipitate, formed by reaction of mercurous salt solution and sodium hydroxide solution, mercuric oxide (HgO), (1) yellow

precipitate, formed by reaction of mercuric salt solution and **sodium** hydroxide solution, (2) red solid, by ignition of mercuric nitrate, or by heating mercury somewhat below its boiling point in an enclosed volume of air or oxygen

Sulfates mercurous sulfate (Hg_2SO_4), white precipitate, formed by reaction of mercurous salt solution and **sodium** sulfate solution, mercuric sulfate ($HgSO_4$), white solid, soluble, formed by reaction of mercury metal and excess hot concentrated sulfuric acid, basic mercuric sulfate "turpeth mineral" ($HgSO_4$ $2HgO$), lemon-yellow solid, formed by reaction of mercuric sulfate with water, but soluble in **sulfuric acid.**

Sulfides mercuric sulfide (HgS), (1) black precipitate, as final result of reaction of mercurous or mercuric salt solution with **hydrogen sulfide.** With mercurous, free **sulfur** is also formed and with mercuric, the color change is first yellow, then red, brown, black successively Insoluble in dilute nitric acid, but soluble in **aqua regia,** slightly soluble in **ammonium** sulfide, but soluble in **sodium** sulfide and hydroxide mixture Sublimes at 446° C (2) red solid ("vermilion," "artificial cinnabar"), by sublimation of black mercuric sulfide, or by grinding mercury metal and sulfur under slight pressure Sublimes at 580° C Used as a pigment in paints, rubber, and plastics

Thiocyanates mercurous thiocyanate (HgCNS), grayish-white precipitate, by reaction of mercuric salt solution and **potassium** thiocyanate solution, mercuric thiocyanate ($Hg(CNS)_2$), white precipitate, by reaction of mercuric nitrate or sulfate solution and potassium thiocyanate solution An explosive, which upon burning, produces "Pharaoh's serpents" ash

Numerous organic compounds of mercury have been prepared "Mercurochrome" is the disodium salt of 2,7-dibromo-4-hydroxymercurifluorescein, used in medicine

All mercury containing substances, when dry and mixed with dry sodium carbonate and heated in a glass tube, yield a metallic mercury mirror in the colder part of the tube

All solutions of mercury salts deposit mercury metal on a strip of **copper** placed in the solution. (W K G, R K S)

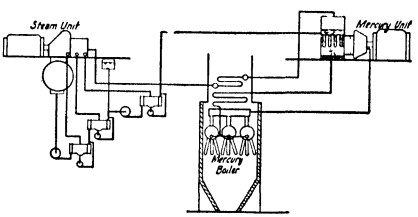
MERCURY ARC. The electric discharge through mercury vapor, between electrodes either of mercury or of some solid metal, is among the richest sources of **ultraviolet** radiation and has long been used as such In the more common forms now in use at least one electrode is of mercury, deposited in a suitable reservoir at the end of a quartz tube As these tubes are operated on moderate voltage, it is necessary to start or "strike" the arc by temporarily running a small stream of mercury through the tube from one electrode to the other This makes a mercury conductor which quickly grows hot and fills the tube with mercury vapor, after which the mercury stream is broken and the arc is self-sustaining The temperature is not nearly so high as in solid-electrode arcs, and these lamps are quite efficient If the mercury vapor becomes too dense, the conductivity falls off, therefore in some forms, as the Cooper-Hewitt lamp, arrangements are provided for condensing the vapor to a fixed density The bulb must be made of quartz for ultraviolet because glass is highly opaque to that radiation In some forms, a fluorite window is inserted, instead, in a glass bulb Mercury arcs with glass tubes have proved useful to some extent for illumination and especially in photography, the light being a highly actinic blue-green (L D W)

MERCURY VAPOR CYCLE. Although water vapor has been the standard working medium of the commercial power plant employing an external **combustion** cycle, it was recognized long ago that water vapor had physical properties not altogether desirable at either the high temperature or low temperature end of the cycle, but at no time has any vapor been discovered which would be more satisfactory at both extremes of the expansion range than steam The use of two vapors in series makes it possible to keep an extensive temperature range and eliminate several of the disadvantages attending the use of a single vapor The mercury-steam is the only binary vapor cycle operated on a commercial scale at present This cycle was pioneered by Emmet After experimenting with small-size units, the problems peculiar to **mercury** vapor were solved, and a few large mercury vapor installations have recently been built

The advantages of mercury as a binary cycle vapor can be briefly stated

1 At high temperatures its vapor pressure is moderate
2 The liquid is of sufficient density to be returned to the boiler by gravity, thus eliminating a boiler feed pump
3 Its high vapor density results in moderate spouting velocities and simple turbines can be used Exhaust passages can be small, and the size of the heat-exchanging mercury condenser is not excessive
4 No tube scaling or other difficulties attending poor feed water are possible Feed treatment is eliminated as mercury is a stable liquid

Against these advantages must be weighed the high cost of mercury, the apparent limitation of its supply, its toxic qualities, its pervasiveness, and the possible higher investment cost per kilowatt



Elements of the mercury steam binary vapor cycle

The diagram in the accompanying figure may be taken as illustrating the mercury-steam cycle as it is developed at present Liquid mercury is vaporized in the many short dead-ended tubes which project down from the drum into the combustion space There are many of these drums in parallel discharging into a vapor dome which feeds the turbine Exhaust from the turbine passes into the heat exchanger which acts both as a mercury vapor condenser and a steam boiler The exchanger is divided into two parts by a diaphragm, the upper section is the steam, the lower the mercury A number of dead-ended tubes similar to those used in the boiler project down into the mercury condenser section and supply the required heat transfer surface Steam which is formed in these tubes by the heat given up by the condensing mercury is then led through a superheater located just beyond the mercury liquid heater, after which it can be used in a steam cycle. (F T M)

MERGANSER. Duck.

MERIDIAN. On the **celestial sphere** a meridian is a great circle passing through the poles of rotation and, hence, perpendicular to the celestial **equator.** The local meridian is the great circle passing through both the poles of rotation and also through the **zenith.** It is both a **vertical circle** and also an **hour circle.** However, the local meridian differs from the ordinary circles on the sphere in that it apparently remains fixed as the

celestial sphere apparently rotates once each day An object on the local meridian is said to be in culmination and if it is on that section of the meridian between the horizon and above the pole it is said to be in upper culmination, if below the horizon or below the pole and still above the horizon it is said to be in lower culmination The **spherical coordinates** both of **hour angle** and **astronomical azimuth** are measured from the local meridian in the direction of apparent rotation of the celestial sphere

A terrestrial meridian is a curve cut on the surface of the earth by a plane containing the earth's axis of rotation The local meridian of a point on the surface of the earth is the meridian passing through that point The plane of the local terrestrial meridian coincides with the plane of the local celestial meridian Terrestrial **longitude** is measured from the local meridian of Greenwich, England (W K G)

MERIDIAN CIRCLE. A meridian circle is a telescope adjusted so that the **collimation plane** of the instrument is in the plane of the local meridian, and capable of rotation about a horizontal axis The instrument is usually fitted with a circle, accurately graduated in degrees, minutes, and seconds, which is perpendicular to the axis of rotation and hence is in the plane of the meridian In case the instrument does not carry the circle in the meridian, the instrument is known as a transit circle

At the principal **focus** of the telescope is placed a **reticle** with an odd number of vertical wires, the middle one of which is in the collimation plane, and one horizontal wire through the optic axis of the telescope

The instrument is used to determine the **equatorial coordinates** of the stars, when the local sidereal time and terrestrial **latitude** are known, or, conversely, to determine accurate local sidereal time by observation of stars of known right ascension The local sidereal time of the instant of passage of a star across the middle wire of the reticle must be the **right ascension** of the star The declination is obtained from the readings of the graduated circles when the star passes through the field of view along the horizontal wire The instrument is also used for the accurate determination of terrestrial **longitude** by determining the local sidereal time and knowing the corresponding Greenwich time (W K G)

MERISTEMATIC Parenchyma

MERLE. Aves, Passeriformes The common **blackbird,** *Turdus merula,* of southern Europe A French name (A W L)

MERLIN. Falcon.

MEROGONY Development of an egg deprived of its nucleus, or of a cytoplasmic fragment of an egg, after **fertilization** by a normal sperm The process is biologically interesting as proof that the nucleus of the male germ cell is capable of bringing about embryonic development although the cell itself is unable to develop because its cytoplasm is chiefly in the form of specialized structures (A W L)

MEROPODITE. Biramous appendage.

MEROSOMA. The broad anterior part of the **abdomen** of **scorpions** Preabdomen (A W L)

MESA. A flat topped, steep-sided, table-like mountain capped with a formation or stratum which is relatively horizontal and resistant to **erosion** When such a topographic feature is less than one square mile in area it is usually called a butte (R M F)

MESCAL. Cactus.

MESENCHYME. A diffuse tissue formed chiefly from the middle **germ layer** (mesoderm) It appears in the embryo as a mass of scattered angular or stellate cells with long processes

The mesenchyme of vertebrates forms the **connective tissues, bone, cartilage,** and other special tissues. (A W L)

MESENTERY. A thin **tissue** which attaches the intestine to the wall of the body and in some cases holds it suspended in the body cavity It is formed in animals with a **coelom** by the splitting of the mesoderm (**germ layer**) around the alimentary tract to form this cavity Separate splits occur on the two sides of the body. In some parts they meet in the median line and become confluent, and elsewhere a thin mesodermal partition persists between them, continuous with the lining of the cavity and with a mesodermal covering of any organ around which the advance of the cavity has taken place. This median partition in connection with the intestine is the mesentery

The mesentery of vertebrates persists only above the alimentary tract as a dorsal mesentery save in very limited regions The liver grows into the ventral mesentery, which persists as the gastro-hepatic ligament between liver and stomach and as the falciform ligament between liver and body wall The regions of the dorsal mesentery are named for the regions of the tract with which they are connected That of the stomach is the mesogastrium, that of the duodenum the mesoduodenum, and that of the large intestine the mesocolon In mammals the dorsal mesogastrium forms a saccular extension called the great omentum

In the sea anemones and related **coelenterates** the tubular stomodaeum is held in place by radiating septa from the body wall formed of a central **mesogloea** covered with endodermal tissue These structures are also called mesenteries Similar thin septa extending inward from the body wall but not reaching the stomodaeum bear the same name Those which connect with the stomodaeum are primary mesenteries, the next longest are secondary mesenteries or metacnemes, and still shorter septa are tertiary mesenteries (A.W L)

MESOCARP Fruit.

MESODERM. Germ layers.

MESOGLOEA. A layer of material between the ectoderm and endoderm in **diploblastic** animals, including **sponges, coelenterates,** and possibly **ctenophores.** The layer does not form like the other **germ layers** as a compact mass of cells but is of unorganized material containing specialized cells derived from the formed layers In the sponges these cells form the spicules and the reproductive cells and in the coelenterates they include many nerve cells

The **jellyfishes** have a thick jellylike mesogloea which is responsible for their common name, and in the ctenophores this layer is similar but contains all of the muscular tissue of the body Some observers regard it as a true mesoderm in the latter group It is, in any case, at the border between the diploblastic and triploblastic forms (A W L)

MESOHIPPUS. Fossil Mammals; and Oligocene

MESOPHYLL. Leaf.

MESOTHORIUM. Symbol $MsTh_1$, and $MsTh_2$ Two radioactive elements of the thorium series (See **Radioactive Changes.**)

MESOZOIC A major subdivision of the geologic time-scale The **era** of "Middle" life, or the age of reptiles Subdivided from the base up, into the following periods **Triassic, Jurassic, Comanchean, Cretaceous.** The Era was characterized by the rise of **dinosaurs** (Triassic), rise of birds and flying reptiles (Jurassic), rise of flowering plants (Comanchean), great development of **ammonites** which became extinct at the end of

the Cretaceous; culmination and extinction of most reptiles, and rise of the **archaic mammals** between the Cretaceous and the **Tertiary.** The Mesozoic era began 200 million years ago and lasted 140 million years (R M F)

METABASIPODITE. A subdivision of the **basipodite** of the **biramous appendages** of some crustaceans, also called the preischiopodite (A W L)

METABOLISM. The interchange of materials between living organisms and the environment by which the body is built up and energy for its vital processes is secured

Within the body of the individual both constructive and destructive processes take place The incorporation of materials is known as anabolism and the breaking down of these materials for the release of the energy contained in them is katabolism

Among different kinds of living things three principal types of metabolism are recognized, that carried on by green plants, that of plants which have no chlorophyll, including bacteria, yeasts, molds, etc, and that of animals

The metabolism of green plants, based on the process of photosynthesis, is also carried on by some one-celled creatures classed with the **protozoans.** They are not strictly plants or animals but are intermediate forms with some characteristics of each Briefly this process consists of the utilization of water, carbon dioxide, and mineral salts as raw materials for the formation of complex organic compounds rich in energy The green substance, chlorophyll, is the active agent in the process and the sun is the source of energy **Carbohydrates** are formed by the union of carbon dioxide and water, with the release of oxygen By the reorganization of these compounds and the addition of nitrogen, sulfur, and other elements from inorganic salts the **fats** and **proteins** are made

Such plants as the bacteria and yeasts secure energy by chemical transformations of many kinds Some act on carbohydrates and produce carbon dioxide and alcohol Others oxidize ammonia and produce nitrites, and still others form nitrates from atmospheric nitrogen The net result of their activities is that all compounds discarded by either green plants or animals, or left in their bodies at death, are transformed into substances which can be used again by one or another form of organism Thus the three types of metabolism are related in a cycle Any one alone would gradually transform the available foods into unavailable wastes, and would automatically come to an end Together they carry on an endless circulation of materials

Animals are utterly dependent on the complex compounds as foods and so must rely directly or indirectly on the green plants They break the compounds down partially in digestion and resynthesize similar compounds from the resulting products Both plants and animals utilize compounds of the three groups as sources of energy, releasing the energy by oxidation in the process of respiration. The resulting simplified wastes are then disposed of by excretion

From the chemical changes included in metabolism, life is maintained and heat, mechanical energy and electric currents are produced within the body Metabolism may be measured as heat produced To produce the changes of metabolism, oxidation of food must take place Oxidation in the body is a slow process, but the same amount of heat is produced in this way as occurs when the food products are burned outside of the body

The unit of measure used for metabolic heat production is the **kilogram calorie** This unit represents the **heat necessary** to raise one kilogram of pure water one **degree** Centigrade, 1 gram of carbohydrate yields 4 1 **kilogram calories,** 1 gram of fat yields 9 3 **kilogram calories;** 1 gram of protein yields 4 1 **kilogram calories,** 1 **gram alcohol** yields 7 **kilogram calories**

Heat production, and therefore metabolism, may be measured directly by the **calorimeter** (by means of a compartment so constructed that all heat given off by the body may be measured), and indirectly by the respiration calorimeter (by measuring the oxygen absorbed by the lungs and the carbon dioxide given off) In medicine the respiration calorimeter is used exclusively for measuring the basal metabolism The heat produced by a fasting individual at rest twelve to fifteen hours after the last meal is called basal metabolism Thus basal metabolism forms a standard for comparison of metabolism under varying conditions of health and disease Particularly does it indicate the activity of the thyroid gland (A W L, R S M)

METACENTER Buoyancy; Hydrostatics.

METACHROSIS. The change of colors in animals Changes occur relatively slowly in fishes, fairly rapidly in some reptiles, and as a rapid play of different shades in the octopus and related mollusks (A W L)

METACNEME. A secondary **mesentery** of sea anemones and related **coelenterates** (A W L)

METACRYST or **METACRYSTAL.** A term proposed by A C Lane, in 1902, for large pseudo porphyritic crystals (**porphyroblasts**) which occur in the **metamorphic rocks.** (R M F)

METAGENESIS Alternation of Generations

METALLOGENY. The genetic study of ore deposits (R M F)

METALLURGICAL CHEMISTRY. See each metal

METAL-MARK. Insecta, Lepidoptera **Butterflies** of small or moderate size, in many species marked with metallic spots and dashes They constitute the family Rhiodinidae (Erycinidae) Relatively few species occur in temperate climates but in the tropics they are numerous and varied (A W L)

METALS, PHYSICAL PROPERTIES OF. Most substances that are chemically classified as metals have certain characteristic and almost unique physical properties Among these are high electrical and thermal conductivity, attributed to free electrons, great opacity and high reflectivity for light, due to the same cause, and responsible for the "luster" commonly associated with metals, malleability,—a sort of plasticity by virtue of which a metal may be cold-worked and rolled into thin sheets, ductility,—a combination of malleability and toughness which permits a metal to be drawn into wire Metals in their normal, pure state are crystalline They exhibit a characteristic effect upon **polarized light** reflected from their surfaces A highly useful property is their ability to mix with each other to form an almost endless variety of alloys, having properties often subject to wide control For example, an alloy of 60 per cent copper with 40 per cent nickel, called constantan, developed for use in resistance coils, has almost invariable electrical resistivity under varying temperatures Some substances such as selenium, not chemically metals, exhibit one or more of these metallic physical properties Mercury is the only metal of low melting point (L D W)

METAMERE. A division of the animal body occurring as one of a series along the principal axis Segments of this type are well developed in the earthworms As a general rule each segment of such a body contains similar internal organs but a certain amount of specialization of the segments is evident both internally and externally in different parts of the body **Arthropods** and **vertebrates** are also metameric but in these animals the specialization of segments is more advanced and has given rise to body regions The arthropods have a head, thorax, and abdomen, with metameres clearly evident

only in the abdomen in many species. **Vertebrates** have a head, trunk, and tail, and as a rule show metameric segmentation only internally. (A.W.L.)

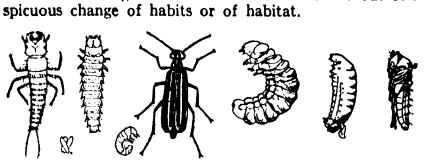
METAMORPHISM. Derived from the Greek, meaning change of form. Confined to rocks that have been derived from pre-existing rocks by mineralogical textural and structural changes within the original mass. All metamorphic rocks are either **crystalline** or **cryptocrystalline**, the crystallization or recrystallization usually producing alignment and segregation of the minerals into bands. This type of banding is called **foliation**. In the case of the fine-grained metamorphic rocks, such as **slate**, the foliation results in a high degree of fissility or cleavage. **Schists** usually display both banding and cleavage. The processes of metamorphism may be roughly classified as follows: (1) contact metamorphism. The result of igneous intrusions into **sedimentary, igneous** or **metamorphic rocks**, producing at the contact bands or aureoles of metamorphism. This type of metamorphism causes alteration of the intruded rock by the heat and solutions of the **magma**. Sometimes also the margins of the intrusive body are chemically affected by impregnations of solutions from the rock which is intruded. A number of varieties of valuable ore deposits occur in zones of contact metamorphism.

Regional metamorphism is from a quantitative point of view, a type of greater importance, and originates well below the surface of the earth (zone of metamorphism) very slowly, often the result of differential pressures; but high temperature, hydrostatic pressure, and the effects of solutions may produce certain types of regionally metamorphosed rocks. Sedimentary rocks may be metamorphosed with or without apparent crystallization.

Hydrothermal metamorphism is the result of hot, aqueous solutions circulating through fractures, and usually causing the alteration of the adjacent rocks. (R.M.F.)

METAMORPHOSIS. Development of the individual, after birth or hatching, involving marked change in form as well as growth and differentiation.

Metamorphosis usually accompanies change of habitat or of habits. In some forms, however, it is merely development through a succession of forms which probably represent ancestral stages in the evolution of the species. The first type is illustrated by many **insects** and by **amphibians**. Immature **dragon flies** are aquatic although the adults are flying insects, and **frogs** undergo a transition from the aquatic tadpole to the air-breathing, if not entirely terrestrial, adult. Change of habits is illustrated by the transformation of free-swimming young of many aquatic invertebrates into **sessile** adults, and by the development of adult **butterflies** and **moths** with sucking mouths from caterpillars which eat solid food. The **crustaceans** afford many examples of transformation through several immature forms without conspicuous change of habits or of habitat.



3 2 4 5 1 6 7 8

Hypermetamorphosis of a blister beetle. Number shows stage in development. (After Riley and Chittenden.)

The immature stages are wholly or partly designated by the term **larva**. In the complex metamorphosis of **insects**, however, only the first stage is called the larva and even it sometimes bears a different name. The distinction depends on the nature of the metamorphosis.

Some insects hatch from the egg with the general form of the adult and the attainment of the adult stage is marked chiefly by the completion of the wings. This type of metamorphosis is said to be gradual and in its early stages the insect is called a nymph. The orders that develop in this way are grouped as the **Paurometabola**. A few orders are aquatic in early life and are then called naiads. They transform directly into the terrestrial adult and are known as the **Hemimetabola**, or insects with incomplete metamorphosis. The **Holometabola**, with complete metamorphosis, pass through a larval stage, then enter an inactive stage known as the **pupa**, and finally become the conspicuously different adult. A few beetles undergo **hypermetamorphosis** with a sequence of different larval forms preceding pupation. (A.W.L.)

METANILIC ACID ($NH_2C_6H_4SO_3H$). This is a **dye** intermediate and an isomer of **sulfanilic acid**. (R.K.S.)

METAPHOSPHATE. Phosphoric Acid.

METAPLASM. Inactive or lifeless matter included in living **protoplasm**. (A.W.L.)

METAPODIUM. The posterior part of the foot of **mollusks**. (A.W.L.)

METASOMA. The slender posterior part of the abdomen of **scorpions**. Postabdomen. It bears the sting at its tip. (A.W.L.)

METASOMATISM. This term was proposed by Naumann to designate that type of mineral alteration whereby one mineral is dissolved and removed by the solution which introduces and deposits a new mineral in its place. Metasomatism is therefore a process of replacement with or without the formation of **pseudomorphs**, and is frequently a very important process in the formation and enrichment of ore deposits. (R.M.F.)

METASTABLE. A term proposed by Oswald in 1897 for the condition of a **supersaturated solution** when the presence of a solid phase is necessary to precipitate the solute (Holmes). (R.M.F.)

METASTOMA. A structure behind the **mandibles** in some **crustaceans**. Formed of the fused **paragnatha**. (A.W.L.)

METASTOMIUM. The posterior part of the head of segmented **worms**. (A.W.L.)

METATHERIA. Mammalia. Synonymous with Didelphia.

METAZOA. All animals except the one-celled species and the sponges. Characterized by multicellular structure and by the organization of the body in compact tissues and organs coordinated by a nervous system. In most metazoans the food is digested in a special cavity, although some may be taken into cells as in the sponges and protozoans. (A.W.L.)

METEORIC WATER. Ground water.

METEORS (OR METEORITES). Meteors, or "shooting stars," are visitors from space which come into the atmosphere of the earth with velocities from 24 to 240 kilometers per second (15 to 150 miles per second). They are made visible by being raised to incandescence by resistance offered by the atmosphere of the earth.

The term meteor comes from the fact that since the late eighteenth century they have been associated with the atmosphere of the earth. The terms **fireballs, bolides**, and **meteorites** or aerolites are also applied to meteors. The difference between the various objects depends merely upon their observed characteristics and there is considerable evidence in support of the hypothesis that they are all made up of the same fundamental

materials The term meteor is sometimes restricted to that class which does not attain a brightness greater than zero stellar **magnitude** (i e , is not brighter than the **planet Jupiter**) Objects which attain a brightness greater than this, and which leave behind them trails which may persist for several minutes, are known as fireballs Frequently, the direction of flight of a fireball is observed to change suddenly, and not infrequently a distinct sound is heard either during or shortly after the passage of a fireball A fireball which is observed to explode into several fragments is known as a bolide, and frequently a loud detonation is heard following the explosion Meteors, fireballs, and bolides, in the true sense of the terms, are so completely disintegrated during their passage through the earth's atmosphere that they fall to the surface of the earth as dust Any one of these classes of objects which is large enough to penetrate the atmosphere and arrive at the surface of the earth as a solid body is known as a meteorite, or aerolite

Meteors are observed most frequently by pure chance, but at present there are a number of systematic photographic surveys in progress The most effective method for determining accurate data regarding the heights, velocities, and other characteristics of a meteor is to have two cameras situated about twenty miles apart, with the distance between them accurately known If the same meteor is photographed by both cameras, it will be found to be projected against different backgrounds of stars on the two plates From the difference in position relative to the stellar background, the angle subtended by the meteor at the length of the distance between the cameras may be determined, the triangle solved, and the height of the meteor obtained If one of the cameras is equipped with a rotating shutter, which will produce breaks in the meteor trail at accurately timed intervals, the lengths of the segments of the trail may be measured and the velocity at which the object is moving be determined after the height has been found

The results of the recent and accurate surveys are just beginning to appear, but from these results thus far obtained it appears that about half the meteors enter the earth's atmosphere with velocities less than 42 kilometers per second (26 miles per second), while the remainder have velocities greater than that Furthermore, those with velocities less than 42 kilometers per second are found to be members of meteoric showers emanating from **radiant points**, and hence are actually members of the **solar system** It may be shown theoretically that any true member of the solar system when situated at a distance from the sun equal to that of the earth, cannot have a velocity greater than 42 kilometers per second This seems to indicate that at least half of the observed meteors are actually visitors to the solar system from interstellar space How many such objects there may be in interstellar space we have no means for determining at present

Another result of the recent surveys indicates that the average height of the middle of a meteor trail is about 89 kilometers (55 miles) The fact that this is the same as the height of one of the layers of the earth's atmosphere which reflects radio waves has led to interesting speculation as to the constitution of this region of the atmosphere

The determination of the actual number of meteors which enter the atmosphere of the earth in a given period of time is a difficult task The most recent surveys indicate that there may be as many as a hundred million each day The size of the average meteor may be determined from studies of the brightness of the object and is found to average about the order of magnitude as the size of a drop of water A hundred million objects of this size, and of the density of the average meteorite, would have a total mass of about one hundred tons Such an increase in the mass of the earth would slightly increase the rotation period and would increase the radius by about a quarter of an inch in the three thousand million years that the earth has had its present form

The composition of meteors may be determined only from meteorites or from fragments of meteoric dust which have been collected A more complete discussion of the actual composition of meteorites will be found elsewhere There has never been anything found in meteorites which has not previously been found on the earth, and the average percentages of the different chemical elements found in meteorites is comparable with the distribution found elsewhere in the solar system The wholly metallic meteorites are chiefly an iron-nickel alloy and are called siderites **Siderolites** are meteorites composed of both metallic and silicate materials Meteorites made up almost entirely of silicates are called **aerolites**

Nothing is known regarding the origin of those meteors which enter the earth's atmosphere with velocities greater than 42 kilometers per second, and hence come from outside of the solar system Of the slower objects we know that some of the radiant points are following orbits similar or identical with orbits of comets The cases are too frequent and the agreement too close to be assigned to mere chance and hence we know that many meteors are definitely connected with comets As soon as the question as to how many of the slow-moving meteors are members of meteoric showers is answered, we shall be able to make more definite statements regarding the origin of these terrestrial visitors Such objects, however, must be actual members of the solar system

Since by far the greater percentage of meteors fall to the surface of the earth as fine dust, there is no danger to the earth or its inhabitants from these objects The meteorites, however, are a potential source of danger The air wave and earthquake which would follow the impact on the surface of the earth of a mass of, perhaps, several hundred tons, moving with a velocity of many miles per second, are almost beyond imagination The results of such impacts are found in the huge meteor crater in Arizona and in the more recent fall in northern Siberia Fortunately, large meteors are very rare and they seem to have the happy faculty of selecting uninhabited portions of the earth for their descent The fall of such an object on a city would completely destroy it (W K G)

METEOR SHOWER. This term is applied to indicate a number of meteors coming from the same general part of the sky known as a **radiant point** (W K G)

METEPIPODITE A broad thin lobe on the outer side of the appendage and at its upper end, in crustaceans which have the flattened form of **biramous appendage** called a **phyllopodium** An epipodite Also called the branchia (A W L)

METER. The fundamental unit of the **metric system** is called the meter The standard platinum meter bar, known as the **mètre des archives**, deposited at Sèvres, was supposedly so constructed that at 0° C its length is one ten-millionth of the earth's meridian quadrant at sea level It is one of three similar bars constructed at the same time (1793) and kept in different places This standard superseded a provisional meter based on the length of a seconds pendulum Its ratio to the standard yard of the **English system** is about 1 0936 (1 meter equals 1 0936 yards)

The term meter is applied generally to indicating and recording devices Closer attention to costs and increasing competition for business have stimulated achievements in economy of design and operation that have been predicated on a liberal use of metering equipment.

Meters are installed in a plant for a number of reasons To operate a plant, for example a steam plant, most efficiently, the operating force must know the conditions of pressure, temperature, flow, etc , throughout the plant Meters replace guesswork on the part of

attendants with accurate information for guidance to safe, continuous, and proper plant operation They give those charged with the supervision of the plant a basis upon which to direct its operation so as to achieve the best performance possible Cost accounting systems will be based on adequate meter readings and correct cost allocations may point towards possible economies to be effected

The functions of meters are

1 Operating guidance
2 Economical supervision
3 Performance calculations
4 Costs and cost allocation
5 Maintenance guidance

Probably the most useful classification of meters is a division into those measuring mechanical quantities and those measuring electrical quantities This classification should not be confused with a division into mechanically operated and electrically operated instruments, for there are several meters recording mechanical quantities that are electrically operated

Mechanical Instruments

1 **Temperature** measurement
   a Glass tube mercury thermometers
      These are used for installation in thermometer wells in flow lines, measuring temperature of condensate, circulating water, feed water, bearing oil, etc They are necessarily local reading but are often installed as a check on remote reading bulb and tube thermometers
   b Gas-filled bulb and tube thermometers
      These can be applied to measure temperature of gases or liquids up to 1000° F and indicate or record same at a point as far distant as 300 feet from the location of the bulb
   c Vapor pressure thermometer
      A type used to measure temperatures up to 500° F It consists of a bulb partially filled with a liquid connected to a length of tubing It has fewer power plant applications than the gas-filled type
   d Electrical resistance thermometer
      A thermometer for accurate measurement of feed-water and condensate temperatures, and for measurement of the temperature of windings of electrical machines
   e Thermocouple thermometer or pyrometer
      The thermocouple is used to measure high-range temperatures such as furnace, flue gas, preheated air, or superheated vapor temperature
2 **Pressure** measurement
   a Standard, Bourdon tube type, steam pressure gauge
      Extensively used for measuring pressure of all types
   b Helical tube or diaphragm type low steam pressure gage
      Such are used to measure bleeder steam pressures, exhaust pressures, etc
   c Vacuum gages.
      These are used to measure the vacuum in condensers, evaporators, etc
   d Draft gages (inclined glass tube, diaphragm, and liquid-sealed bell types)
      The draft gage is employed to obtain and maintain the best furnace conditions, to check the operation of automatic combustion equipment, and to check the condition of the boiler setting and flues Draft gages also measure the performance of draft fans and of chimneys
   e. Miscellaneous pressure gages on oil, air, and water lines.
3 **Flow** measurement
   a Steam flow meters.
      The steam flow meter is used to measure individual boiler output, group boiler output, turbine supply, auxiliary steam and industrial steam
   b Water flow meters
      Measure condensate, feed water, pump discharge, etc.
   c Air flow meters
      When these are used, they are generally in the form of a differential draft gage
4 **Fuel** measurement
   a Coal
      Coal is usually weighed in batches, although belt conveyor weighers and some pulverized coal weighers are continuous
   b Gas meters
      These are either the positive displacement or differential head type The latter type predominates
   c Oil meters
      Positive displacement type.
5 **Carbon dioxide** measurement
   The types of carbon dioxide meters in present use employ one of the following principles
      Chemical—Modifications of the Orsat apparatus
      Electrical—Based on measurement of the conductivity of flue gas
      Mechanical—Flue gas density balanced against air
6 **Speed** measurement
   a Vibrating reed tachometer (local reading)
   b Electrical tachometer (remote reading)
   c Clock type tachometer (local reading)
   d Revolution counter
      Tachometers are employed to gage turbine speed, also the speed of some of the large plant auxiliaries
7 Level recorders
   Liquid level in boilers, tanks, canals, etc
   Pulverized material in bins or silos
8 Gong alarms
   Gong alarms, with or without annunciators, are used to give warning of high temperatures, of high water in the hotwell, or of low water in the boiler feed tank The annunciator system, when used, is usually mounted on the main switch or panel board
9 Atmospheric measurements
   Barometer, hygrometer, thermometer

Electrical Instruments

1 **Ammeters**
   Ammeters are used in generator leads, feeder circuits, auxiliary power circuits, and field circuits
2 **Voltmeters.**
   Voltmeters are used to maintain proper voltage, check automatic voltage regulators, synchronize, and, with proper connection, detect grounds
3 **Wattmeters.**
   Show power in generator or feeder circuits.
4 Synchroscope
   Used to parallel alternators
5 Power factor meters
   These meters are used in alternator leads to check excitation and load division, or on the bus bars if a synchronous condenser is used to maintain power factor
6. Reactive volt ampere meter
7. Ground detector

A further classification of meters is based on their type, whether indicating, recording, or integrating

1 Indicating Used chiefly for operating guidance
2 Recording Used for operating supervision and for calculation of performance
3 Indicating and recording Combining the functions of the two previously named
4 Indicating and integrating For operating guidance, calculation of performance, and allocation of cost,
5 Indicating, recording, and integrating Combining the separate functions

Unless a record is needed for operating supervision or for plant calculations, the initial expense and maintenance of recording instruments plus the fact that index instruments are more easily read precludes the use of recording instruments as operating guides alone However, many applications will be found for which recording instruments will be selected There are two types of recording instruments those using circular charts and those using strip charts The circular charts must be replaced each day, the strip charts last several days Circular charts are (1) less expensive than strip charts, (2) more easily planimetered, (3) rugged and easily filed, (4) of a form to expose a full day's record at all times, (5) accurately held in position by the centering point Considering points in favor of the strip chart (1) they are more suitable than circular charts when many records are to be centralized or when multiple records of draft, temperature, etc, are to be put on one chart (2) Being electrically operated, strip chart meters are, as a rule, more accurate than circular chart meters (3) The chart speed may be changed (F T M, L D W)

METES AND BOUNDS A method of describing, in **surveying** terms, tracts of land for the purpose of establishing legal titles is known as metes and bounds In early days the boundaries of a piece of land were described in a haphazard manner, but as property became more valuable it was necessary to define these boundaries in terms of definite quantities Legal titles called deeds now contain the length and **bearing** (direction) of the individual sides, a description of the **corners**, the names of the adjoining property owners, and the calculated area Thus, if one of the original corners is known, the boundaries of a tract of land may be relocated from this description by metes and bounds (C W C)

METHANE Methane, "marsh gas," "fire damp" (CH_4), is a colorless, odorless gas, boiling point —161° C, density 0 72 gram per liter at 0° C, 760 mm (specific gravity 0 55, air equal to 1 00), practically insoluble in water, moderately soluble in alcohol, burns when ignited in air with a pale, faintly luminous flame, forms an explosive mixture with air, when between 5% and 13% methane, with excess air the products are **carbon dioxide** plus water, with deficiency of air, **carbon monoxide** plus water, when mixed with air and passed over **magnesium** oxide at 350° C and 500° C **formaldehyde** is found among the products Methane is among the chemically less reactive organic substances It reacts, however, with **chlorine** (and similarly with **bromine**) to form mixtures of methyl chloride (CH_3Cl), methylene chloride (CH_2Cl_2), **chloroform** ($CHCl_3$), **carbon tetrachloride** (CCl_4), depending upon the conditions (one-half of the chlorine used forms **hydrogen chloride**), or may form free carbon with explosive violence, as is the case when one volume of methane plus one volume of chlorine is exposed to direct sunlight. Methane occurs in natural gas, of which it is the main constituent, forms in coal mines and swamps, where vegetable matter is decaying under water (anaerobic fermentation), and is a constituent of coal gas The fuel value of methane (995 British Thermal Units per cubic foot) is high (hydrogen and carbon monoxide about 320 units each). Methane has been synthesized from carbon and hydrogen at 1200° C, and is formed by reaction of magnesium methyl iodide in anhydrous ether (**Grignard's reagent**) with substances containing hydroxyl (—OH) group Methyl iodide (bromide, chloride) is preferably made by reaction of methyl alcohol and **phosphorus** iodide (bromide, chloride)

Important methane derivatives, by replacement of each hydrogen atom, step by step, by hydroxyl are (1) **methyl alcohol** (CH_3OH or H CH_2OH), (2) **formaldehyde** ($CH_2(OH)_2$ by loss of water to CH_2O or H CHO), (3) **formic acid** ($CH(OH)_3$ by loss of water to CHO(OH) or H COOH), (4) **carbonic acid** ($C(OH)_4$ by loss of water to $CO(OH)_2$ or HO COOH or H_2CO_3) Methyl alcohol is, therefore, the simplest **alcohol**, formaldehyde the simplest **aldehyde**, and formic acid the simplest **carboxylic acid** Amino derivatives of carbonic acid are of outstanding interest (See **Amines**) (R K S)

METHYL ALCOHOL Methyl **alcohol**, methanol, "wood alcohol" (CH_3OH or H CH_2OH), is a colorless liquid of pleasant odor, boiling point 64 5° C, miscible in all proportions with water, alcohol, or ether, when ignited burns in air with a pale blue transparent flame, producing water plus **carbon dioxide**, the vapor forms an explosive mixture with air Methyl alcohol reacts (1) with **sodium** metal forming sodium methylate, sodium methoxide (CH_3ONa) plus **hydrogen** gas, (2) with **phosphorus** chloride, bromide, iodide, forming methyl chloride, bromide, iodide, respectively, (3) with **sulfuric acid** concentrated forming dimethyl **ether** ($(CH_3)_2O$), (4) with organic acids, warmed in the presence of **sulfuric acid**, forming **esters**, e g , methyl acetate (CH_3COOCH_3), methyl salicylate ($HO(2)C_6H_4COOCH_3$), possessing characteristic odors (See the various individual acids), (5) with magnesium methyl iodide in anhydrous ether (**Grignard's solution**) forming **methane** as in the case of primary alcohols, (6) with **calcium** chloride forming a solid addition compound ($4CH_3OH$ $CaCl_2$), which is decomposed by water, (7) with **oxygen**, in the presence of heated smooth copper or silver forming **formaldehyde** The density of pure methyl alcohol is 0 792 at 20° C compared with water at 4° C (the corresponding figure for ethyl alcohol is 0 789), and the percentage of methyl alcohol present in a methyl alcohol-water solution may be determined from the density of the sample Anhydrous methyl alcohol may be obtained by fractional **distillation** (anhydrous ethyl alcohol must be obtained by special treatment) Methyl alcohol is obtained (1) by the destructive distillation of hardwoods at about 350° C along with **acetic acid** and small percentages of **acetone** in the water condensate After neutralization of the acetic acid, methyl alcohol is recovered by distillation, usually accompanied by acetone and **acetaldehyde**, and then purified by further distillation, (2) by reaction of **carbon monoxide** plus **hydrogen** in the presence of a **catalyzer**, such as **zinc** oxide or basic **zinc** chromate, at 400° C and 150 to 250 atmospheres pressure, (3) by regulated reduction of formaldehyde or formic acid

A common test for methyl alcohol is by its **oxidation** with a hot copper wire to **formaldehyde**, which is then determined

Methyl alcohol is used (1) as the source of the methyl group (CH_3—) in organic chemistry, using methyl alcohol or methyl chloride, bromide, or iodide, and of the methoxy group (CH_3O—), using methyl alcohol or sodium methoxide, (2) in the manufacture of formaldehyde, (3) as a solvent for many organic substances, especially in the preparation of lacquers, varnishes, (4) as a denaturant in the form of crude wood spirit for ethyl alcohol (R K S)

METOL. Photography.

METRIC SYSTEM. The metric system had its origin in the need, imposed by the development of scientific

thought, for immutable, and at the same time conveniently related, units of physical measure. Prior to the end of the eighteenth century, uniformity and consistency in this matter were notably absent The French Revolution revolutionized many things besides government Even the system of number notation was brought into question, but fortunately was not disturbed One outgrowth of the upheaval was the metric system. In 1791 a committee of the French Academy, including the well known Lagrange and Laplace, made a report to the National Assembly which, after much delay, was finally put into effect Their report fixed the standard of length as the **meter**, defined as one ten millionth of the earth's meridian quadrant at sea level, and determined from elaborate geodetic surveys between Barcelona, Spain, and Dunkirk, France The unit of mass then became a secondary standard, viz, the **gram**, based on the centimeter and the density of water, but this was soon displaced by the present standard **kilogram**, which departs rather seriously from the original ideal All subdivisions and multiples in the system are decimal, with terminology in accord with the following scheme.

deci- = one-tenth (decimeter, decigram)
centi- = one-hundredth (centimeter, centigram)
milli- = one-thousandth (millimeter, milligram)
deka- = ten times (dekameter, dekagram)
hecto- = one-hundred times (hectometer, hectogram)
kilo- = one-thousand times (kilometer, kilogram)

While the metric system has come into general use throughout continental Europe and most of the civilized world, it has yet to gain general recognition in Great Britain and the United States, for other than scientific purposes (See **C G S. System**) (L D W)

MEXICAN ONYX. Travertine.

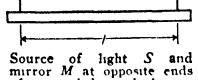
MIASKITE. An old term proposed by Rose, in 1839, for an **oligoclase-nephelite-syenite** in which the chief **mafic** mineral is **biotite** The type locality for this **igneous** rock is at Miask, in the Ural Mountains (R M F)

MICA. The mica group of minerals includes several closely related species, having a highly perfect basal **cleavage**, all are **monoclinic** with a tendency toward pseudo-**hexagonal** crystals, and are closely similar in chemical composition The highly perfect cleavage, the most prominent characteristic of the group, is explained on a basis of **x-ray** studies of these minerals, which seems to show a sheet-like arrangement of the atomic structure and a hexagonal grouping of **atoms** which apparently explains the pseudo-hexagonal crystals above mentioned The word mica is believed to have been derived from the Latin *micare*, meaning to shine, in reference to the brilliant appearance of this mineral, especially when in small scales

The following members of the mica group are treated under their respective headings **Biotite, Muscovite, Lepidolite,** and **Phlogopite** (E S C S)

MICA-SCHIST. Schist.

MICHELSON-MORLEY EXPERIMENT. In 1881 two American physicists, Michelson and Morley, first carried out an experiment which was destined not only to raise doubts regarding the behavior of the supposed **ether**, but ultimately to revolutionize a large part of our thinking about physical phenomena The details of the experiment are somewhat complicated, involving an adaptation of the **interferometer**, but its essential principle may be set forth as follows



Source of light S and mirror M at opposite ends of a rigid bar which carries them with it when it moves

A source of light S and a mirror M, facing it, are mounted on a rigid base at a distance l apart (see figure). Light travels from S to M and back in a certain time, expressed by $t_1 = 2l/c$, where c is the speed of light Suppose now the whole apparatus is set moving lengthwise with a speed v If this is actually the relative motion of apparatus and ether, so that the ether is "blowing past" the source and mirror with the speed v, then a very simple calculation shows that the time now required for the journey $SM + MS$ should be greater, namely, $t_2 = 2l/c \left(1 - \frac{v^2}{c^2}\right)$ It is true that the term v^2/c^2 is necessarily small, but by utilizing the earth's orbital speed of about 18 5 miles per second as the value of v, the change to be expected was brought well within the reach of observation This was accomplished by turning the whole apparatus, first across, then parallel to, the earth's orbit

No difference whatever could be detected between observations in the two positions, the result indicated that $t_1 = t_2$ And no one has yet been able to obtain even an approximate approach to the effect predicted

Naturally this discrepancy aroused much speculation The only satisfactory explanation in classical terms was that offered by Lorentz, following a suggestion of Fitzgerald, and known as the **Lorentz-Fitzgerald contraction**, which has now been incorporated in the foundation of the **relativity theory** (L D W)

MICROBE. Bacteria.

MICROCLIMATE. The aggregate of physical conditions in limited habitats, corresponding to the climate of large geographical areas (A W L)

MICROCLINE Feldspar.

MICROCRYSTALLINE The term applied to the ground mass of an **igneous rock** in which the individual crystals can only be made out with the aid of a microscope Compare with **crypto-crystalline.** (R M F)

MICRO-FELSITE. The term for the ground mass of an **igneous rock** which is not glass but which is still so finely grained that it is extremely difficult, or impossible, to determine the constituent minerals by **polarized light** Many such textures are probably the result of **devitrification.** (R M F)

MICROGAMETE Gamete.

MICROLITES The general term for microscopic tabular or prismatic **crystals.** Microlites differ from crystallites in that the former may be distinguished by the **petrographic** microscope under **polarized light.** (R M F)

MICROMETER The micrometer represents a general principle of **physical measurement,** used on various instruments such as **comparators, spherometers, compensators, interferometers,** etc It is essentially a screw of accurately known, uniform pitch (commonly 1 millimeter or 0 5 millimeter), provided with a large head whose periphery is divided into equal parts, forming a scale Turning the screw through a given number of these parts causes the shaft to travel through a distance which is a proportionate fraction of the pitch. For example, if the pitch is 0 5 millimeter and the head is divided into fiftieths, each scale division corresponds to a travel of 0 01 millimeter A familiar application is the micrometer caliper, an instrument resembling an ordinary screw clamp The screw is, however, of the micrometer design, with its scale reading zero when the caliper is closed When unscrewed and closed again upon a thin plate or wire, the scale reading of the caliper shows the thickness of that object Measuring **microscopes** and astronomical **telescopes** are frequently equipped with a **filar micrometer.** (L D W)

MICRON. The 1/1000 of a millimeter A unit of measure used for microscopic objects.

MICRONUCLEUS. A small nucleus found in many one-celled animals associated with a large **macronucleus** It is active in **cell** division Most species have only one micronucleus but in some two or more occur (A W L)

MICROPALEONTOLOGY. **Paleontology.**

MICROPEGMATITE. A microscopic intergrowth of quartz and feldspar similar to the coarser textured **graphic granite.** A form of **pegmatite.** (R M F)

MICROPHONE. The microphone is now most familiar as the transmitter placed before speakers in radio-broadcasting and amplifier systems In the development of the telephone transmitter, a large variety of means were devised for causing sound vibrations to modulate an electric current; and to certain of these which proved especially sensitive, the term "microphone" was originally applied Some of the effects used were the variation of the contact resistance between conductors, the variation of the capacitance of an air condenser with the vibration of one of the plates, and the generation of an electromotive force by vibrating a coil in a magnetic field or by alternating the magnetic reluctance through the coil, all three of these methods are used in commercial microphones, and the first is also the basis of the ordinary telephone transmitter In the carbon microphone, a box or capsule filled with loosely packed carbon granules between the conducting terminals is fitted with an elastic diaphragm for catching the sound waves, and the whole suspended by rubber bands in a ring so as to avoid mechanical shocks The sound vibrations vary the pressure between the granules, and hence their contact resistance, the current being thus modulated in synchronism with the sound A small microphone of this type has been designed to attach to the coat-lapel of a speaker (L D W)

MICROPODIFORMES. The **swifts, hummingbirds,** and related species An order of birds characterized by strong flight Although the swifts resemble the swallows superficially more than they do the hummingbirds, these two forms are anatomically related (A W L)

MICROSCLERES. The smaller **spicules** in the tissues of **sponges** (A W L)

MICROSCOPE. The optical instrument that bears this name consists essentially of two parts (1) The objective is a lens combination, usually of small aperture and short focal length, which forms a real, inverted, and much enlarged image of the object at a point high up in the microscope tube, very much as a stereopticon objective throws an enlarged picture upon a distant screen The objective lens system is composed of several positive lenses, the first of which is hemispherical with its plane surface facing the object Following this is a larger convexo-concave or "meniscus" lens, and then two still larger plano-convex achromatic lenses (2) The **eyepiece** or ocular is placed beyond, with its focal plane coinciding with this image, and acts as a collimator, so that one looking into it sees a virtual image, apparently at an infinite distance, and subtending a wide angle The instrument is focused by varying the distance between objective and object The **magnifying power** of the microscope depends upon the relative focal length of objective and eyepiece, its resolving power depends upon the dominant wave length of the light used (See **Diffraction**) In the **ultramicroscope,** the object has a special type of illumination Sometimes a drop of transparent oil is placed between the anterior surface of the objective and the slide cover in order to cut down the effect of refractive spherical aberration and the loss of light by reflection from these surfaces (oil-immersion objective) In measuring microscopes, a transparent scale or a **filar micrometer** may be introduced into the ocular focal plane, or a pair of cross hairs may be used and the whole instrument moved laterally by a micrometer screw, thus forming a comparator (L D W)

MICROSEISM See **Earthquakes.**

MICROSPORANGIUM **Flower.**

MICROSPORIDIA. **Sporozoa.**

MIDBRAIN. Mesencephalon **Brain.**

MIDDLE LAMELLA The middle lamella consists of the primary walls which surround the cells of plants and the intercellular layer between these walls This composite layer is usually made up of pectic materials (**colloids** which have a great affinity for water), one of which is calcium pectate The function of the middle lamella is to hold adjoining cells together Sometimes, particularly in mature fruits, the middle lamella substance breaks down As a result the cells of the fruit separate easily, giving to the fruit a meal-like character (R M W)

MIDGE Insecta, Diptera **Insects** resembling mosquitoes but with strong veins only near the anterior margin of the wing and without scales along the veins Only a few can bite Family Chironomidae Insects of the family Dixidae, called dixa midges, also resemble mosquitoes but differ in the lack of scales on the wings and in the venation (A W L)

MIDRIB. **Leaf.**

MIGMATITE. The term proposed by Sederholm, in 1907, for composite gneiss, the result of **lit-par-lit** injection of granitic **magma** between the thin, closely spaced **foliation** planes of **schistose** rocks Migmatites are closely related to **injection gneisses** and probably represent a form of **contact metamorphism** in the wall rock, or roof, of a granitic batholith (R M F)

MIGRAINE. Severe paroxysmal headache frequently associated with vomiting and visual disturbances

The cause of this disorder is unknown **Heredity** is a strong factor in many cases Neurotic and mentally active individuals are more apt to be affected than phlegmatic and dull ones

Many theories are advanced for its causation: (1) Transient spasm of the cerebral arteries with or without pressure disturbance of the cerebrospinal fluid in the cavities of the brain To support this is the fact that temporary paralysis has been known to occur with some attacks, (2) Disturbances of the sympathetic nervous system brought on by toxic, psychic, emotional, or fatigue states These disturbances of the sympathetic nervous system could cause the vascular disturbances cited above in (1), (3) Various **allergic** states with sensitivity to food may indirectly precipitate an attack, (4) In a similar way deficiency or over-supply of certain **glands** of internal secretion (endocrine glands) may be responsible—causing disturbances mentioned in (1) and (2), (5) Certain **toxemia** from disturbances of natural digestion or from toxins generated in the body may be the factor again causing the disturbances mentioned in (1) and (2)

Migraine attacks occur as paroxysms which are felt at more or less regular intervals Most often they begin during or after puberty and in some cases disappear in both sexes at the age when the menopause terminates The attack may last one, two, or three days and utterly prostrate the patient Some emotional, fatigue, or other factor seems to precipitate and release the attack Many patients can tell when the attack is coming on The headache is usually on one side, and is of a pulsating, boring, sharp type difficult to bear, and is located around the eyeball, temporal region, or forehead, later spreading to involve a larger area The patient finds it impos-

sible to be up and around but does not find much relief from rest in bed, as sleep is difficult without drugs

Formerly various measures, both preventative and towards relieving the attack, left much to be desired, except when recourse to narcotics was taken (a pernicious practice) At present most attacks can be aborted or terminated by hypodermic injection of ergotamine tartrate (an ergot derivative) which depresses the activity of the sympathetic **nervous system** (R S M)

MIGRATION. Movement from one region to another over greater distances than are covered by the incidental wanderings of the individual

The most familiar example is the seasonal migration of birds from their nesting grounds at higher latitudes to regions nearer the equator and back Some species cover thousands of miles in these semiannual flights, while others winter only a few hundreds of miles from their summer homes

The underlying causes of bird migration have been the subject of too extensive discussion to be reviewed here They are undoubtedly closely correlated with the ability to migrate, which results from specialization for flight Birds are able to see long distances from the altitudes at which they fly, sometimes thousands of feet above the ground, and are able to proceed far more rapidly than any running animal The advantages of wintering in a region of plenty are obvious, and the release of pressure during the breeding season by removal to less crowded regions is scarcely less so At that time not only hungry adults must be fed but voracious young as well Recent experimental work has emphasized the role of the endocrine glands and of seasonal changes in the environment in stimulating them as factors partially explaining the mechanism of bird migration

Migrations of other animals are less common, but the movements of the great herds of bison on the western plains were a similar adjustment to seasonal food supply The migrations of the European **lemming**, ending in the destruction of great numbers, are less easily understood It has been suggested that they originate in a scarcity of food

Many species of fish also migrate, either from one part of the ocean to another or between fresh and salt water Two of the most noteworthy migrations are those of the salmon and the eel Eels grow up in fresh water and migrate to the Atlantic Ocean in the neighborhood of Bermuda to spawn Their young gradually work their way back to the rivers to develop Salmon, on the other hand, are chiefly ocean fish, but during the breeding season they migrate far up the coastal rivers to spawn in fresh water

Migrations of invertebrates have also been noted, but as a result of the small size and slow locomotion of most species they are usually mass movements over relatively short distances Flying insects, however, often cover hundreds of miles, and in the case of some species of butterflies great hordes of individuals may take part in the migration The southward flights of the North American milkweed butterfly are the most common example Occasionally these butterflies move in such hordes that they cover large trees when they come to rest at night The northward flight of the cotton moth in the summer is also noteworthy This species is abundant in Ohio, far beyond the nearest cotton, which is its sole food plant (A W L)

MILDEW. Fungi.

MILKWEEDS Asclepiadaceae A family of some 325 genera with over 1700 species of shrubs, woody vines, and perennial herbs All contain a milky juice from which **rubber** may be made The family is particularly abundant in the tropics, especially in Africa The forms are extreme many are **lianas** of great length; others have leaves modified into **pitcher**-like forms; some are **epiphytes**; while many, especially in Africa, are very much like **Cacti** in appearance. Indeed, many species are sold under the name of cactus The uses made of various milkweeds are many and varied. The young shoots of many species are eaten as greens, other species yield dyes The juices of several are violent poisons, as *Gonolobus*, from which an arrow-poison is obtained, and *Cynanchum*, which is used to stupefy fish. Many are grown for their weird shape, or because of their beauty, as the Wax-plant, *Hoya carnosa* (R M W)

MILKY WAY. The milky way, or galaxy, appears to the naked eye as a broad irregular band of misty light which encircles the sky The telescope shows that it is in reality made up of myriads of faint stars interspersed with gaseous **nebulae.** Its light is due to these faint stars, and if all of the stars which can be distinguished as individuals with the unaided eye were blotted out, the milky way would still remain undiminished in intensity against the otherwise dark sky. A mere casual examination of the milky way on a dark night will reveal that its intensity varies from point to point, which is an indication that the faint stars are not uniformly distributed

For many years the milky way itself, and the clustering of faint stars in the general direction of its plane, have been taken to indicate, not that the stars were actually closer together in that direction, but rather that the volume of space which contains all of the stars is more extensive in that direction The first line of attack on the general problem of the distribution of matter in space was made by Sir William Herschel, in 1784 His method, which is essentially that of the modern methods of star counting, consisted in counting the number of stars visible in his telescope when it was directed to various directions in the sky As a result of his observations he announced that all of the stars were contained in a volume of space shaped like a "grind stone," with the plane of the grind stone in the direction of the plane of the milky way The relative dimensions of this grind stone-shaped volume of space were 850 to 155

With the application of photography to astronomy and the construction of telescopes of greater light-gathering power the limiting brightness at which stars could be counted was extended down to about the nineteenth magnitude It was immediately recognized that to cover the entire sky to such limits of faintness would be a hopelessly long task, and the plan of **selected areas** was proposed by Kapteyn and adopted by most astronomers

The details of the methods of star counting and the results of the various counts are far too involved to be discussed in a work of this type, but the general results are of tremendous interest For the purpose of interpretation a system of **spherical coordinates** known as **galactic coordinates** was devised It should be remembered that all of the results are based on a statistical examination of a definitely limited amount of space and that the stars are counted only to an arbitrarily selected limit of faintness It is believed that for every star which can be observed with the 100-inch telescope (the largest at present) there are 29 stars which cannot be observed, and hence the results are based upon a statistical study of less than 5% of the stars in the selected areas

The first result of the star counts confirms the original statement of Herschel, and we find that all of the stars are contained in a more or less lens-shaped volume of space Sears, of Mt Wilson Observatory, believes that this volume has a maximum diameter of between 200,000 and 300,000 **light years** and a minimum diameter of about one-tenth the maximum The total number of stars within this volume is estimated as of the order of magnitude of 100,000,000,000 These stars, together with galactic nebulae and **star clusters**, go to make up what is known as the galactic system, or the sidereal universe

The star counts indicate that, in addition to the main galactic system, there is also a local system in the vicinity

of the sun which is more or less lens shaped with a major diameter of the order of magnitude of 20,000 light years The sun is about 275 light years from the center of this local system The plane of the local system is inclined at about 12° to the plane of the main galactic system, or the plane of the milky way This local system is far from the center of the galactic system, the sun being estimated at about 65,000 light years from the center of the main system

The distribution of material in the galactic system is far from uniform, as is evidenced by the huge star clouds which appear in certain portions of the milky way It is quite possible that our local system may be one of these star clouds, although if such is the case, it is the largest of them all The problem of determining the actual structure of the galactic system is complicated by the presence of large masses of dark nebulous material Present data seem to indicate that there is a central condensation of material in the general direction of the constellation of **Sagittarius** This central condensation is partially hidden behind a huge cloud of dark nebulosity which produces the easily recognized rift in the milky way extending south from **Cygnus** to Circinus

The question regarding the maximum dimensions of the milky way system cannot be considered as definitely answered Data obtained by different methods show discordances which cannot be accounted for in any known way It seems possible that there may be general absorption of radiation in what has hitherto been considered as "empty space" Until this question is answered conclusively we must consider the outline given above for the size and shape of the main system to be purely provisional

The problems regarding the dynamics and evolutionary processes of the galactic system are in too undeveloped condition to be discussed in a work of this character There is evidence, both theoretical and observational, that the whole milky way system is in rotation about its minor axis

It is believed by many workers on the structure of the milky way, or galactic system, that from the outside the structure would appear as a huge **spiral**, such as the one in Andromeda appears to us If such is the case, and the present estimates of the dimensions of our own system are approximately correct, our own is the largest of any of the other systems which have been thus far observed (W K G)

MILLER INDEX. Crystallography.

MILLERITE (CAPILLARY PYRITES). The mineral millerite is **nickel** sulfide, NiS, whose slender **hexagonal** interwoven crystals so suggestive of hairs has led to the application of the name "capillary pyrites" It occurs also as radiated masses and coatings It is brittle, hardness, 3-3 5, specific gravity, 5 3-5 6, luster, metallic, color, brass yellow, often with an iridescent tarnish Millerite is found in association with other nickel-bearing minerals and other sulfides European localities are Bohemia, Westphalia, Wales, etc, and in the United States at Antwerp, New York, with **pyrrhotite** in Lancaster County, Pennsylvania, at St Louis, Missouri, Keokuk, Iowa, and Milwaukee, Wisconsin In Canada millerite occurs in Oxford, Quebec, and in the famous Sudbury District, Ontario It is used as an ore of nickel Millerite was named for the English mineralogist, W H Miller (E S C S)

MILLER'S THUMB. Pisces, Teleostei A small fish (**Pisces**), *Cottus bairdi*, with very large pectoral fins and the head and anterior part of the body large and somewhat flattened Common in the northeast quarter of the United States and southward in the mountains In clear streams and lakes One of the fresh-water sculpins (A W L)

MILLET. Gramineae. Cereal and forage grasses of several different genera are included in the term millet All have a fibrous root system, ample foliage, and rather small grains They are grown extensively in Occidental countries as forage crops and in many Oriental countries for human food as well as for forage

Pearl millet, or *Pennisetum glaucum*, is an erect grass with solid stems three to eight feet tall The **inflorescence** is a dense cylindrical spike six inches to a foot long The **spikelets** are two-flowered, the lower floret being staminate (See **Stamen**), the upper pistillate (See **Pistil**) Cross-pollination normally occurs This plant is very variable in the structure of its inflorescence and has been given a number of names, such as African millet, Japanese millet, and Indian millet

Panicum miliaceum is an erect grass two to three feet in height and with frequent branching from the basal portion of the stem The inflorescence is a **panicle** from four to twelve inches long and variable in appearance in different varieties

Foxtail millet, *Chaetochloa italica*, is an erect grass two to five feet tall, with occasional branches from the base of the stem The leaves are long, rather broad and tapering to a sharp point The inflorescence is a narrow spike four to eight inches long The elliptical spikelets are subtended by a group of long bristles and are two-flowered Cross-pollination occurs in this grass, as is also the case in the preceding species Hungarian, German, Siberian, and Common Millet are varieties of this plant, an Old World native which is now widely distributed in North America.

Barnyard millet *Echinochloa crus-galli*, is a coarse branching annual from two to four feet tall The inflorescence is a branched panicle with two-flowered spikelets densely crowded on one side of the branches This grass is another European native which has become a widely distributed weed in both cultivated and waste land in North America

Millets as a group are drought-resistant plants widely distributed as forage or pasture grasses and for hay The seeds are a valuable poultry food A valuable feature of the group is their very rapid growth, which allows them to be used at times when other crops have failed, about six weeks after planting the seed, the plant is ready to cut for hay (R M W)

MILLING. Milling, from the machine standpoint, consists of machining work, generally of a metallic character, by means of a multi-toothed cutter which revolves against the work As the cutter wheel makes a cut, the work moves past it so that a plane surface is "milled," having the width of the cutter face and the length of the travel of the work under the cutter This simplest form of milling can be used to surface a part, or to cut channels, slots, etc, on a surface By employing a combination of cutters, various shaped grooves can be milled, and if the cutters themselves are specially shaped, an endless variety of work may be done by milling Furthermore, if the work rotates as it moves forward, spiral cuts, such as the flutes on a reamer or drill, may be made Practically all forms of tools can be made on the milling machine, and it has become an important tool, both for the general shop and for specialized tool making The bringing of surfaces to exact dimensions, making of gears, dividing and indexing of dials, ruling bars, and smoothing castings such as bedplates, are examples of milling machine work The common form of this machine is known as the universal miller, by virtue of its adaptability to a wide assortment of tasks, and in contradistinction to the various specialized milling machines built to fill the needs of industry

The accompanying diagram (Figure 1) is intended to explain the principle of the universal milling machine, but is no indication of the complexity of the actual machine In order to mill, a cutter must revolve, and the work must be able to move in a horizontal plane In addition, either the cutter must move vertically, or the

work must be able to move vertically In the vertical spindle millers, the vertical head, which carries the cutter, has this vertical motion, but in the machine dia-

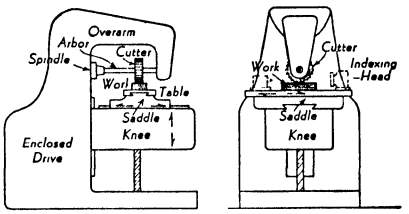


Figure 1 Principle of the milling machine (Arrows show direction of motion)

grammed, the work is moved upwards against the cutter for depth of cut Direction of motion is shown by arrows The knee moves vertically, being driven by a threaded screw and guided by the dovetail way on the main frame Similarly, the saddle moves on the knee, and the table on the saddle These motions are mutually perpendicular, and are accomplished through gearing and screws, or manually by hand-operated cranks The work to be milled is held on the table in a vise Milling machines may be driven by step pulleys from a countershaft, but modern design provides individual electric drive Usually two motors are provided, one to revolve the spindle, the other to operate the feed For most work, the cutter is mounted on an arbor which extends from the spindle to a bushing in the overarm, but for end milling and drilling, the cutter is cantilevered from the spindle Work that is to be held between centers and revolved on succeeding cuts (as in the case of cutting gears) is held by the indexing head and tail stock, both of which are mounted on the table and replace the vise

Explaining a plane surfacing operation such as is set up in the diagram, the cutter is caused to revolve and the work, securely clamped to the table or held in a vise, is brought up against it by raising the knee Since the cutter is not as wide as the surface to be milled, when the table has carried it once past the cutter, the saddle is moved over on the knee so that on the next pass of the work under the cutter, a parallel cut will be taken This continues until as much of the surface as is to be milled has been covered, whereupon the work is returned to its initial position, and the knee again raised if a further cut is to be made

There is a large variety of milling machine cutters, varying from the plain straight-toothed cutters to cutters built especially for some specific milling job To mention a few types, there are the plain milling cutters with either straight or helical teeth, herringbone teeth cutters, end cutters, T-slot cutters, key-seating cutters, slitting saws, gear cutters and hobs, etc Cutters are made of steel, and, depending on the material which they are to cut, may be plain or heat-treated For tough cutting jobs or long wear, some cutters are equipped with inserted teeth of high-speed steel, stellite, or other hard material. The cutting speed and the clearance required on the teeth vary with the material being cut A coolant is employed, directed as a stream against the forming chips to prevent any temperature rise at the point of milling, and to lubricate the cutter

Work which requires rotation under the cutter, like the gear blank shown in the figure, must be held by a device which will permit an accurate rotation of the work The universal indexing head, whose location is shown dotted in the diagram of the milling machine, is such a device For example, the gear blank would be held on a mandrel which, in turn, would be held between the indexing head and tail center. After the cutter moved through the blank one time the indexing head would be turned just far enough so that the next pass of the cutter through the blank would leave one tooth profiled on the blank In this way, by rotating the indexing head the proper distance after each traverse of the table, a gear can be cut from a disk It is ob-

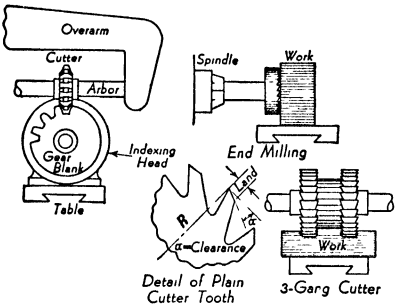


Figure 2 Milling machine work

vious that the indexing head must be accurate and permit perfect control For cutting gears, it is moved only between cutting operations, but for fluting and cutting spirals, it must be moved in conjunction with the table, and for this service is driven by gears from the table feed For gear cutting, indexing, and dialing, the head is rotated by a hand crank

The milling machine, as has been described, is suitable for many different operations However, in quantity manufacture, as, for example, automobile engines, special multiple-spindle millers are built, in which sometimes as many as six surfaces are milled simultaneously Naturally, these machines are highly specialized and are not readily adaptable to a wide variety of jobs (FTM)

MILLIPEDE Diplopoda.

MILLON'S REAGENT. Aminoacids, Polypeptides, and Proteins.

MIMETITE. The mineral mimetite is a **chloro-arsenate of lead** corresponding to the formula $(PbCl)Pb_4(AsO_4)_3$ It is **hexagonal**, brittle, hardness 3 5, specific gravity, 7 0-7 25, luster, resinous, color, usually yellow to brown but may be colorless or white, translucent Mimetite is a rather rare secondary mineral occurring in altered lead deposits Found in Bohemia, Saxony, Cornwall and Cumberland, England, South West Africa, Mexico, and in the United States in Pennsylvania and Utah The name mimetite is derived from the Greek word meaning imitator, because of the similarity of mimetite and **pyromorphite** (ESCS)

MIMICRY. The resemblance of an animal to some other living thing or inanimate object Mimicry may involve both color and form, hence it is closely related to **coloration** It is supposed to benefit the mimic either by concealing it from its enemies, by causing them to mistake it for something undesirable, or by enabling it to approach its prey without giving alarm

Some cases of mimicry are probably incidental, though it is easy to imagine value in all of them The brightly colored king snakes, for example, may be avoided because of their resemblance to the poisonous coral snake, but it is difficult to know that this is true On the other hand, some butterflies are distasteful to monkeys, and by actual experiment it has been shown that after one unpleasant taste the monkey avoids both the unpalatable species and others that resemble it closely Here there can be no question of the value of the mimicry

Mimicry of inanimate or immovable objects is shown by many insects Tree hoppers may look like stout thorns, some caterpillars resemble stubby dead twigs, leaf insects and leaf butterflies are much like leaves, and some moths that rest on the trunks of trees are scarcely distinguishable from bark One of the most remarkable examples is that of a little North American moth which resembles a bird dropping Its front wings are chalky white with mottled gray markings When at rest they are folded close about the body and hind wings and the tip of one overlaps the other, thus concealing the symmetry of the insect Most moths found near the ground in the woods perch among dry leaves or on the under side of leaves or on stems of low plants, but this one remains in full view on the upper surface of a leaf, where a bird dropping would naturally fall

Aggressive mimicry occurs in the **ambush bugs** and some of the **robber flies** The ambush bugs hide in flowers, where their color and markings make them nearly invisible They pounce on insects which visit the flowers for nectar Some robber flies capture bees for food, and in one genus differ greatly from the usual form but resemble bumblebees very closely (A W L)

MINERAL. A natural inorganic substance having a characteristic range of chemical compositions, usually a definite **crystal form**, and exhibiting other specific, physical characteristics such as **cleavage**, **fracture**, **hardness**, **color**, **luster**, and **heft** (specific gravity) The study of minerals is called Mineralogy One who studies minerals is called a Mineralogist (R M F)

MINERALIZERS. The term applied by petrologists to magmatic gases such as water vapor, **hydrogen**, and compounds of the rarer elements and volatile substances which are retained in solution under varying degrees of pressure and temperature, but which tend to escape from the effusive **lavas** under atmospheric pressure alone These original constituents of **magmas** are essential to the origin of all types of intrusive and relatively coarsely crystalline **igneous rocks**, as they tend to.

(1) Lower **viscosity** and thus lower the temperature at which certain minerals crystallize
(2) Act as **catalyzers** in aiding the formation of compounds and crystals
(3) Combine with other elements and compounds to form minerals which require mineralizers
(4) Concentrate metallic and other compounds which otherwise would tend to remain dispersed

(R M F)

MINERALOGIST. Mineral.

MINERALOGY. Mineral

MINERAL OIL. Petroleum.

MINETTE. The term proposed by Voltz, in 1822, for "ironstones" of Jurassic age in the Briey basin and Lorraine, France A **lamprophyric dike** rock whose principal minerals are **orthoclase** and **biotite** (R M F)

MINIVET Aves, Passeriformes A brightly colored **shrike** The several species inhabit eastern Asia and India (A W L)

MINK Mammalia, Carnivora A slender semiaquatic animal with short legs, partially webbed toes, and a short, moderately bushy tail Related to the polecats One species, *Mustela sibiricus*, occurs in Siberia, one, *M lutreola*, in eastern Europe, and one, *M vison*, throughout North America The fur varies from light to very dark brown and is thick and soft, mixed with long glossy hairs It is among the more valuable furs commercially (A W L)

MINNOW. A small fish (**Pisces**), especially certain species related to the carp, dace, and chubs, which never exceed a few inches of length The members of the genus *Hybopsis* are the typical minnows but the name is not limited to this genus (A W L)

MINOR OF A DETERMINANT. Determinants.

MINT FAMILY. Labiatae The greater number of the three thousand species of this family are herbaceous plants, widely distributed in the temperate regions The family also includes a few small trees and shrubs, found mostly in the American tropics The characters distinguishing these plants are so outstanding as to make identification easy Commonly the stem is four-angled, appearing square in cross-section, with the leaves opposite, simple, and without **stipules** The flowers are borne in **racemes** or more frequently in dense axillary **cymes** The flowers are irregular, with the **calyx** composed of five **sepals** united to form a tube, and the **corolla** composed of fused petals which form a two-lipped tube, the upper lip of three, the lower of two lobes The **stamens**, either two or four in number, are inserted on the corolla tube The **pistil** is composed of a bicarpellate **ovary**, each of whose **carpels** becomes constricted early in development to form a four-parted ovary, from which a two-lobed style arises The fruit is commonly composed of four **achenes** or nutlets The flowers of this family are mainly cross-pollinated by insects in some species the corolla tube is short enough to allow bees to obtain the nectar located in a disk at

Pollination by insects of sage, *Salvia glutinosa* The flower is visited by a bee which pushes the stamen in such a way that its pollen covered anther strikes the insect on the back (1) The anther (3) is hinged and has a projecting appendage which the bee touches with its head, thus tilting the anther over (see 4 and 5) When the bee visits another and older flower (2) in which the style and stigma project, cross pollination is effected (From Kerner, *Natural History of Plants*, Henry Holt & Co)

the base of the ovary. Pushing into the corolla tube to reach this nectar causes the pollen in the anthers to be shaken onto the insect's back, where it will be carried to the stigmas of another flower Other species having longer corolla tubes are cross-pollinated by butterflies

Many members of this family have **volatile oils** located in epidermal glands on the leaves, giving to the plants characteristic odors Because of these volatile oils many of them are useful to man, some as condiments, some as **perfumes**, and some as **drugs** Food products are rare in this family, the genus *Stachys* having species which form tubers, eaten in some European countries *Salvia* species are widely grown because of the showy scarlet flowers, often accompanied by brightly colored bracts The leaves of the Garden sage, *Salvia officinalis*, are used as flavoring for poultry dressing The stamens of *Salvia* species are interestingly modified to insure pollination The filaments are long and arching under the upper lip of the corolla, and so attached that a downward projecting portion stands across the corolla tube Any insect pushing against this projection in order to reach the nectar at the base of the flower causes the filaments to swing down, bringing the anthers against his back, on which the pollen is dusted

After discharge of the pollen from the anther, the style elongates so that the forked stigma is in a position to touch the back of a pollen-laden insect and thus receive pollen, insuring cross-pollination This stamen structure of *Salvia* is almost unique Several species of *Monarda*, native plants of North America, are cultivated for their showy red or pink flowers These plants are variously known as Bee Balm, Horse Balm, Oswego Tea The leaves of some of them are used medicinally

The leaves of *Ocimum basilicum* (basil), *Thymus vulgaris* (thyme), and *Origanum vulgare* (marjoram), as well as *Salvia*, are used for flavoring *Rosamarinus officinalis* gives rosemary oil, *Lavandula vera* and other species, oil of lavender, and *Pogostemon Patchouly*, oil of Patchouli—all these oils being used in making perfumes

Many species of *Mentha* yield valuable **volatile oils**, used in medicine and as flavoring *Mentha Pulegium* is pennyroyal American pennyroyal is another mint, *Hedeoma pulegioides*, yielding a similar oil used as a stimulant and an emmenogogue *Scutellaria lateriflora* contains a volatile oil used as a tonic and anti-spasmodic *Marrubium vulgare*, or horehound, contains a volatile oil used as a treatment for catarrh and chronic infections of the lungs

Certain species of Mints, commonly called nettles, are troublesome weeds, often with strong rank odors Of these two species of *Nepeta* are worthy of note One is *Nepeta Glechoma*, the Gill-over-the-ground, or Ground-ivy, a prostrate trailing vine, freely rooting at the nodes and bearing small deep blue flowers It is often a persistent weed in lawns and gardens The other is *Nepeta Cataria*, Catnip or Catmint, an erect, branching plant with pale bluish flowers and hairy leaves It has a stimulating effect on cats, the dried leaves and stems, sometimes put up in cloth bags, are frequently sold to cat owners (R M W)

MIOCENE. Next to the last **period** in the **Tertiary** subdivision of the **geologic time-scale** Type locality the Paris Basin The term Miocene was first proposed by Lyell in 1832 Miocene sedimentation started approximately 20,000,000 years ago and continued for about 12,000,000 years In the United States the marine formations are best developed on the Pacific Coast, where they reach a maximum thickness of some 21,000 feet There is no distinct evidence of an unconformity between the **Oligocene** and Miocene, but the **paleontological** record shows that the plants and animals of the Miocene are distinctly modern, especially those occurring in the terrestrial deposits which cover a wide area of the Great Plains. There was considerable volcanic activity during this period, as disclosed by beds of volcanic ashes and **andesitic** and **basaltic** lava flows in the John Day Basin and Columbia River Plateau Volcanic **agglomerates** also occur interbedded with ashes and conglomerates in the Yellowstone Park Region The Miocene is also an important period of mountain building, especially in the Alps, Apennines, and Himalayas The plants of this period were similar to modern types, including the grasses, pines, and hard woods (Sumach, Elm, Oak) Most of the **fossil** marine **invertebrates** belong to the same genera living at the present time During the Miocene there was a great development of modern mammals, especially in North and South America The principal and peculiar South American types are Cladosictis (carnivorous **marsupial**), Stegotherium (giant **armadillo**), Propalaeohoplophorus (glyptodont) Hapalops (giant ground **sloth**) The principal North American forms are the primitive types of dogs, horses, camels, antelope, elephants, and rodents The development of grass-covered plains formed a suitable environment for the grazing instead of browsing herbivores Mammalian adaptation is shown in both the tooth and limb structure, as well as in the increased size of the brain For a description of the mineral resources of this period see the Tertiary (R M.F)

MIRA. Mira (omicron Ceti) has the distinction of being the first **variable** star ever announced as such In 1596 the Dutch astronomer Fabricus noticed a star of about the third **magnitude** which had not previously been recorded The star faded within a few weeks, but was again seen and recorded by Bayer in 1603 In 1638 Holwarda, another Dutch astronomer, again observed the star and found that after disappearing it returned to visibility about eleven months later At maximum brightness the star is easily visible to the naked eye, having a magnitude of about 3 5, but at minimum it can be seen only with a telescope of aperture greater than one inch, for its magnitude is only about 9

Many determinations of the period of variability have been made, the time from maximum to maximum averaging about 330 days, with variations between times of successive maxima amounting to as much as one month The diameter of the star is of the order of magnitude of 260,000,000 miles, or large enough to contain the sun and all the members of the **solar system** in their **orbits** out to beyond the planet **Mars** Coupled with the variation in brightness there is also a variation in diameter amounting to about 32,000,000 miles, together with a temperature variation of roughly 500° K (900° F). (W R G)

MIRACIDIUM. Larva.

MIRAGE A curious atmospheric phenomenon caused by the **total reflection** of light at a layer of rarefied air The most familiar manifestation is observed in warm weather on paved highways The air next the pavement becomes heated and rarefied in comparison with that above it, so that at a sufficient angle of incidence, objects beyond the area are mirrored as if by polished silver, giving the almost irresistible impression that one is looking at a layer of water Travelers in hot desert regions are sometimes thus deceived Much more rarely the phenomenon appears in the air at a higher level than the observer In either case the images are inverted, and because of the irregular contour of the air-layer, they are usually distorted A somewhat different effect, known as 'looming," is produced by the refraction of light passing from rarefied air to a lower and denser layer This results in distortion, making distant objects appear grotesquely elongated vertically, or in lifting into view objects beyond the horizon It is most frequently observed at sea (L D W)

MIRRORS AND LENSES. We shall here be chiefly concerned with spherical or plane reflecting and refracting surfaces A spherical mirror may be treated as a one-base zone of a spherical surface, the axis of which is the straight line passing through the center of curvature and the pole of the zone When the diameter of the mirror is small compared with its **radius of curvature**, and when the rays make only small angles with the axis, so that **spherical aberration** may be neglected, such a mirror produces fairly sharp images which are

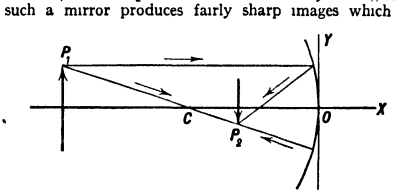


Figure 1 Formation of real image by concave mirror

easily calculated from the laws of **reflection** Taking the pole O as origin and the mirror axis as X-axis (Figure 1), and representing the radius OC by r, the image of a point $P_1(x_1,y_1)$ in the plane XY is the

point P_2 whose coordinates, for either a concave or a convex mirror, are

$$\left.\begin{aligned} x_2 &= \frac{rx_1}{2x_1 - r}, \\ y_2 &= \frac{-ry_1}{2x_1 - r} \end{aligned}\right\} \quad (1)$$

r is + or — according as the mirror is convex or concave If x_2 turns out positive, it means that the image is virtual In Figure 1, r, x_1, and x_2 are all *negative*, as is y_2, so that the image is real and inverted If the incident rays are parallel to the axis, the focus of the reflected rays, called the "focal point" of the mirror, is on the axis at $x = r/2$ For a plane mirror, $r = \infty$ and $x_2 = -x_1, y_2 = y_1$.

Spherical lenses have various combinations of convex, concave, or plane surfaces There is always a point on the axis, called the "optical center," such that if a ray in traversing the lens is in line with this point, the entering and emerging parts of the ray are parallel

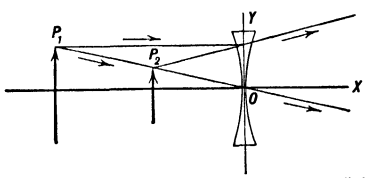


Figure 2 Formation of virtual image by "negative" lens

For a very thin lens this point may be considered at the center of the lens and is a suitable origin (O, Figure 2) If the radii of curvature r_1, r_2 are large compared with the diameter of the lens, and if the refractive index of the lens is n, the equations giving the image of the point x_1, y_1 made by a thin lens are

$$\left.\begin{aligned} x_2 &= \frac{r_1 r_2 x_1}{r_1 r_2 + (n-1)(r_2 - r_1)x_1}, \\ y_2 &= \frac{r_1 r_2 y_1}{r_1 r_2 + (n-1)(r_2 - r_1)x_1} \end{aligned}\right\} \quad (2)$$

r_1 and r_2 refer to the left and right surfaces, respectively, which is the order in which the light encounters them The "focal length" is obtained by letting $x_1 = \infty$ and calculating x_2 from (2), which gives

$$f = \frac{r_1 r_2}{(n-1)(r_2 - r_1)}. \quad (3)$$

This enables us to write (2) in simpler form:

$$\left.\begin{aligned} x_2 &= \frac{fx_1}{f + x_1}, \\ y_2 &= \frac{fy_1}{f + x_1} \end{aligned}\right\} \quad (4)$$

If x_2 turns out negative, the image is virtual, if y_2 is negative, it is inverted For lenses of appreciable thickness or of strong curvature, the calculations are not so simple, and in general there are two unequal focal lengths, depending upon which way the rays pass through the lens

The reciprocal of the focal length of a lens, called its "focal power," is a measure of the converging or diverging effect of the lens It is commonly expressed in "diopters" or reciprocal meters, thus if the focal length is 50 centimeters or ½ meter, the focal power is 2 diopters (L D W)

MISCEGENATION. Reproduction by parents of different races A form of intraspecific **hybridization.** (A W L)

MISFIT STREAM. U-valley.

MISPICKEL. Arsenopyrite.

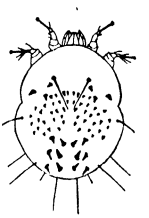
"MISSING LINK." Paleontology of Man.

MISSISSIPPIAN PERIOD. A geologic period in the **Paleozoic** Era Term first proposed by H S. Williams in 1891 Type locality Mississippi Valley The period began about 280 million years and lasted for about 25 million years The term Mississippian is roughly equivalent to the more general term, Lower **Carboniferous.** In Britain, the formations of this system are grouped under the terms **Culm** and **Mountain Limestones,** which, as in the United States, immediately succeed the **Devonian** and are followed by the upper Carboniferous, or **Pennsylvania** System (U S), and Coal Measures (Britain) The formations of this system are chiefly sandstones and shales in the **Appalachian Geosyncline,** representing **delta** and **estuarine** deposits of considerable thickness which pass Westward into thinner **facies** of marine **shales** and **limestones.** In the Rocky Mountain region occur a great thickness of marine Mississippian called, locally, the **Madison Limestone.** The marine life of the Mississippian is chiefly characterized by **echinoderms** and **foraminifera.** Petroleum occurs in the Mississippian formations of Southeastern Ohio, West Virginia, Southeastern Pennsylvania and Eastern Kentucky (R M F)

MISSOURITE. The term proposed by Weed and Pirsson, in 1896, for a **basic, intrusive igneous** rock of **granitic texture** containing an abundance of **pyroxene, olivine** and **leucite** This rock is the deep seated equivalent of leucite **basalt.** Type locality, Highwood Mts, Montana (R M F)

MISTLETOE. Parasitic plants.

MITE. Arachnida, Acarina Minute animals related to the spiders They have a compact body without well marked regions The many species include scavengers and external parasites, many of them serious pests of domestic animals and man



Mite.

The group includes the harvest mites, also called the **chigger** or jigger in the United States, the red **spider,** and numerous species known as mites Among the latter are the scab mites, mange mites, and itch mites which attack animals and man, and the gall mites which live on plants

The forms called fresh-water and salt-water mites are **ticks.** (A W L)

MITOCHONDRIA. Cell.

MITOSIS. Cell division.

MIXED ACID. Mixtures of **nitric acid** and **sulfuric acid** used for nitrating organic substances, such as **glycerol, toluene, phenol,** in the manufacture of **explosives** and **plastics.** A standard acid consists of 36% nitric acid, 61% sulfuric acid and 3% water. (R K S)

MIZAR. Mizar (**Ursae Majoris**) is, perhaps, the most interesting star in the "big dipper" It is probably the first **double star** ever observed The fourth **magnitude** star Alcor forms with it a naked eye double, and Mizar itself has a close companion which is telescopically visible It was the first star observed as double by Riccioli in 1650 Tradition says that observation of the pair Mizar-Alcor was considered a good test of eyesight among the American Indians If this was a difficult pair for them to separate, their eye sight could not have compared very favorably with that of modern times, for it is an easy double for most people

As well as being the first visual double star to be discovered, Mizar also has the distinction of being the first **spectroscopic binary** discovered In 1889 E C Pickering discovered that the **spectral lines** of this star were alternately double and single, a phenomenon which

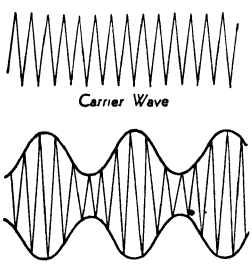
can only be adequately explained if the star is a close binary In 1908 the fainter companion of Mizar and also the more distant, bright companion Alcor were both found to be spectroscopic binaries (W K G)

MOA. Aves, Apterygiformes Giant flightless birds (**Aves**) of New Zealand Now extinct, although they probably existed until about five hundred years ago They are known from skeletons, feathers, dried remains of soft parts, and egg shells The largest moas, *Dinornis maximus*, were about twelve feet tall (A W L)

MOCCASIN. Reptilia, Sauria A name applied to two poisonous snakes of North America, the **copperhead** and the **cottonmouth.** (A W L)

MODE A term used in Iddings and Washington's classification of the **igneous rocks** (1902) for the actual mineral composition expressed quantitatively in percentages by weight As opposed to the chemical composition, expressed in the standard mineral molecules in terms of **oxides**, and called the norm (R M F)

MODULATION. The intelligence transmitted in **radio** or carrier current **telephone** systems goes out as a high frequency wave varied by being modulated with the low **frequency** voice waves The process wherein some characteristic of the carrier wave is varied in accordance with the voice wave, is known as modulation The modulation can be frequency modulation, phase modulation, or amplitude modulation, but amplitude modulation is the only one commercially used to any great extent The frequency of the carrier wave must be well above that of the modulating waves, in fact, it may lie above 10,000 cycles per second in telephony, and several times this in radio broadcasting The most important modulators at the present time are the thermionic tube modulators See **Vacuum Tube, Detection.** (F T M)



Modulation of a high frequency carrier wave by a voice wave

MODULUS OF ELASTICITY. The ratio of the unit **stress** to the unit **deformation** of a structural material is a constant, as long as the unit stress is below the **proportional limit,** and is called the modulus of elasticity See **Ultimate Strength, Proportional Limit.** (C W C)

MOERITHERIUM. Fossil Mammals.

MOHS SCALE Hardness

MOLAR. The broad grinding teeth of mammals, located at the back of each jaw (A W L)

MOLAR SOLUTION. Concentration.

MOLASSES Sugar.

MOLD Phycomycetes.

MOLE. Mammalia Burrowing animals of small size, highly specialized for life underground They have short legs but the front pair are powerful with broad feet and strong claws The eyes are rudimentary and there are no external ears

The true moles of the Palaearctic region belong t the order Insectivora, which also contains the closel related shrew moles and web-footed moles All c these forms are related to the shrews The golden mol of Africa, *Chrysochloris*, are animals of similar form an habits, related to the **tenrecs.**

In the order marsupialia a single rare Australian ani mal adapted for subterranean life is called the pouche mole or **marsupial mole**

The name appears also in the mole voles, mole ra and Cape mole rats, all burrowing animals of the Ol World belonging to the order Rodentia They ar much less extremely adapted than the moles

Mole (or mol) is also a common name for gram molecule (A W L)

MOLE CRICKET. Insecta, Orthoptera Burrowin crickets whose large fore legs give them a superficia resemblance to moles (A W L)

MOLECULAR PUMP. Air Pumps

MOLECULAR RAYS If a narrow opening or sli is made in the wall of an enclosure containing a ga or a vapor, surrounded by a vacuum, those molecule which chance to encounter the opening pass out throug it, a process known as effusion The escaped molecule move in a wide variety of directions But if, instea of a simple slit, we have a succession of similar, paralle slits in plates set one in front of the other, the onl molecules finally emerging will be those whose direc tions of motion are nearly parallel with the commo axis of the slits Such an emergent stream is a bear of "molecular rays" Much study has been devoted i recent years to such beams By heating the enclosure the vapors of metals may be studied in this way T detect a beam of metallic molecular rays, a "target" c very cold glass or porcelain may be interposed for i to condense upon in the form of a visible spot Th motions of the molecules are unidirectional (no colli sions) and their speeds should be in accord with th **Maxwell distribution law;** a point which has been in geniously verified by Eldridge Many studies have bee made possible regarding the properties and behavior o individual molecules, the **Stern-Gerlach experiment** a notable example The importance of this field is ju beginning to be realized (L D W)

MOLECULAR SPECTRA The spectra of sub stances in the molecular state, like **atomic spectra,** ar really made up of lines, though they are much mor complicated The transitions in a molecule which re lease the most energy (largest quanta) are due to elec tron changes, as in atoms, and the results of thes changes are observed as lines in the **ultraviolet** regior But there are other ways in which a molecule can releas or absorb energy Thus the component atoms oscillat with reference to each other within the molecule, an this motion apparently is "quantized," i e, change abruptly from one state to another of different energy (See **Quantum Theory**) But these "vibrational" en ergy changes are much less than the electronic, so tha the resulting quanta and spectrum lines are of muc lower frequency, and appear in the extreme red or nea **infrared** Again, the molecule rotates, and the quan tization of its rotational energy results in the emissio of quanta of still lower frequency, appearing as lines i the far infrared

Atomic spectra (due to electronic transitions) ar characterized by series of lines progressively crowde together toward a "series limit" This is due to a variety of possible transitions of successively greater en ergy The same is true of the changes in molecula rotational energy, but here the differences between th successive quantum energies are so very small and th lines are thus crowded so close together that a whol series of them appears merely as a "band," coming to a sharply defined edge on the low-frequency side and fad ing away gradually on the other side Not only this

but the vibrational and electronic transitions are accompanied by rotational transitions, giving combined spectra which, on account of the close-grained character contributed by the rotational component, is composed of bands like the rotational bands themselves

Thus a molecular spectrum appears as an array of bands instead of distinct lines, but arranged, like lines, in groups and series The study of these bands and their groupings has furnished a surprising amount of information as to the structure and internal mechanism of molecules. (L D W)

MOLECULAR WEIGHTS. Chemical Composition.

MOLECULES. Chemical Composition.

MOLLIER DIAGRAM. The properties of a vapor, as recorded in vapor tables, may be displayed graphically in a number of ways, among which the most used, and probably the most valuable, is the charting upon a plane whose coordinates are enthalpy or total heat and **entropy.** Generally, the total heat is made the ordinate, and entropy the abscissa This chart of the properties of vapor is named the Mollier Diagram, and is of considerable use in tracing both theoretical and actual **expansions** of vapor A throttled expansion on the Mollier Diagram is parallel to the constant heat lines, and **adiabatic** expansion is parallel to the constant entropy lines Pressure, quality or superheat, and total temperature are shown on the Mollier Diagram as series of lines curved and inclined to the axes Thus all characteristics of a vapor except volume may be displayed on the Mollier Diagram. (F T M)

MOLLUSCA. A major division of the animal kingdom containing the **snails, oysters, clams, mussels, squids, octopus, nautilus** and related forms **Mollusks** are the most highly developed of the unsegmented invertebrates and are both diverse in form and numerous in species

The phylum is characterized by the following structures 1 The body is unsegmented 2 A well developed head is found in most species 3 The body bears a ventral muscular protuberance, the foot 4 A fold extends in most species from the dorsal wall, enclosing a cavity associated with respiration The fold is the **mantle** and the cavity the mantle cavity 5 In many species the mantle secretes a shell 6 The **circulatory system** consists of tubular vessels and open spaces, with a **heart** made up of a ventricle and two auricles

Some mollusks are important as food Clams, oysters, and scallops are the most familiar of the edible species but others are eaten Pearls and mother of pearl are also molluscan products

The phylum is divided into the following classes:

Class **Amphineura.** Without a distinct head Shell absent or composed of a series of plates **Chitons.**

Class **Gasteropoda.** With a distinct head Shell absent, conical, or spiral **Snails** and related forms

Class **Scaphopoda.** Head indistinct Shell cylindrical.

Class **Lamellibranchiata** (Pelecypoda) Head indistinct Shell of two lateral parts (bivalve) **Clams, mussels, oysters,** etc

Class **Cephalopoda.** Head distinct, with long tentacles. **Squids, octopus, nautilus,** etc (A W L)

MOLLUSCOIDEA. A name originally applied to a major group of animals including the **Bryozoa** and **Tunicata** and now used by some biologists to include the Bryozoa and the **Brachiopoda.** (See also **Invertebrate Paleontology.**) (A W L)

MOLOCH. Reptilia, Sauria An Australian **lizard** found in arid country It is about eight inches long and resembles the horned toads of the southwestern United States in form, but is covered with stout spines which give it a forbidding appearance Like the horned toads it does not eat readily in captivity (A W L)

MOLPADONIA. Holothuroidea.

MOLYBDENITE. The mineral molybdenite is **sulfide of molybdenum,** MoS_2 Its **hexagonal** crystals are usually tabular to short prismatic, but if in massive form it may be **foliated** or granular Has a perfect basal cleavage, is sectile; hardness, 1-1 5; specific gravity, 4 7-4 8, luster, metallic, color, very slightly bluish, lead gray, streak, greenish gray, opaque Molybdenite is one of the few minerals soft enough to give a distinctly greasy feel Molybdenite is found as a contact mineral with **cassiterite** and **wolframite,** in **granite pegmatites** and sometimes in granites, **syenites,** or **gneisses.** It is found associated with tin ore in Saxony and Bohemia; in Norway, England, Australia, and in the United States in Washington County and Oxford County, Maine, in New Hampshire, Connecticut, Pennsylvania, and Washington Its name is derived from the Greek meaning lead, was formerly applied to minerals containing lead, to graphite and to molybdenite as well Later the term was restricted to the latter mineral It is an ore of molybdenum, and the chief commercial source in the United States is the Climax mine, Colorado (E S C S)

MOLYBDENUM. Symbol: Mo Atomic number: 42 Atomic weight 95 5 Density. 10 2 Melting point 2622° C

Molybdenum is a silver-white, tough, malleable metal softer than glass, not oxidized by air at ordinary temperatures but above 600° C burns to form white molybdenum oxide, dissolved by dilute **nitric acid,** and by **aqua regia,** made passive by concentrated nitric acid, and attacked by fused **alkalis.** Chemically related to **chromium, tungsten** and **uranium** elements. Discovered by Scheele in 1778

The principal use of molybdenum metal is in the production of special alloy tool steels for cutting purposes, 0 2%-0 75% molybdenum imparting marked toughness and hardness at high temperatures

Molybdenum occurs as **molydenite** (molybdenum sulfide, MoS_2), and **wulfenite** (lead molybdate, $PbMoO_4$) Roasting of molybdenite in a current of air yields white crystalline sublimate of trioxide, from which the metal is obtained by reduction with **aluminum** or **carbon** at high temperatures Fusion of the ore with carbon and **sodium** carbonate in a blast furnace yields a sodium molybdate matte from which ferro-molybdenum is made in an electric furnace

Hydroxide molybdenum trihydroxide ($Mo(OH)_3$), brownish black solid, molybdenum tetrahydroxide ($Mo(OH)_4$, possible $MoO(OH)_2$)

Oxides Molybdenum dioxide (MoO_2), brown and sometimes blue solid by reduction of the trioxide or ignition of ammonium molybdate $(NH_4)_2MoO_4$, molybdenum sesquioxide (Mo_2O_3), black solid by the reduction of the trioxide with zinc metal, molybdenum trioxide (MoO_3), white, somewhat volatile, solid, yellow when hot, greenish-yellow after ignition, soluble in alkalis to form molybdates, which form complex compounds with excess trioxide The trioxide is the source to most molybdenum compounds.

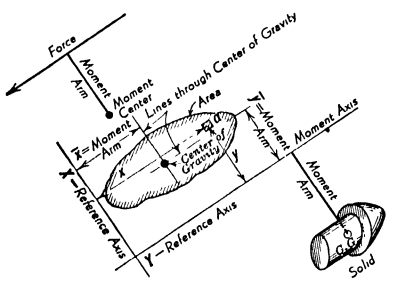
Many reducing agents, e g, **hydrogen, zinc** metal, **tin** metal, **ferrous** salts, **sulfurous acid,** oxides, sucrose react with molybdates usually forming a mixture known as "molybdenum blue" Lower valence forms are readily oxidized to molybdate by ignition or by nitric acid

Ammonium phosphomolybdate, yellow precipitate, of variable composition, and ammonium arsenomolybdate, similar, are important compounds in the identification of **phosphates** and **arsenates** respectively A common test for molybdenum is as follows **Ammonium** phosphate added to a molybdate solution strongly acidified with **nitric acid,** produces a yellow crystalline precipi-

tate Arsenates give the same type of precipitate but arsenic can be eliminated by other tests See **Arsenic.** (R K S)

MOMENT. Moment consists of the product of a quantity and a distance to some significant point connected with that quantity The principal moments are moments of forces, moments of lines, moments of areas, and moments of masses Two types of moments are statical moment and the **moment of inertia.** Unless specifically stated to be otherwise (See **Statics**), the word moment would be taken to mean statical moment A physical picture of moment may be obtained by considering the moment of a **force** (called torque). It is the magnitude of the force multiplied by the moment arm which is a perpendicular dropped from the moment center to the line of action of the force This moment is the turning effect on a body against which the force is applied The moment of an area is the magnitude of the area multiplied by the perpendicular distance from the centroid of the area (center of area) to the axis of moments Similarly the moment of a solid is its weight multiplied by the distance from its center of mass to the axis of moments

The summation of moments of a force enters into one of the three equations of statical equilibrium (See **Statics**) In a case of equilibrium, this summation must always equal zero about any chosen moment center The moment of an area about a line is of use in finding the centroid of an area, since the magnitude of the area multiplied by the distance to a parallel line through the centroid must equal the summation of all the incremental areas multiplied by the perpendicular distances from the



Moments of force, area and mass

centers of these areas to this reference line Thus in the irregular figure shown the distance from the *Y*-reference axis (any convenient line) to a parallel line through the centroid of the figure is determined by summing the elementary moment, i e , ay, and equating the summation to the product of the total area, A, and the centroidal distance $\bar{y}$

$$\bar{y} = \frac{\text{Summation of } ay}{A}$$

In a similar manner the location of a line, through the center of gravity, may be obtained in relation to the *X*-reference axis (any other convenient line not parallel to the *Y*-reference line) That is

$$\bar{x} = \frac{\text{Summation of } ax}{A}.$$

The intersection of these two lines, whose location is given by $\bar{x}$ and $\bar{y}$, is the center of gravity of the area The center of gravity of a solid may be found in a similar manner by the use of three reference axes

The use of the statical moment in finding centroid of areas or masses extends to areas and shapes which are made up of a number of elementary areas or masses whose centroids are common knowledge. Thus a trapezoid could be considered as made up of two triangles and a rectangle, a rivet, of a hemisphere and a cylinder This method is also useful in computing centroids when the outline of the figure is expressed by a mathematical equation, since then the summation of ax and ay may be obtained as definite integrals Cases of irregular figures which would not be analyzable by either of these methods can be treated by graphical means. (F T M)

MOMENT COEFFICIENT. The reaction of air upon an **airfoil** varies with the **angle of attack** both in magnitude and position of its result The moment of the air reaction about some moment center located on the chord and the airfoil is, to a fair degree of approximation, at least, equal to the lift multiplied by the distance to the center of pressure A coefficient which will bear the same relationship to moments as to coefficients of lift and drag to the lift and drag forces,

is obtained by dividing the moment by $\frac{\rho}{2} SV^2c$ ρ is

the mass density of air, S wing area, V air speed, c wing chord The moment coefficient so defined is a constant if the moment center used coincides with the aerodynamic center of the airfoil On most airfoils, this is about one-quarter of the chord back of the leading edge (F T M)

MOMENT OF INERTIA. The moment of inertia of a plane area taken with respect to a line in the plane is the sum of the products obtained by multiplying each elementary area by the square of its distance from the line The moment of inertia with respect to a line at right angles to the area is called the polar moment of inertia It can be shown that this quantity is equal to the sum of the moments of inertia of the area taken with respect to any two mutually perpendicular lines which lie in the plane of the area and intersect the polar axis

The **radius of gyration** is the distance from the axis or reference line at which the total area must be assumed to be concentrated in order that the product of the area and the square of this distance will equal the actual moment of inertia

If the moment of inertia of an area with respect to any axis, which lies in the plane of the area and passes through the center of gravity, is known, the moment of inertia with respect to any other parallel axis may be found from the following formula

$$I = I_0 + Ad^2$$

in which I = Required moment of inertia
I_0 = Moment of inertia referred to the line (called the gravity axis) through the center of gravity
A = Area of surface
d = Perpendicular distance between the parallel lines

The transfer of the polar moment of inertia may be made by means of a similar formula

The analysis of the **stresses** due to bending or the **deflections** in many engineering structures requires the use of the moment of inertia of cross-section areas This quantity is actually a measure of the strength of the body or the resistance to deflection The moment of inertia with respect to a particular line of a cross-section may be changed by varying the disposition of the material in relation to the line (See **I-beam**) Consequently the most effective shape is that which renders the moment of inertia a maximum, provided that this distribution of material does not violate the principles of good design

The moment of inertia of the **mass** of a body with respect to an axis is the sum of the products obtained by multiplying the mass of each individual particle of the body by the square of the distance from the axis.

It represents the force moment or torque required to change the angular speed of the body about the given axis at the rate of one radian per second This quantity involves not only the volume multiplied by the square of distance, but the per unit of volume Following are formulae for the moments of inertia of certain homogeneous solids with respect to the axes specified (M is the mass of the body in each case).

Particle distant r from axis	Mr^2
Sphere of radius R, with respect to any diameter	$\frac{2}{5} MR^2$
Cube of edge L, with respect to axis through center parallel to edge	$\frac{1}{6} ML^2$
Rectangular plate, dimensions $A \times B$, with respect to axis perpendicular to it at center	$\frac{M}{12}(A^2 + B^2)$
Cylinder of length L and radius R, with respect to axis perpendicular to its length at center	$M\left(\frac{L^2}{12} + \frac{R^2}{4}\right)$
Cylinder of radius R, with respect to its own longitudinal axis	$\frac{1}{2}MR^2$
Any body with respect to any axis distant r from the center of mass, the value for a parallel axis through that point being I_0	$I_0 + Mr^2$

Experimental methods of obtaining moments of inertia by the use of a **torsion pendulum** are explained in any laboratory manual of elementary dynamics (C W C, L D W)

MOMENTUM. The momentum of a body is the product of its mass and linear velocity, while the moment of momentum (or angular momentum) of a body is the product of its moment of inertia and angular velocity Thus linear momentum is MV, and angular momentum is $I\omega$ Momentum is a vector quantity, its direction being that of the velocity Because of the relation of momentum to force as set forth in the second of Newton's laws, this is a fundamental concept of dynamics

A body tends to continue unchanged in momentum unless acted upon by external forces such as applied working forces, resistance, friction or air drag The force F acting on a body for t seconds alters its momentum by Ft The product Ft is known as the impulse, with a free body equal to change of momentum In rotation, the corresponding quantity is the moment of impulse, that is, the product of the time by the applied torque or force moment

M = mass
I = moment of inertia
ω = angular velocity

One of the consequences of Newtonian dynamics is the principle of conservation of momentum This states, in effect, that no operation of forces between the bodies in a system can change the momentum of the system as a whole, which is the vector sum of the momenta of its particles As a simple example, take the collision of two balls They may have very different velocities before and after the encounter, but their resultant momentum is the same, and this is true whether they collide "head on," or one overtakes the other, or one is at rest and is struck by the other, also whether they are moving in the same or in different lines In the event of a collision or other suddenly applied force, the change of momentum resulting is the measure of the impulse, defined above This is well illustrated by the impulse given to a croquet ball when another ball in contact with it is held by the foot and struck with the mallet. (F T.M., L.D W)

MONADNOCK. **Peneplain.**

MONAL. Aves, Galliformes Brightly colored **pheasants** of several species found in the higher forests of the mountains of Asia (A W L)

MONAZITE The mineral monazite is essentially a **phosphate** of the rare-earth metal **cerium,** $CePO_4$, but other rare-earth metals are usually present. So constant is the presence of **thorium** that monazite is the chief source of thorium dioxide It is **monoclinic,** but found ordinarily as translucent yellow to brown grains with a resinous luster, often as sand Its hardness is 5-5 5, specific gravity, 4 9-5 3 Monazite is found in **granites, pegmatites** and similar rocks, but rarely in any concentration The commercial deposits are residual sands The Ilmen Mts in Russia, Norway, India, Madagascar, South Africa and Brazil are well known for their monazite deposits In the United States monazite is known from Connecticut, New York, Virginia, North Carolina and Idaho Monazite derives its name from the Greek word meaning solitary, in reference to the relative rarity of this mineral (E S C S)

MONCHIQUITE. The term proposed by Rosenbuch and Hunter, in 1890, for a **basic microcrystalline** or **porphyritic dike** rock composed chiefly of **femic** minerals with little or no **feldspar,** in a matrix of **analcite.** Accessory minerals may be **olivine, nepheline** and **leucite.** (R M F)

MONEL METAL. **Alloys.**

MONGOOSE, MUNGOOSE. Mammalia, Carnivora Slender animals with short legs and a long tail, related to the civets but without scent glands They live in Africa and the Oriental region and have been introduced successfully into the West Indies and other regions Mongooses kill many small animals and are valuable for destroying rats and other vermin They are particularly noted for their ability to kill snakes, including the poisonous species The India mongoose, *Herpestes mungo,* is readily tamed and is often kept to free premises of undesirable pests

The Egyptian mongoose, *H ichneumon,* is also called the ichneumon (A W L)

MONKEY. Mammalia, Primates A name applied to most members of the order excepting the man-like **apes** and the **lemurs** It is not as accurately defined as the names of the various kinds of monkeys but in general monkeys differ from the other forms in the possession of nails on all fingers and toes and in their long tails Apes, some **baboons,** and a few monkeys have short tails or none, the **marmosets** have claws except on the great toe, and the lemurs and related forms have claws on at least one digit

The monkeys of the New World form a well marked group constituting the family Cebidae, characterized by the widely separated nostrils, the non-opposable thumb, and the usually long and prehensile tail All of them inhabit the tropical forests of South and Central America

The family includes monkeys of several types These are the woolly monkeys, woolly spider monkeys, spider monkeys, and squirrel monkeys, and under distinctive names the sapajous or capuchin monkeys, the douroucolis, titis, sakis, uakaris, and howlers

The Old World monkeys, including the baboons, make up the family Cercopithecidae, characterized by the thin septum of the nose, the usually opposable thumb, and the lack of a prehensile tail They occur in Africa and the Oriental region and one species, the Barbary ape, is established at Gibraltar

This family includes, in addition to the baboons, the **langurs, guenons, mangabeys, macaques,** the peculiar

proboscis monkey, the black ape and gelada baboon, and the African thumbless monkeys (A W L)

MONOCHROMATIC ILLUMINATOR. An instrument used to supply a beam of light having some desired, narrow range of wave lengths, sometimes called "monochromator" The common form resembles a prism spectroscope White light, entering the fixed **collimator** as usual through a narrow slit, is dispersed by a special, four-sided prism after one internal total reflection (see figure) The image of the resulting **spectrum** falls on a metal plate, and a second, fixed, narrow slit in this plate allows light of approximately only a single wave length to emerge The purity of this beam depends upon the narrowness of the two slits The prism is mounted so that it can be rotated by a tangent screw, thus bringing different parts of the spectrum to the second slit as desired The tangent screw may be provided with a graduated head reading directly in wave lengths, but too much reliance must not be placed on the indications, since the adjustment is affected by fluctuations of temperature For **ultraviolet** or **infrared** radiations the prism and lenses must be of materials other than glass, or mirrors may be used instead of lenses (L D W)

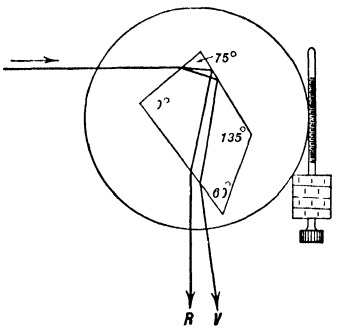


Diagram of dispersing prism and micrometer tangent screw of monochromator

MONOCLINE If horizontal or slightly inclined beds or stratified formations change their **dip** by increasing their steepness of inclination and then flatten out or resume their normal gentle dip, such a structure is called a monocline Monoclinical folds may pass into faults. (R M F)

MONOCLINIC SYSTEM. Crystallography.

MONOCOQUE Monocque refers to a type of construction which is in the nature of a shell, the skin of which is stressed A simple form of monocoque structure is a large thin walled tube subjected to transverse load The monocoque construction has gained considerable prominence in recent years because it has been used in the construction of **aircraft,** particularly the large all-metal transports The true monocoque construction has not been used, since it has been found necessary to provide some reinforcement in the form of bulkheads, stringers, diaphragms, etc, because of the thin skin employed This construction is more properly referred to as semi-monocoque Cost, weight, and serviceability are in favor of stressed skin construction for large aircraft Semi-monocoque construction is used for a great many fuselages, some of which are plywood, but most of which are duralumin

The skin of a monocoque structure may fail by wrinkling or buckling Corrugations and stiffening angles are incorporated to hold down local failure until the desired strength is developed in the skin One of the difficulties of a monocoque structure is the transmission of concentrated loads to the skin If there are many of these concentrated loads, they may require fittings of excessively large weight The perfect type of fitting for taking applied loads on a monocoque structure is a solid bulkhead filling the cross-section at the point of application of the load Solid bulkheads, however, not only add weight unduly, but may be in the way of equipment which is to be mounted inside the structure There is some possibility of reducing the weight by skeletonizing the bulkhead, or by distributing the concentrated load over a sufficiently large skin area by means of local strengthening of the skin at the point of application of the load In a general way, the monocoque structure may be analyzed by the principles of structural analysis, and details may be worked out on the same basis A monocoque airplane fuselage offers several impediments to full statical analysis, and the ultimate strength is not readily found except by testing a full scale structure (F T M)

MONOCOTYLEDONS. One of the two subclasses of the **angiosperms,** containing about 25,000 species, many of which are of the greatest value to man All the **cereal grains** and other grasses belong in this subclass **Bananas, pineapples** and **palms** are tropical monocotyledons Many monocotyledons are widely cultivated for their beautiful flowers Among these are lilies, cannas, irises, and **orchids.**

Certain features are characteristic of plants of this subclass, distinguishing them from the **dicotyledons.** The stems show secondary growth only in a very few monocotyledons The vascular bundles are usually scattered irregularly in the ground tissue of the stem The leaves are typically parallel-veined, that is, the several main veins run parallel to one another from the base of the leaf to its tip The parts of the flowers are generally in multiples of three, that is, there are three **sepals,** three **petals,** three (or six) **stamens,** and a compound **pistil** composed of three **carpels** The **embryo** of the **seed** is quite unlike that of dicotyledons, having a single seed leaf or cotyledon In many species this cotyledon is greatly modified, becoming an absorbing organ which never emerges from the seed during germination

Almost all the monocotyledons are herbaceous plants of small size A few, such as certain species of *Yucca,* **bamboo,** and the **palms,** become tree-like Some of the palms have stems 50–100 feet tall

The majority of the monocotyledons are perennial plants which seem well fitted to survive in competition with other plants (See also **Paleobotany**) (R M W)

MONODELPHIA. Mammalia.

MONOECIOUS PLANTS. The flowers of many plants are unisexual, that is, they contain only **stamens** or **pistils,** but not both When these two kinds of flowers are borne on the same plant, the plant is said to be monoecious Familiar monoecious plants are oaks, corn, squash, begonia, and castor beans The corresponding zoological term is hermaphrodite (R M W)

MONOGONONTA Rotatoria.

MONOMANIA. Insanity confined to a single subject or to a group of related subjects (R S M)

MONOPISTHOCOTYLINEA. Trematoda.

MONOPISTHODISCINEA. Trematoda.

MONOSACCHARIDES Carbohydrates

MONOTOCARDIA. Gasteropoda.

MONOTREMATA. The egg-laying mammals. A primitive order containing only the duck-billed **platypus** and the **spiny anteaters** of the Australian region (A W L)

MONSTER. An abnormal individual A sport Departure from the normal range of variation of the species which does not breed true

Monsters occur in a small percentage of animals as a result of accidents during embryonic development In man and other mammals they include two-headed individuals, one-eyed individuals, and various degrees of duplication in the body up to Siamese twinning Some of them are presumably due to hereditary factors although the conditions surrounding the embryo may be responsible The latter cause is especially evident among the invertebrates, where experimental modification of the environment during development may cause monstrosities to appear (A.W L)

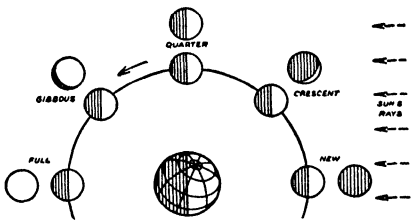
MONTH Originally the term month was used to indicate the period of time required for the **moon** to pass from some particular phase (i e, full moon) back to the same phase again Astronomically the term is used to indicate the period of revolution of the moon from any reference point back to that reference point again The sidereal month is the time it takes the moon to make one revolution from a given star back to the same star again as seen from the center of the earth It averages $27^d\,32166$ (mean solar days) but it varies approximately seven hours on account of **perturbations.** From the purely mechanical point of view this is the true revolution period of the moon The synodic month is the period described above (i e, the period between successive full moons) and averages $29^d\,53059$ varying by more than thirteen hours principally because of eccentricities in the moon's **orbit** Other types of month which are in use with their average lengths in days are Tropical (from one celestial **longitude** back to the same again) $27^d\,32156$, Nodical (from one **node** back to the same) $27^d\,21222$, Anomalistic (from some point in orbit back to same) $27^d\,55460$, and Solar (1/12 of a tropical **year**) $30^d\,43685$ (W K G)

MONUMENT (Geologic Term) **Cirque.**

MONZONITE. A deep seated granular **igneous** rock composed of equal amounts of **orthoclase** and **plagioclase feldspars** together with **hornblende, augite** or biotite as accessories The name is derived from Monzoni in Tyrol It may be considered as a variety of **diorite.** (E S C S)

MOON. (C f tables of satellite data, page 982) The moon, the **satellite** of the earth, is, next to the sun, the most conspicuous of all of the astronomical objects In spite of its apparent brightness and the fact that it has been the subject of countless legends and superstitions throughout the existence of mankind, the moon is in reality a small and unimportant member of the vast universe of celestial objects

The physical and orbital data regarding the moon will be found in the tables of satellites of the solar system (page 982), and we shall limit ourselves to the peculiar features of this, our closest neighbor in space All observational evidence and theoretical calculations point to the fact that the moon is devoid of any **atmosphere.** Its distance from the sun averages, over a period of time, the same as the distance of the earth from the sun with the result that the moon will receive the same amount of heat as does the earth Knowing the reflecting power of the moon we can calculate the surface temperature of the moon It is found that at noon on the moon the temperature is approximately 400° K (261° F), while at midnight, the temperature falls to about 120° K (— 243° F) These calculated values have been verified observationally. Such extremes of temperature coupled with the lack of atmosphere preclude the possibility of there being on the moon any form of life such as we know it on the earth.



The phases of the Moon The outer figures show the phases as seen from the earth

Probably the most strikingly interesting characteristic of the moon, as seen by the average observer without a telescope, is the so-called **phase change.** The moon shines solely by reflected sunlight and the phase changes can best be understood by reference to the accompanying figure on which the names of the various phases are given It should be noted that at the time of new moon the dark side of the moon is toward the earth and the moon is invisible, in fact it is a safe statement to make that no one has ever seen a strictly "new" moon, except possibly at the time of a solar **eclipse** It should further be noted that the illuminated side of the moon is always toward the sun so that, against a dark sky, the horns of the crescent always point away from the horizon The various weather proverbs connected with "the moon pouring water," etc, are entirely without foundation The angle which the line connecting the horns of the crescent makes with the horizon depends entirely upon the relative positions of the earth, sun and moon and has no connection whatever with the weather

At the time when the moon is slightly beyond new phase, and appears as a thin crescent in the western sky, the earth, as seen from the moon, is practically in full phase That part of the moon which is not illuminated by direct sunlight is lighted by "earthlight" and is visible as "the old moon in the new moon's arms" The apparent difference in size between the sunlit crescent and the earthlit moon is an optical illusion due to the fact that a brighter object always appears larger than a fainter one

The moon rotates on its axis in the same direction that the earth rotates, and in the same direction that the moon revolves about the earth This means that the moon keeps approximately the same face toward the earth at all times Hence, at periods of full moon we always see the face of the "man in the moon" and never the back of his head However, due to effects known as **librations,** the moon apparently rocks slightly in all directions As a result of these librations, about 41% of the moon's surface is always visible from the earth, about 41% has never been observed from the earth, and the remaining 18% is invisible or visible, depending upon the particular time of observation and position of the observer on the surface of the earth

The study of the surface geography of the moon, or selenography, has been carried on ever since the invention of the telescope and that portion of the surface which is visible to the earth has been very carefully mapped From the reflecting power of the surface and the characteristics of the reflected light we find that the surface is composed of a brownish yellow rock Much of the lunar nomenclature was developed two or three centuries ago and the descriptive terms are unfortunate For example, the so-called seas, which are the most conspicuous features in a small telescope, and go to make up the imaginative figures of the "man," the "lady,"

the "crab's claw," etc, to the naked eye, are in reality broad flat plains In addition to these plains we find mountain ranges with peaks comparable in height to the highest peaks on the earth, rills, or cracks in the surface as much as half a mile wide and of undetermined depth, rays, or bright streaks radiating out from certain points on the surface, and the so-called lunar craters

Certainly the most remarkable of all of the surface features are the so-called craters In accordance with a system of lunar nomenclature first introduced in the middle of the 17th century by Riccioli these craters bear the names of distinguished scientists and philosophers The craters have a generally circular form, with high mountain ranges rising abruptly from the surface of the moon and frequently with an isolated peak near the center There are over 30,000 of these craters ranging in size from great walled plains with diameters of nearly 150 miles down to small craterlets 1000 feet or less in diameter In some cases the floors of the craters are depressed below the surrounding surface of the moon, while in others the floors are elevated The surface of the plain inside the walls is very rough in some cases and very smooth in others

There is no complete theory to account for all of the lunar surface features The plains, and large mountain ranges may be accounted for on the same theories as those which explain the major geologic features of the earth, but the craters have not thus far been explained There are two main theories for the origin of the lunar craters the volcanic and the meteoric Of these the volcanic is the older and is the theory which gave rise to the name "crater" for these features The chief objective to this theory is the great difference in size between the explosive volcanoes on the earth, such as Vesuvius, which do not exceed a few miles in diameter, and the great walled plains on the surface of the moon The meteoric theory was advanced during the latter half of the 19th century and was revived about twenty-five years ago Airplane photographs of craters produced on the surface of the earth by bombs bear striking resemblance to the appearance of the lunar formations Also, there are several meteoric craters on the surface of the earth, notably the great crater near Winslow, Arizona However, the tremendous size of the lunar craters as compared with similar features on the earth appears as an almost insurmountable objection

Throughout the ages much has been written and said regarding the influences of the moon on mankind, and upon the weather Practically all of these influences are purely imaginative and the various proverbs relative to the proper time for planting corn, etc, may be relegated to the field of pure superstition The theory that the first frost of the fall always occurs during the "bright of the moon" may be readily explained by the fact that the first frost will occur on a night when the sky is clear, with a correspondingly high rate of radiation from the surface of the earth, and on clear nights the moon frequently is bright The amount of energy which the earth receives from the full moon is only about 1/500,000 part as much as is received from the sun, and hence it is obvious that any lunar effects on climate must be negligible The moon is, however, the dominant factor in the production of **tides** and through this medium exerts a powerful influence on commerce, and may, indirectly, produce some effects on weather conditions near the coast There is also some slight, but distinct relationship between the changes in distance of the moon from the earth and terrestrial **magnetism.** (W K G)

MOONEYE. Pisces, Teleostei Moderately large fishes (**Pisces**) of several species found in rivers and lakes of eastern and central North America One species is also called the silver bass, *Hiodon tergisus* They are not valuable as food (A W L)

MOONSTONE. **Feldspar.**

MOORHEN Aves, Gruiformes An English name loosely applied to **gallinules** and related species (A W L)

MOOSE. Mammalia, Artiodactyla A large **deer** with a broad muzzle, prehensile upper lip, and high shoulders. The male has broad palmate antlers Two species occur in North America, one, *Alces americana*, ranging over the northern United States and Canada and the other in Alaska The European species, closely related to the common species of North America, is called the **elk.** (A W L)

MORAINE. The general term for debris of all sorts originally transported by glaciers or ice sheet long since melted away The following are commonly recognized types of moraines **Lateral moraines, Medial moraines, Terminal moraines, Recessional moraines, Interlobate moraines** and the **Ground moraines.** (R M F)

MORBIDITY. (1) Condition of being sick or diseased (2) The sickness rate or ratio to disease and health in a city or community (R S M)

MORDANT. A substance which unites with a dyestuff to form an insoluble compound which colors materials permanently (See **Dyes.**) (R M W)

MOREPORK Aves A name applied in New Zealand to a species of **owl** and in Tasmania to a **nightjar.** (A W L)

MORGANITE. **Beryl.**

MORIBUND. The state bordering on death (R S M)

MORMON CRICKET. Insecta, Orthoptera A large wingless long-horned **grasshopper** of the western United States It varies in color from pale green or yellow to black It eats vegetation of all kinds and is a cannibal and scavenger, even eating dead animals When abundant it is a serious crop pest and one which is difficult to combat (A W I)

MORMYR. Pisces, Teleostei Peculiar African fresh water fishes (**Aves**) They vary greatly in form but many have the jaws prolonged into a snout Family Mormyridae (A W L)

MORNING GLORY. **Sweet Potato.**

MORNING SICKNESS Nausea and vomiting which commonly occurs in the first few months of **pregnancy** It is called morning sickness because it occurs upon rising (R S M)

MORPHINE. This is probably the most valuable drug in medicine It is the chief and most powerful of the **alkaloids** of **opium,** occurring as colorless shining crystals It is usually given as one of the salts of morphine In this form it is most soluble Morphine is given by mouth, hypodermic and less frequently by rectum and intravenously Medically, morphine is the one drug that best overcomes severe pain and brings on sleep Perception is dulled and anxiety and apprehension disappear In **hemorrhage, cardiac failure,** surgical shock, and following traumatic accidents morphine in adequate dosage is life saving It is much used following operations for peritonitis, as it keeps the patient quiet and lessens intestinal activity It is valuable in allaying spasmodic coughing states

While morphine is a boon to suffering, morphine indulgence or addiction is a curse Its use among addicts is based on the same psychic need as is found in alcoholism, the inability to face life's problems or misfortunes or one's own inadequacy. While heroin addicts are usually young, the morphine addicts are as a rule older,—chiefly because morphine brings forgetfulness

from sorrow, sad memories and defeats of the past. Not infrequently patients who suffer continuous unbearable pain become addicts from its constant medical use They, of course, differ from the psychologic addicts and the habit is broken after the need is past The early signs of addiction are selfishness, carelessness and changes in personality Indifference and forgetfulness become more marked as the doses of morphine are increased, because of the developing tolerance to the smaller doses Initiative becomes increasingly less and the addict will often remain in bed for long periods simply because he lacks the will power to move When a habit of long standing, sleep is interfered with and hallucinations may be present Most women addicts are made sterile by the continued use of morphine Children when born of "addict mothers" are normal after they are freed from the habit which is present in them at birth Such infants will die shortly after birth unless small doses of morphine are administered Sudden withdrawal of morphine from an addict produces marked symptoms These symptoms are usually restlessness, watering of the eyes, dull drawn facial expression, trembling, vomiting, intense abdominal pain, and a sensation of burning and tearing in the muscles and joints results Patients in this state may become maniacal, will commit any crime and go to any lengths to get the drug Without the drug some of these patients will actually die

The curing of a "psychologic addict" is difficult Unless the inadequate personality can be compensated by other means or the original psychologic unbalance, which forced the patient to take the drug, can be corrected, he will return to addiction as soon as possible (R S M)

MORPHOLOGY The division of biological science which deals with structure Due to the ease and accuracy with which structural differences can be recognized they have always served as the prime means of recognizing both animals and plants and have consequently served as the most useful basis for **taxonomy.** In other fields of biology, such as embryology, histology, cytology and anatomy the first studies were morphological descriptions, followed later by investigations of function (A W L)

MORTALITY. The total deaths in a population Usually expressed as a mortality rate of so many deaths per thousand of population It is a fundamental factor in studies of population development Maintenance of a normal population depends upon the birth rate being sufficient to balance the mortality or death rate, and all factors tending to influence the reproduction of animals or their destruction influence this balance (A W L)

MORTAR Mortar is the material which is used to bind together the stone or brick of **masonry** construction Mortar is mixed wet to a plastic state, spread upon the brick to a thickness of from ¼ to ½ inch, and the next course of brick pressed into it The material of mortar hardens in a short time, firmly locking the bricks or stone together in a solid masonry structure Ordinary mortar consists of a cementing agent and a filler Lime, sand, and cement are the materials from which mortar is usually made The mortar plays no small part in masonry construction, since one cubic yard of brick masonry, requiring approximately 500 bricks, will take from ¼ to ⅓ of a cubic yard of mortar (See **Calcium**; and **Cement**)

A test comparison of lime and cement mortars show the latter to be much stronger However, cement and sand mortar does not work easily under a trowel, and lime paste, made by slaking lime with water, is added to render the mortar more easily worked This does not materially impair the strength In earlier days, a great deal of masonry was laid in mortar consisting entirely of lime and sand The proportions of Portland cement, lime, and sand used in brick construction nowadays is approximately in the volumetric ratio of 1 1 6.

The use of mortar is not confined to masonry, for the mixture used to plaster interior walls, or to stucco exterior walls is called mortar when in the state ready for application by workmen Plaster mortar consists of lime and sand, with fiber or hair as a binder Such mortars are usually applied in two or more layers, the "scratch" coat being a sand and lime mixture applied directly to lath or other base, and which forms the backing for a thin surface coating made of lime paste to which is added a certain amount of plaster of Paris to give a hard-surfaced finish The finish coat may also be lime and fine sand, in which case it is known as sand finish Pigments may be added to the sand finish coating in order to give desired coloration The thickness of the finish coat is very thin compared to the scratch coat Stucco is applied to brick, stone, wood or metal lath, and is made of cement, lime, and sand It is applied in two or three coats, the exterior coat being colored with mineral colors not affected by the cement, lime, or weather Colored sands usually give better results than the addition of pigments It is customary for the surface coat of stucco to be left rough, as the appearance is much superior to a troweled finish (F T M)

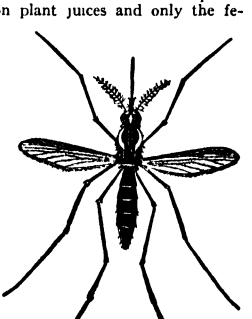
MOSAIC VISION. A theoretical interpretation of the action of compound **eyes** of **arthropods** Each visual unit (ommatidium) of such an eye forms an image of part of the object toward which it is directed and the total image seen by the animal is supposed to be composed of many such partial images formed by the many units in the eye This type of vision is supposed to be inferior to that of other kinds of eyes in the sharpness of the image perceived but to be extremely sensitive to motion (A W L)

MOSASAUR Fossil Reptiles.

MOSELEY'S LAW. X-Ray Spectra.

MOSQUITO. Insecta, Diptera A small two-winged **fly** with slender body, long legs, and narrow wings bearing scales along the veins The **larvae** are aquatic Male mosquitoes feed on plant juices and only the females suck blood, but in some species neither sex sucks blood

Mosquitoes are well known as a nuisance and in warmer climates they are also dangerous because some species transmit disease **Malarial** parasites are carried by mosquitoes of the genus *Anopheles* and **yellow fever** by species of *Aedes* In regions where these diseases occur the destruction of mosquitoes by draining swampy areas where they may breed, and by applying oil to water that cannot be drained, is important The protection of patients from the attack of mosquitoes so that the disease cannot be carried to others is accomplished by adequate screening, a measure which is valuable both for comfort and safety in all dwellings (A W L)



Yellow fever mosquito, *Stegomyia fasciata* (Howard, F B, U S Dept of Agriculture)

MOSS AGATE. Agate.

MOSSES. Bryophytes.

MOTH. Insecta, Lepidoptera. **Insects** with the four wings at least partly scaly, the mouth parts formed for sucking, and the antennae rarely clubbed near the tips. No one character serves to distinguish all moths from the butterflies and skippers. Most moths are nocturnal but many are diurnal or **crepuscular.** Most of them have the antennae slender and tapering or broadened by **setae** or by processes from the segments, forming a comblike (pectinate) structure, but a few have an expansion just before the tip like that found in most skippers. Most of the caterpillars of moths pupate in a cocoon or a subterranean cell or in the tissues of plants but a few form a brightly colored naked **pupa** like those of the butterflies. The term does not apply to a principal division of the order but includes many families making up one entire suborder and most of the second. (A.W.L.)

MOTHER. The female parent. Also applied to any unit which gives rise to others, as mother cell, mother colony, etc. (A.W.L.)

MOTHER OF PEARL. The smooth lining of the shells of **mollusks,** consisting of calcareous and organic matter, usually iridescent and sometimes brightly colored. Also called nacre.

A large amount of mother of pearl is used commercially for pearl buttons, knife handles, etc. For such uses it forms only the exposed surface, with a variable thickness of the middle layer of the shell beneath. Blister pearls are protuberances cut from shells and true pearls are of the same material, deposited about some foreign particle which irritated the animal. (A.W.L.)

MOTMOT. Aves, Coraciiformes. *Momotus.* Birds (**Aves**) with a long tail and serrated beak, found in Mexico, Central and South America. Several species are reported to nest in burrows in the banks of streams. (A.W.L.)

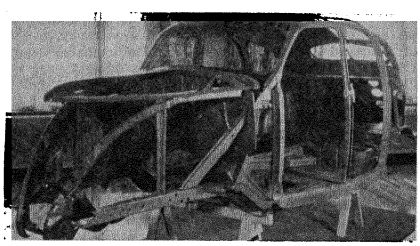
MOTOR. Electric Motor, and articles immediately preceding; also **Internal Combustion Engine; Diesel Engine; Otto Cycle Engine.**

MOTOR VEHICLE. By motor vehicle is designated that class of road vehicles, employed generally on the public highways, which serve some useful purpose, such as the carrying of passengers or freight, and which are propelled by a **motor** which is an in-built part of the vehicle. A survey of the motor vehicles in operation at present reveals that there are principally three types, the passenger car, or automobile; the motor coach, or bus; and the motor truck. Almost without exception, these are propelled by **internal combustion engines,** of which the bulk are of the **Otto cycle** type, the remainder operating on the **Diesel** cycle. The application of the engine to propulsion of road vehicles was experimented with during the latter part of the nineteenth century, and the industry might be said to have been born commercially in the ten years centered around the turn of the century. In the United States, Duryea and Haynes introduced the gasoline-engined antomobile to the American public. By 1905, several manufacturers were regularly producing automobiles, and five years later they were being turned out by factories which embodied the essentials of the present quantity production methods. The American system of automotive building tended to crowd out the many small independent builders, and the decade from 1915 to 1925 saw consolidations and eliminations which greatly reduced the number of bona fide automobile manufacturers. This period also saw the change from an automobile which was principally an assembly of independent manufacturers' parts into a machine which was largely manufactured, fabricated, and assembled under one management.

The principal parts of an automobile are:

1. Frame.
   Steel frame of channel, I-beam, or tubular members, mainly located in horizontal plane and providing rigidity by beam action principally. The other elements are assembled on this frame.
2. Running gear.
   Wheels.
   Axles.
   Springs.
   Brakes.
   Steering device.
3. Propulsion.
   Engine and clutch.
   Change speed gears.
   Drive shaft.
4. Body.
   Including upholstery, glazing, doors, and interior fitting.
5. Accessories and auxiliaries.
   Radiator.
   Fuel tank.
   Defroster, etc.

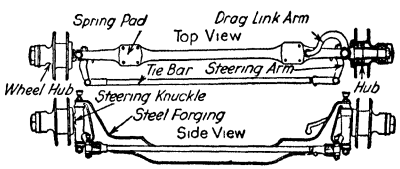
Until very recently, there had been no questioning of the suitability of the method of construction involving the building of a rigid underframe to which the other elements of the motor vehicle were attached by bolting or riveting. Nevertheless, with design of the motor vehicle, principally the automobile, emerging from an earlier formative stage into one where more emphasis can be placed on scientific design and research, the desirability of an underframe construction for the high-speed automobile is open to debate. It has been established that a truss construction, wherein the truss members are located in the side walls of the body, is productive of a greater degree of the right sort of rigidity than is an underframe, and at the same time, is lighter. In motor coach construction, especially where there is more emphasis upon reduction of deadweight, and where the service conditions are particularly severe, the so-called chassisless construction, in which the trussing is incorporated in the body, has found favor with designers.



Trussed-frame body construction.

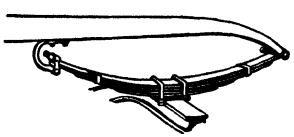
The running gear, which is assembled to the frame, is commonly of a four-wheel type, the wheels having typically a tread of about 54 inches, and a wheelbase of 110 to 130 inches. The overall length of an automobile, bumper to bumper, may often exceed the wheelbase by as much as 30% of the latter. Almost from the inception of the automobile, the pneumatic tire, having an outer casing and an inner air-tight tube, both being founded on rubber as the material, has been standard. These have, however, been built in a wide variety of sizes, many of which were unnecessary and tended to increase the tire cost to the user. There is, however, some standardization among the larger producers of modern and low-priced cars, upon the 16-inch tire, that is, the tire which will be mounted on a rim 16 inches in diameter. **Brakes** are applied by internal expanding

shoes faced with suitable material, which bear upon drums rigidly fixed to the wheel These brakes are actuated either mechanically by cables and jointed rods, or hydraulically by oil pressure acting against the piston, whose movement is carried mechanically to the brake-shoe cams Early automobiles were often steered by a tiller, but with increasing road speeds, it was soon found that the most suitable steering mechanism was a wheel, arranged in a position comfortable to the driver In the United States, this position is founded on the driver's occupying the forward and left-hand seat in the automobile The principal requirements of the steering device are, first of all, reliability, secondly, freedom from road shocks, and thirdly, ease of manipulation The automobile builders soon found that the bolster and kingpin steering, which was suitable with horse-drawn



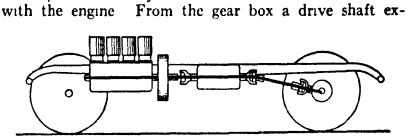
Front-axle showing steering knuckle

vehicles, had to be abandoned in favor of steering knuckles, by means of which the wheels are fastened to yokes at the ends of a fixed axle The pneumatic tire, backed up by spring shock absorbers in the steering mechanism and an irreversible gear connection between the hand wheel and steering mechanism, combine to take the road shock from the steering wheels At the


Semi elliptical spring

same time this incorporates a reduction ratio so that the full swing of the road wheels is accomplished only through several turns of the steering wheel

The automobile engine is fairly well standardized today on six- and eight-cylinder gasoline engines, arranged either in line or as a V These engines are characterized by **poppet valves**, pressure oil **lubrication**, **water cooling**, **carburetion**, and high-tension spark plug **ignition** The engine and clutch are usually built as a unit, to which the change speed gear box is attached, so intimately that in effect it becomes a unit with the engine From the gear box a drive shaft ex-


Method of drive.

tends to the rear axle and transmits the power as a **torque** Although each new year sees improvements in automobile engines, these are chiefly an aggregate of small refinements New designs endeavor to increase efficiency or output, to reduce size or weight, to promote quieter, smoother operation, and to increase life or decrease maintenance The automobile industry is viewing, and has for some time been cognizant of, the possibility that the **Diesel** engine may prove as suitable or even more desirable than the gasoline engine for the propulsion of motor vehicles It seems entirely possible that these two engines may both prove suitable for the automotive field, and that certain combinations of circumstances will point to the selection of one of them where other circumstances might indicate the alternative engine The overall operating thermal efficiency of the automobile is very low It is lower than the efficiencies one customarily associates with the **Otto cycle**, because public demand for performance has led to the creation of automobiles whose engines customarily operate at part load, under which conditions the Otto engine efficiency is penalized Also, in addition to mechanical friction of the drive and running gear, the automobile engine must furnish an ever-increasing amount of electrical power for the operation of the electrical accessories, i e , lights, horn, defrosters, cigarette lighters, radio, etc The power required to propel has increased with the demands for higher speed operation While these might have been offset by proper streamlining, the public mind changes very slowly, and since true streamlining involves radical changes in the conventionally styled car, designers have had to produce the higher speed by engines of greater power These conditions have led to this situation Although refinements of engine design have increased their efficiency, the demands for higher peak powers and the auxiliary services have so offset these engine refinements that the mileage achieved per gallon of fuel has remained substantially constant for many years

Engineers could in a very short time produce a design which would, to a mind unprejudiced by many years of conventional car shapes, appear eminently suitable as a road vehicle Furthermore, this vehicle would not be any slower, although it would consume only about half as much fuel per mile traveled as the current models It would be more comfortable and just as safe But, unfortunately, it would require altogether different styling, and such radical changes as engine in rear, chassis-less construction, and others While these developments are expected to be consummated with time, the fact that the motor vehicle is the personal possession of a large part of the American public, coupled with the slowness of a large population to change its preconceived ideas, prevents any immediate attainment of the technically proven and technically desirable See also **Axle**, **Brakes**, **Bus Carburetion**, **Clutch**, **Detonation**, **Diesel Engine**, **Differential**, **Highways**, **Ignition System**, **Internal Combustion Engine**, **Otto Engine** (F T M)

MOUFLON. Mammalia, Artiodactyla A European wild **sheep**, *Ovis musimon*, found on the islands of Sardinia and Corsica The rams have very large horns. (A W L)

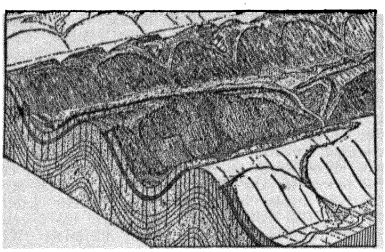
MOULD. **Foundry.**

MOULDING SAND. **Foundry.**

MOULT. 1 **Ecdysis** 2 The shedding of old feathers by birds preparatory to the development of new Most birds moult at least once a year, beginning just after the breeding season Most flying birds shed the large flight feathers in pairs but a few shed them all together and temporarily lose the power of flight The rest of the plumage is also shed and renewed little by little Moulting is accompanied in many species by the seasonal changes in plumage which make some species so different in summer and winter 3 The shedding of the outer layer of the skin by reptiles (A W L)

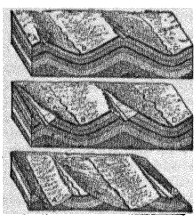
MOUNTAIN All mountains may be roughly classified as mountains of accumulation or mountains due to degradation In the former class are volcanoes, in the latter orogenic or folded and faulted structures, the character of whose present topographic features are primarily due to the erosive agents, the present stage in the

cycle of **erosion**, and the structural control. Structural mountains are those whose form and relief have not, as yet, been particularly modified by erosion. The ridges



Block diagram showing slightly eroded mountain folds. Jura Mountains, Switzerland. (After W. M. Davis.)

are still **anticlinal** and the valleys **synclinal**. Later, in the cycle of erosion, the synclines may become mountains and the anticlines, valleys. If the folded mountainous region is ultimately reduced to a peneplain, and the peneplain is then lifted without further folding, a new cycle of erosion operating on the same, but base-leveled, structure will develop the type of topography now seen in the Appalachian mountains. (See **antecedent** stream.) (R.M.F.)



Block diagrams showing how erosion may develop anticlinal valleys and synclinal mountains. (From Tarr, *New Physical Geography*, Macmillan Co.)

MOUNTAIN BOOMER. Reptilia, Sauria. The collared **lizard**, *Crotaphytus collaris*, a small species ranging from central California to Missouri and southward. In limited areas as far north as Idaho and Oregon. (A.W.L.)

MOUNTAIN LION. Puma.

MOURNING CLOAK. Insecta, Lepidoptera. A large **butterfly**, *Euvanessa antiopa*, of Europe and North America. The wings are very deep maroon above, bordered with yellowish white, and are slightly angular. The species hibernates in the adult stage and is often in flight on the first warm days of spring. (A.W.L.)

MOUSE. Mammalia, Rodentia. A name loosely applied to many species of small burrowing and gnawing **rodents** with slender bodies, long tails, and either the front legs or both pairs short. They are related to the hamsters, jerboas, lemmings, rats, and voles.

Most of the North American species are included in the family Muridae, of which the house mouse is a typical species. The family also contains the grasshopper or scorpion mice, harvest mice, the pine mouse, red-back mice, meadow or field mice, also called voles, and a group variously named wood, deer, vesper, and white-footed mice. The family Heteromyidae contains the pocket mice and kangaroo mice and the family Zapodidae the jumping mice. In addition to these details of classification, a number of species in various groups bear special names. Mice of one or another group are found on every continent, although they predominate in the northern hemisphere. The house mouse is *Mus musculus*. (A.W.L.)

MOUSTERIAN. Paleontology of man.

MOUTH. The external orifice leading into the **alimentary tract**. Commonly but less correctly applied to designate the terminal cavity of the tract which is the buccal or oral cavity in the vertebrates. (A.W.L.)

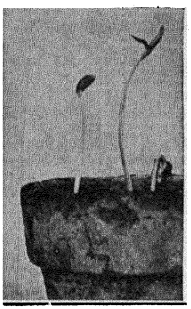
MOVEMENT IN PLANTS. Motility is not an outstanding characteristic of plants, except in a few lower forms. However, careful observation will show that a plant does adjust itself to changing conditions, and that it does this by moving its various parts. These responses are usually called tropisms.

One of the characteristic properties of living **protoplasm** is irritability, the property of responding to changes in the environment. In animals the stimulus received by certain cells is immediately transmitted by the nervous system to other cells which respond. In the plant no nervous system exists. The stimulus is received by certain cells, usually those located near the tip of the stem or root. The stimulus is transmitted to the cells of the elongating region and there the response occurs. In the older regions of the plant, where the cells have completely matured, the power to respond is lost except in a few special and often very striking cases.

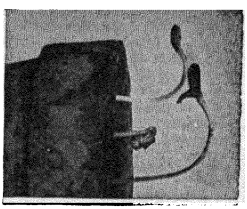
Light is one of the factors which produces a definite response in most plants. This response to light is known as phototropism. It is a matter of common observation that green plants turn toward the light, the leaves of plants grown indoors in a window all grow so that their surface is perpendicular to the light rays coming through the window. Turn the plant around and in two or three days all the leaves have turned so that once more they face the light. This response is due to changes in the cells of the **petiole**. The tip of the stem also responds to light, bending towards the source of light. Young seedlings respond very quickly and conspicuously to changes in the direction of the light source. Because of this they have been much used in experiments on phototropism. The seedlings of certain grasses, such as oats, wheat, and corn, are especially favorable material. One of these experiments, often repeated, adds considerably to our knowledge of the nature of the process. If the tip of the young seedling be cut off about one millimeter from the end, and the decapitated seedling lighted from one side, the response produced is very slight, while an undamaged seedling under similar conditions would turn almost 90° in a very few hours. From this one may gather that the stimulus is received in the cells of the stem tip. If a thin sheet of metal or glass is pushed into the stem just below this tip and the tip then exposed to light from the side the response is varied. If the inserted strip is in the side away from the light, the response is very much diminished, while if inserted on the other side, the effect is slight. This indicates that something is passing down the stem and causing a response in the cells lower down. Further proof that some substance actually does move down the stem is obtained by stimulating the stem tip, removing it and placing it on a thin sheet of agar for a short time. A tiny cube of the agar beneath this stem tip, if placed on the stump of an unstimulated stem, will cause a definite response. Agar which has not been under a stem tip will not cause any response. So definitely there is some substance coming from the tip and passing into the cells of the elongating zone. This substance has been variously named growth **hormone**, or growth substance, or growth-promoting substance. Many roots respond to light but in a negative direction, turning away from light. A turning towards light is called positive phototropism, and a turning away a negative phototropism.

Both stems and roots also respond to gravity. If a plant, kept in darkness to prevent any effect of light, be placed on its side and left for some time, it will be observed that the stem tip gradually turns to an upright position. At the same time the roots, less easily observed, have turned downward. Many explanations for

this phenomenon have been advanced. One of these is based on the observation that small granules, perhaps starch grains, are present in the growing cells. These grains, being heavier than the **cytoplasm** around them, settle to the bottom of the cell. There they cause some sort of stimulus which in turn produces a change in the growth rate of the cells in the elongating region. This explanation, known as the statolith theory, is not widely accepted. Other explanations based on observation and experiment have been offered. Of these the theory that a growth substance is formed in the cells of the tip and that it effects the observed responses when it diffuses back into the elongating cells is most generally accepted.



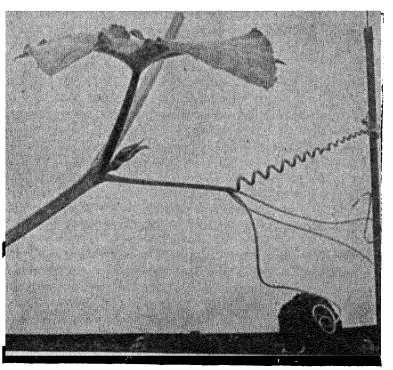
Sunflower seedling growing in a normal position.



Sunflower seedlings showing a negative response to the stimulus of gravity when the pot in which it was growing turned on its side.

Roots especially also respond to the presence of water. If more water occurs on one side than on another, the roots tend to grow towards the side on which water is more abundant. Observation of this fact has led to the frequently repeated statement that roots seek water.

Many plants respond to contact with solid bodies. A response of this sort is called a thigmotrópism or a stereotropism. **Tendrils** are very favorable objects to observe for responses of this sort. A young tendril is nearly straight except at its tip, which is curled up into a short, loose spiral. If the tendril, which is constantly swinging around, happens to touch any solid substance, at once it begins to wind tightly around this until it is firmly fastened. The straight part of the tendril may also coil tightly, drawing the stem from which it grows closely to the support. The winding stems of climbing vines show similar responses. The leaves of many **insectivorous plants** respond very quickly to the contact of small bodies against their surface or against certain hairs growing thereon. Certain plants, and particularly one known everywhere as the sensitive plant, respond notably to touch. This plant, *Mimosa pudica*, a member of the pea family, has bipinnately compound leaves which are attached to the stem by special swollen structures called pulvini. Pulvini also occur at the base of each pinna and each part of the compound leaf. If one of the pinnae is touched sharply not only does it fold up but all the adjoining **pinnae** fold up also. If the stimulus is strong enough, all the pinnae of the entire leaf may also close together. The **petiole** of the leaf also bends down. Sudden currents of air or a lowering of the temperature produce the same result. Experiment shows that here also some substance is formed which apparently passes downward to the base of the pinna and petiole and causes a response. The water in the cells of the pulvini passes out into the intercellular spaces, causing a decrease in the volume of the cells. As a result of this decrease, the position of the leaf changes. Gradual absorption of this water restores the leaf to its original position. Frequent repetitions of the stimulus cause longer and longer recovery periods. Seemingly the plant tires and has to rest.



Tendril of squash attached to a slender rod. Note that a portion of the tendril twines clockwise and a portion counter clockwise. If the tip of an extended tendril attached itself to a support, and then the plant was drawn close to the support by a further twining of the tendril in one direction only, there would be a tendency to twist the tendril off.

Sensitive plant. One leaf is responding to the stimulus of touch. (From Pfeffer's *Physiology of Plants*, Clarendon Press, Oxford.)

Chemotropism is a response to chemicals. This is best shown by motile cells such as swimming **gametes** or reproductive cells and by those lower organisms which are normally motile at all times. If certain substances, for example, malic acid, are placed in water and allowed to diffuse gradually through the water, the sperm cells of certain plants will be positively affected, swimming towards the diffusing substance. Different plants react to different substances and often to different concentrations of the same substance. A **sperm** may be attracted by a weak concentration of the substance, while a stronger concentration will repel it; as a result the sperms if numerous may form a hollow sphere about the center of diffusion, and gradually move back as the concentration of the diffusing substance increases.

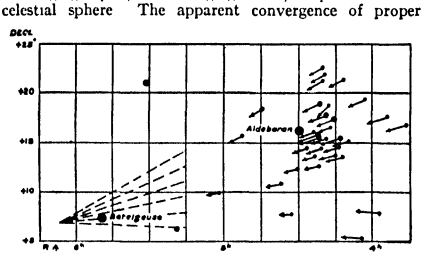
When the organism moves freely towards or away from a stimulus, the response is commonly a taxis or a tactism. This response of sperms to chemicals is a chemotropism or a chemotaxie. Responses to light, gravity, and electric currents also occur and are **called** phototaxis, geotaxis, and galvanotaxis, respectively.

Certain movements in plants are produced by external stimuli but are not dependent on the direction of the stimulus Responses of this type are called nasties Two common examples may be given An increase in light may cause a flower to open The common dandelion, for example, remains closed until the light is quite bright, then it opens But when the light diminishes at nightfall, the flower closes together again and remains so till the following morning Dark, cloudy days may prevent opening The flowers of certain alpine and arctic plants may close if a passing cloud casts a shadow on them and open when the shadow passes Responses of this kind are photonasties if the stimulus is light, and thermonasties if temperature The other common nastie is often called sleep movement The compound leaves of the locust tree, of the sensitive plant, and many others, fold together when night comes on and remain closed as long as it is dark, but spread out when again lighted

An entirely different movement occurs in the stem tip of growing plants, and in growing tendrils These are constantly swinging around in a slow movement as a result of internal changes in the cells of the plant These changes are within the plants and not due to the effect of external factors Commonly such movements are called nutations or circumnutations In many plants the amount of swing is very small, in others, and especially in vines, the stem swings through a wide angle The use of moving pictures in connection with the study of living plants has shown these movements most clearly (R M W)

MOVING CLUSTERS Statistical studies of the various stellar motions, such as **proper motion, radial velocity,** and **space velocity,** have proved conclusively that there are a number of groups of stars that are moving through space together These motions can be considered under two main headings moving clusters and star streams

A relatively small number of stars which are known to be moving through space together in parallel paths constitute what is known as a moving cluster Due to a perspective effect, similar to that discussed in connection with meteoric **radiant points,** the proper motions of the members of the moving cluster will appear to be converging upon, or diverging from, a point on the celestial sphere The apparent convergence of proper



Convergence of stars in Taurus cluster
(Adapted by Lewis Boss)

motions of a moving cluster is illustrated by the figure which shows a group of stars in the **constellation** of **Taurus** which form part of the so-called Taurus moving cluster About one hundred stars have been found which belong to this cluster A number of moving clusters have been found in various parts of the sky and they frequently carry the name of a constellation in which a number of the members of the cluster are found, e g, the Ursa Major group, the Scorpio-Centaurus group, the Orion group, etc It must not be understood that all members of a particular moving cluster are to be found in the constellation for which the group is named, for such is rarely the case For example, members of the Ursa Major cluster are to be found not only in the constellation of **Ursa Major,** but also in **Canis Major,** Corona Borealis, **Auriga,** and others

A study of the geometry of a moving cluster will indicate that the angular distance of any member of the cluster from the convergent or divergent point is the angle β as defined in the discussion of **space velocity** It may be further shown that if the radial velocity of only one member of the cluster can be determined, not only the distance of this star, but also the distance of every member of the cluster, may be determined With these data at hand, it is possible to find the space distribution of all of the members of the cluster An analysis of the Taurus cluster indicates that all members of this group are contained within a roughly globular volume of space about 35 **light years** in diameter with its center about 130 light years from the sun The velocity of the cluster indicates that 800,000 years ago the cluster was only 65 light years from the sun, while 65,000,000 years hence it will have receded to such a distance that it will appear as a sparse globular star **cluster** not more than 20′ in diameter At present the sun is within the Ursa Major cluster, with the members moving by on both sides This cluster is somewhat larger than the Taurus group, having a diameter of 500 light years So far as is known, the sun is not a member of any moving cluster

The common motions of so many different groups of stars cannot be accounted for on any chance arrangement and at once suggests a common origin for all members of a moving cluster This hypothesis receives support from the fact that in many cases the various members of a cluster are of similar **spectral class** Jeans has shown that the attractive forces of stars other than members of the cluster will eventually produce disintegration of the group and on this basis he calculates ages of the order of magnitude of 10^{12} years for the group

In the early part of the present century Kapteyn was able to show that the space velocities of the stars were not at random, but had two fundamental preferential directions It is as though there were two great rivers or streams of stars, one moving toward the constellation of **Orion** and the other toward the constellation of Scutum (in the southern hemisphere) The points toward which the streams are moving are known as the vertices of preferential motion, and both are close to the plane of the **milky way**

While the fact of star streaming is quite definitely established, a complete explanation of it is as yet undetermined Kapteyn offers an explanation on the basis of two huge clouds of stars moving past each other and intermingling as they flow on toward their vertices Schwarzschild, on the other hand, proposes an ellipsoidal hypothesis in which the star streams may be explained on the basis of relative motions within a rotating ellipsoidal mass of stars (W K G)

MUCK Soil.

MUCKET. Mollusca, Lamellibranchiata A freshwater **mussel,** *Actonomais,* of the St Lawrence and Mississippi River systems It has a heavy shell which is used in button making (A W L)

MUCOUS GLAND. A form of gland whose cells produce a secretion rich in **mucus** Glands may be of this type or may produce watery secretions, in which case they are said to be serous. Some contain secretory cells of both kinds and are said to be mixed (A W L)

MUCOUS MEMBRANE A membrane composed of epithelial cells It lines those canals, cavities, and tracts that communicate with the external air, as the nose and throat and **respiratory** tract, **generative** and **urinary** passages, and the **digestive system** (R S M)

MUCUS. A clear slimy secretion secreted by animals where surfaces must be lubricated or moistened It is produced at the surface of the body by fishes (**Pisces**) and **amphibians** Terrestrial **vertebrates** secrete it in the linings of the **respiratory** and **digestive systems** in abundance. (A W L)

MUD DAUBER Insecta, Hymenoptera Any of several species of **wasps** which make their nests of mud (A W L)

MUD EEL. Amphibia, Urodela A long slender aquatic species, *Siren lacertina*, with external gills, small front legs but no hind legs, and three pairs of gill slits The **eel** is found in swamps throughout the southern half of the United States, east of Texas (A W L)

MUDFISH. Pisces, Holostei The fresh-water dogfish or **bowfin** (A W L)

MUDPUPPY Amphibia, Urodela A large aquatic **salamander**, *Necturus maculatus*, with an elongate body, flattened head, tufted external gills, short legs, and a compressed tail Found in rivers and lakes of the eastern half of the United States, reaching only the northern part of the Gulf States Also called the waterdog (A W L)

MUD SKIPPER Pisces, Teleostei Coastal fishes (**Pisces**) of Africa and the Oriental region, including *Periopthalmus* They have prominent eyes and strong pectoral fins which they use in moving about on the muddy shores and in climbing to a limited extent They are said to be distinctly mud fishes, incapable of thriving if forced to remain in deep water (A W L)

MUDSTONE This is a loosely used term for rocks consisting essentially of consolidated muds, often sandy, which, however, although harder than clay, lack the laminated structure and fissility of **shale** (R M F)

MUFFLER. A muffler, as its name implies, is some device for silencing or muffling an objectionable noise Release of the gases from the cylinders of **internal combustion engines** on the exhaust stroke at pressures considerably above atmospheric, has created a condition which has had to be met by the use of mufflers All things considered, it has been found best to operate the internal combustion engine with incomplete expansion, i e, release above atmospheric pressure When the exhaust valve opens, the pressure in the cylinder exceeds that in the atmosphere by 20 to 50 pounds per square inch The result of the sudden rush of gases out of the cylinder under this driving force is an explosive expansion which creates a sharp, objectionable exhaust noise To reduce this objectionable feature, mufflers are designed to expand the gases more gradually, and keep them confined until the pressure has been lowered nearly to atmospheric The exhaust puffs from the separate cylinders of a multi-cylindered engine are thoroughly intermingled, and issue from the muffler in a steady stream

The simplest form of muffler is an expanding tube of conical shape attached to the end of the exhaust manifold To be effective, this type of muffler must be so large as to be too bulky for automotive purposes Manufacturers have developed compact designs which contain, within a sheet steel cylindrical shell, baffles, perforated plates, perforated tubes, and the like, whose function is to break up the separate puffs, intermingle them, and expand them until they will issue smoothly from the muffler stack The large size of steel mufflers which might be suitable for stationary engines of large capacity would be difficult to maintain, and costly to install, compared to a muffler made of concrete Where portability, light weight, compactness, are relatively unimportant, the concrete muffle pit, with considerable internal volume, supersedes the automotive type muffler However, because of the large-scale production of the latter types, they are applied to many engines which might otherwise have been served with muffle pits The chief drawback of a muffler is that the more effective it is in reducing noise, the more it handicaps the engine performance by creating a back pressure upon the engine manifold One may find examples where the attractiveness of silent operation has been a factor of sufficient importance to warrant a high degree of muffling, and other instances, where, although quietness of operation would be highly desirable, mufflers have been omitted because they reduced horsepower, added weight, and constituted hazards, due to their high operating temperature (F T M)

MUGGER Reptilia, Crocodilia The Indian **crocodile**, *Crocodylus palustris*, distributed from Beluchistan to Burma and south to Ceylon and other Oriental islands From the native name, magar (A W L)

MUGWORT. **Artemisia.**

MULBERRY FAMILY. Moraceae Widely scattered in all but the coldest regions of the world are the more than nine hundred species of the Mulberry Family, including trees, shrubs, and herbs Many are of great economic importance In Asiatic tropics, for instance, *Ficus elastica* has been used as a source for **rubber**, while *Ficus carica*, a related plant, is the cultivated **fig** Another tropical member, *Artocarpus incisa*, is the breadfruit This tree has large glossy incised leaves and bears large fruits which are roasted and eaten **Hemp**, *Cannabis sativa*, is an important fiber plant *Humulus lupulus* yields hops, while various species of *Morus* are important as food for silk worms

All members of the Mulberry Family contain a milky juice The flowers are borne in axillary spikes or heads Many members have **dioecious** flowers, that is, the staminate (See **Stamen**) and pistillate (See **Pistil**) flowers are borne on different plants, while others are monoecious The staminate flower has a variously three- to six-parted **calyx**, no **petals**, and one to four **stamens** with filiform filaments The pistillate flower has a calyx of three to five, more or less united **sepals** and a single one- to two-celled superior **ovary** The fruit varies greatly in different members of the family

The true mulberries, trees or shrubs of the genus *Morus* are widely distributed plants of temperate regions The leaves are alternate On a single tree one may observe interesting variations of the leaves, on one shoot they may all be entire, while on a nearby shoot they are variously and irregularly lobed or divided The flowers develop early in the growing season The plants are either monoecious or dioecious The staminate flowers are borne in long **catkins** and soon fall from the tree The calyx is divided into four lobes and there are four stamens inserted at its base The pistillate inflorescence is a short dense catkin The flowers have a four-lobed calyx and a single one-cell ovary After pollination the calyx lobes become greatly swollen and fleshy, the individual fruits pressing together tightly to form a multiple fruit These fruits may be white or pink in the White Mulberry, red in the Red Mulberry, and black in the Black Mulberry The white mulberry, *Morus alba*, is grown in the Orient largely to supply food for silk worms The roots of the tree yield a yellow dye, and the wood is used for various purposes The black mulberry, *Morus nigra*, is grown largely for the fruits, which are greedily eaten by birds, including domestic poultry The wood is also valuable Red mulberry, *Morus rubra*, furnishes wood used in making shoe lasts, and for other purposes. All species of mulberry are frequently planted as decorative trees

Another member of the Mulberry Family which is very valuable is a perennial climbing plant, *Humulus lupulus*, or the Common Hop This plant has an extensive underground stem, or rhizome, from which rise

the annual climbing stems, which twine in a clockwise direction around any supporting object The hollow stem is ridged, with downward pointing hairs along each of the ridges The opposite leaves are large and **palmately** veined Hops are usually dioecious plants The staminate inflorescence is a loose panicle, the pistillate, spike-like, with conspicuous bract-like structures subtending each branch The staminate flowers have a five-parted calyx and five stamens, there is no corolla The pistillate flower is a single ovary, partially surrounded by a small **bract** and having two long hairy **stigmas**, around the ovary is a cup-like **perianth** Hops are wind-pollinated After fertilization the bracts enlarge greatly On their outer surface, and also on the surface of the perianth and the subtending bract, yellow grains develop These grains are called hop-meal and are multicellular cup-shaped bodies developing from single epidermal cells The cells of these bodies secrete a yellow substance which fills the cup-shaped hollow and which contains the substances which make hops valuable—an essential oil, resins, **tannin**, and a bitter substance, probably **alkaloidal** in nature The resins are bitter and germicidal

The principal use of hops is in the brewing of beer Hops are prepared for the brewing process by drying and bleaching Prepared hops are boiled with the sweet beer wort, which extracts the bitter principle and imparts to the beer an aroma due to the essential oil of the hops (R M W)

MULE. Mammalia, Perissodactyla A hybrid between the domestic horse and ass, produced by mating a mare and a jack The reciprocal cross of stallion and jennet is called a hinny

Mules have the large ears, small hoofs, and tufted tail of the ass and the stature of the horse They are strong and hardy, resistant to disease and adverse conditions Although they are often of uncertain temper they are such valuable work animals that the mule-breeding industry of the United States has reached a value of $500,000,000 per year at its peak Mules are bred for various purposes, including riding and driving as well as work of heavier nature Since they are infertile, they are always bred by crossing the two species (A W L)

MULITA. Mammalia, Edentata A South American **armadillo**

MULLERIAN DUCT. A duct of a pair developed in **vertebrates** of both sexes, from which the **oviducts** and in the mammals the **uterus** and **vagina** of the female are formed The Mullerian ducts of the male become vestigial structures in the adult (A W L)

MULLET. Pisces, Teleostei Fish (**Pisces**) of several families Those of the family Mugilidae are the gray mullets of European terminology and those of the family Mullidae are the red mullets Several species of the family Catostomidae are called mullets in North America, or mullet suckers because of their close relationship with the fishes of the latter name One of these species, the common red horse or white sucker, is confusingly called the red mullet

Most of these fishes are coastal forms which ascend estuaries and even the wholly fresh parts of streams The red mullets are chiefly tropical Some of the Mullidae are good food fishes The Mugilidae are less valued and the Catostomidae are also of moderate worth (A W L)

MULTIPARA A woman who has given birth to several children (R S M)

MULTIPLE EFFECT. **Evaporator.**

MULTIPLE INTEGRALS. **Double Integrals** and **Triple Integrals.**

MULTIPLE PROPORTIONS, LAW OF. If two chemical **elements** unite to form more than two compounds, the different amounts of one which unite with a fixed amount of the other stand in the ratio of small whole numbers, e g, **hydrogen** and **oxygen** can form either **water** or **hydrogen peroxide** Analysis shows that 2 grams of hydrogen combine with 16 grams of oxygen to form water, on the other hand, 2 grams of hydrogen combine with 32 grams of oxygen to form hydrogen peroxide The ratio of oxygen which combines with a fixed amount of hydrogen (in this case 2 grams) is 16 to 32 or 1 to 2 (See **Chemical Composition**) (R K S)

MULTIPLE ROOTS OF AN ALGEBRAIC EQUATION **Polynomial Equations.**

MULTIPLE SCLEROSIS. **Sclerosis** (R S M)

MULTIPLETS. **Atomic Spectra; Hyperfine Structure.**

MULTIPLICATION. Multiplication is one of the fundamental operations with **numbers**, by which two or more numbers are combined to give a number, the result is called the product

This operation is subject to several fundamental rules or laws the commutative and associative laws, and in combination with addition, the distributive law

The commutative law for multiplication of numbers is expressed by the formula

$$a\ b = b\ a$$

for any two numbers a and b, in words, the product of any two numbers is the same in whatever order they are multiplied

The associative law for multiplication of numbers is expressed by

$$(ab)c = a(bc)$$

for any three numbers a, b, c, in words, the product of any three numbers is the same in whatever manner they are grouped

The distributive law for addition and multiplication of numbers is expressed by the formula

$$a(b + c) = ab + ac$$

for any numbers a, b, c, in words, the product of a factor by a sum of two terms is equal to the sum of the products of the factor by each of the terms of the sum A similar statement applies when the sum contains more than two terms

The product of two numbers of the same sign is positive, that of two numbers of unlike signs is negative, the **absolute value** being the product of the absolute values of the numbers

To find the product of two **polynomials**, we multiply each term of one polynomial by each term of the other, and add these results

The following special product formulas are of frequent use

$a(b + c + d) = ab + ac + ad,$
$(a + b)(c + d) = ac + ad + bc + bd,$
$(x + a)(x + b) = x^2 + (a + b)x + ab,$
$(a \pm b)^2 = a^2 \pm 2ab + b^2,$
$(a + b)(a - b) = a^2 - b^2,$
$(a \pm b)^3 = a^3 \pm 3a^2b + 3ab^2 \pm b^3,$
$(a \pm b)(a^2 \mp ab + b^2) = a^3 \pm b^3,$
$a^n - b^n = (a - b)(a^{n-1} + a^{n-2}b + \ldots + ab^{n-2} + b^{n-1}),$
$a^n - b^n = (a + b)(a^{n-1} - a^{n-2}b + \ldots - b^{n-1})$ if n is an even integer,
$a^n + b^n = (a + b)(a^{n-1} - a^{n-2}b + \ldots + b^{n-1})$ if n is an odd integer

From these one may obtain at once certain useful special quotients

By reversing the above product formulas, we obtain formulas for **factoring** (L L S)

MULTISTIGMATEA. Thaliacea.

MULTITUBERCULATES. Fossil mammals.

MUMMICHOG. Pisces, Teleostei. The common **killifish**, *Fundulus heteroclitus*, also called the **mud fish**. A small shore fish, common from Maine to Mexico. (A.W.L.)

MUMPS (Epidemic Parotitis). A generalized contagious disease with marked local involvement of the **parotid gland**, but which may involve other glandular structures, especially those of the endocrine system.

Mumps occur most frequently between five and fifteen years of age. The disease is caused by a filterable **virus** and one attack usually gives immunity through life.

Mumps may be transmitted before signs of glandular swelling appear, and contagion usually persists while this swelling lasts. The incubation period varies from eight to thirty days, usually averaging from fifteen to eighteen days. The first symptom is usually swelling and pain of one or both of the parotid glands. At times the other salivary **glands** are involved—the sublingual and submaxillary glands. In rare cases these glands may be alone involved instead of the parotid.

The most frequent complication is inflammation of the **testicles** occurring in 15% to 30% of cases. Inflammation of the **ovaries** is less common. This symptom may cause severe prostration with high fever. Inflammation of the breast may occur in both sexes as well as inflammation of the **pancreas**. Other complications which are uncommon are pneumonia, bronchitis, encephalitis, and meningitis. Deafness may occur and be permanent. As with any epidemic disease, complications and their frequency vary with the severity of the disease. The death rate from mumps is less than 1%, varying in different epidemics.

Convalescent serum is of use prophylactically after exposure. There is no specific treatment. (R.S.M.)

MUNGOOSE. Mongoose.

MUNIA. Aves, Passeriformes. Any bird of numerous species of weaver **finches** constituting the genus *Munia*. They are native to Africa and the Oriental region. The commonest species is the rice bird, paddy bird, or Java sparrow, which is regarded as a pest in the rice fields and has been kept extensively as a cage bird in Europe. (A.W.L.)

MUNTJAC. Mammalia, Artiodactyla. Small Asiatic **deer** of several species. They stand only about two feet high and have small two-tined antlers somewhat like those of the American prong horn. The common Indian species, *Cervulus muntjac,* is called the kakar. (A.W.L.)

MURAENA. Eel.

MURIATE. Term applied to **chlorides**. Muriate of potash, **potassium** chloride; muriatic acid, **hydrochloric acid**. (R.K.S.)

MURINE. Opossum.

MURMUR. Heart murmur—a soft or harsh blowing sound heard over the heart region either by the ear placed against the chest or by the stethoscope. Murmurs are produced by the heart valves either by variations in their shape or other deformities. A murmur does not always indicate the possibility of **heart** damage or disease as it may be functional, depending on structural differences in the valve, low blood pressure or **anemia**. Murmurs indicating organic disease of the heart are produced by diseases causing scarring, narrowing and destruction of the heart valves—especially by **rheumatic fever** and **syphilis**. (R.S.M.)

MURRAY COD. Pisces, Teleostei. A fish belonging to the large **sea-bass** family. (A.W.L.)

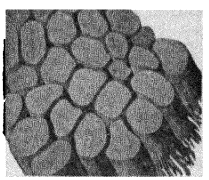
MURRE. Aves, Charadriiformes. Moderately large marine birds (**Aves**) related to the auks. The name is, to some extent, synonymous with **guillemot** but different species have been named as one or the other by ornithologists. They are powerful swimmers and divers. (A.W.L.)

MURRELET. Aves, Charadriiformes. Small species of marine diving birds (**Aves**) of several genera related to the auks and murres. (A.W.L.)

MUSCHELKALK LIMESTONES. Triassic.

MUSCLE. An organ formed of a bundle of contractile fibers attached to parts of the body which are moved in relation to each other when it shortens. Among the invertebrates the fibers of a muscle are loosely associated but in the vertebrates they are bound together and enveloped by special tissues.

The typical vertebrate muscle is surrounded by a connective **tissue** sheath, the external perimysium, which continues into it a series of septa (**Septum**) called the internal perimysium. Between the septa lie bundles of muscle fibers, each surrounded by a delicate continuation of the connective tissue closely jointed to the surface of the fiber. Blood vessels and nerves supplying the muscle course through the perimysium.



Cross section of muscular tissue, enlarged, showing bundles of muscular tissue.

Muscles differ in **form** according to the relations of their fibers to the tendons with which they connect. If the tendon is terminal, the fibers are longitudinal. In penniform muscles the tendon runs along one side and the fibers are oblique to the axis of the muscle, resulting in a featherlike appearance. If the tendon runs down the middle the result is a bipenniform muscle, and even more complex patterns of this type occur. Digastric muscles have a tendon at each end and another in the middle connecting two contractile portions.

Individual muscles throughout the body have received special names according to their anatomical relations or functions. Thus the name extensor communis digitorum applies to the muscle of the human arm whose contraction straightens all of the fingers, and the sterno-cleido-mastoid is a muscle attached to the sternum, clavicle, and mastoid process. Several hundreds of distinct muscles of the human body bear such names.

See also **Muscular System** and **Muscular Tissue.** (A.W.L.)

MUSCLE SPINDLE. A sensory organ found in the muscles of **vertebrates**. It consists of a group of modified muscle fibers surrounded by nerve endings and is supposed to be stimulated by the variations of pressure resulting from the contraction of the muscle. (A.W.L.)

MUSCOVITE. POTASH MICA. The mineral muscovite is an **orthosilicate** of **aluminum** and **potassium** which crystallizes in the **monoclinic** system although frequently found in pseudo-**hexagonal** forms. Usually tabular in **habit**, the most prominent characteristic is the highly perfect basal **cleavage** yielding remarkably thin laminae which are often highly elastic. Hardness, 2.-2.25; specific gravity, 2.76-3.; luster, vitreous to pearly; color, colorless through grays, browns, greens, yellows, and rarely violet or red; transparent to translucent.

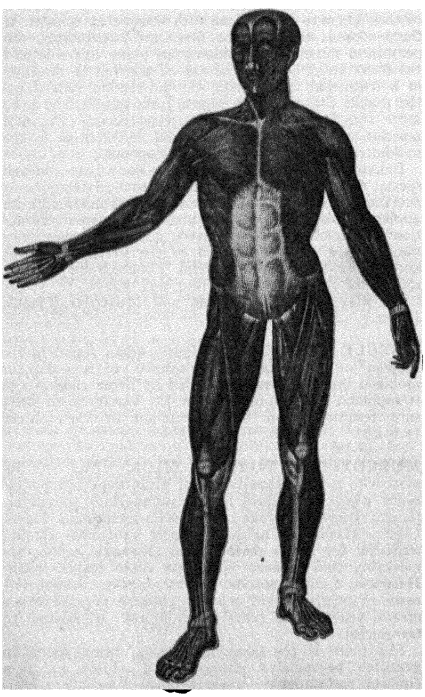
Muscovite is the commonest mica, being found in **granites, pegmatites, gneisses,** and **schists**, and as a **contact metamorphic** mineral, or as a secondary mineral resulting from the alteration of **topaz, feldspar,**

kyanite, etc. In pegmatites it is often found in immense sheets which are commercially valuable. A complete list of occurrences of muscovite would be impossible. In the United States excellent specimens are found in the pegmatites of New England, where they are associated with rarer minerals like **tourmaline**, **beryl**, etc. Pennsylvania, Maryland, Virginia, North Carolina, Georgia, South Dakota, and New Mexico also furnish large and fine examples of this mineral.

The name muscovite comes from Muscovy-glass, a name formerly much used for this mineral because of its use in Russia for windows. It is in much demand for the manufacture of insulating and fireproofing materials and to some extent as a lubricant. (E.S.C.S.)

MUSCULAR SYSTEM. The entire assemblage of contractile structures by which movement is produced in complex animals. **Muscular tissue** consists of several types of specialized cells, variously disposed. Some are scattered in the walls of hollow organs or among other tissues and some are bound together to form separate **muscles**. The latter are more conspicuous since they are separate organs, but all contractile structures properly belong to the muscular system.

In the simplest animals with special muscular tissues, the **worms**, muscle cells pass across the loose tissues within the body and form layers in the body wall. Their disposal is often in a circular layer, with fibers running around the body, and a longitudinal layer with fibers parallel to the main axis. The contractions of these layers lengthen and shorten the body and so carry on the creeping movements characteristic of worms. Special groups of muscle fibers also govern such special structures as the setae of earthworms. These muscles have an attachment to the body wall called the origin and an insertion in the tissues surrounding the part to be moved.



Muscular system.

In animals with a rigid skeleton an arrangement of muscle fibers like that of the body wall of worms persists in hollow organs like the alimentary tract, and in organs like the heart and urinary bladder a less regular arrangement provides for the uniform contraction of all parts of the wall. Locomotion and similar movements, however, are due to the action of muscles on skeletal supports which serve as systems of levers. Usually the contraction of a single muscle moves one part in relation to another; it is said to have its insertion in the part moved and its origin at the other point of attachment.

The nature of movements varies greatly. Extension of jointed appendages, flexion, retraction, rotation, and other movements are carried out by opposed systems of muscles. Any movement is positive, due to the contraction of a specified muscle, and the return of the part to its former position results from the contraction of an opposed muscle, sometimes aided by the action of gravity. The anatomy of the muscular system and the relations of specific muscles have been worked out in great detail in the human body, in other vertebrates, and in some of the **arthropods**. (A.W.L.)

MUSCULAR TISSUE. Muscular tissue is made up of long slender cells specialized for contraction. It is usually mesodermal in origin. There are three kinds of muscular tissue, smooth, cardiac, and striated or skeletal. Among the invertebrates all muscle may be smooth, as in many worms, or striated, as in most arthropods. All three kinds are found in **vertebrates** and cardiac muscle is characteristic of the vertebrate **heart**. Muscle **cells** may contain a few scattered myofibrils or a large number, occupying most of the cytoplasm.

Among the invertebrates the contractile cells vary greatly. Those of **nematode** worms, for example, consist of a contractile and a noncontractile portion and some muscle fibers of **mollusks** show incipient striation in the form of oblique refractory lines.

The smooth muscle tissue of vertebrates consists of slender tapering cells with a nucleus placed centrally. These cells are involuntary in action and are found in the walls of the alimentary tract, excretory system, blood vessels, and other organs.

Striated muscle is so named because the many fibrils in its cytoplasm are made up of alternating zones of different refractive quality which cause the fiber to show light and dark transverse bands. The fiber is long and cylindrical and contains many nuclei located at the periphery. It is surrounded by a delicate membrane, the sarcolemma. Most striated muscle is the foundation of voluntary movements and from its extensive association with the skeleton it receives the name skeletal muscle.

Cardiac muscle, like skeletal, is striated, although the striations are much finer. It differs in the general branching of its fibers and in the centrally placed nuclei. Cardiac muscle is rhythmically contractile, initiating the heart beat of vertebrates. The nerves which innervate the vertebrate heart serve to modify but not to initiate the contraction of the heart muscle. (A.W.L.)

MUSCULO-EPITHELIAL CELL. A **cell** forming part of the layers in **coelenterates** such as *Hydra*, provided with basal contractile processes which serve as muscles. (A.W.L.)

MUSHROOM. **Basidiomycetes.**

MUSICAL SOUNDS. The chief characteristics whereby musical sounds are distinguished from each other and from non-musical sounds are pitch and quality.

Pitch is that which the normal ear recognizes as corresponding to position in the musical scale. It is dependent primarily upon the frequency of the predomi-

nant sound waves, for example, middle *c* on the piano has a fundamental frequency of about 264 per second The frequency of a musical tone may be measured by means of a sonometer in comparison with a standard **tuning fork** The sonometer string is tuned to unison with the unknown frequency, and then with the fork of known frequency, by varying its length at constant tension by means of a movable fret, the frequencies are then in the inverse ratio of the lengths A "siren" may also be used for this purpose, it has a disk with equally spaced holes through which air is blown as the disk is rotated This gives the frequency by direct count

Quality is an attribute due to the complexity of a tone Besides the lowest (and usually the loudest) frequency, called the fundamental, there may be a series of overtones, higher frequencies arising from the vibration of the source in parts or segments Thus, a string may vibrate as a whole, giving the fundamental, or in halves, thirds, fourths, etc The exact quality of a tone depends upon the relative intensity of the several components, which may be ascertained by means of a device called a "phonodeik" for amplifying the wave form and by subsequent **harmonic analysis** Harmony or discord is dependent upon the loudness and frequency of the **beats** between the principal components of the tones concerned

The musical scale at present used in occidental countries is a geometrical progression of frequencies with ratios or "intervals" each equal to $\sqrt[12]{2}$ or 1 05946 An octave comprises twelve such intervals and has the frequency ratio 2 Various harmonious combinations of the notes on this scale form the chords of ordinary music In addition to pitch and quality, music utilizes differences in intensity, duration, and spacing (rhythm) of musical sounds, all of which contribute to that subtle attribute known as "expression" (L D W)

MUSKALLUNGE Pisces, Teleostei A large freshwater game fish (**Pisces**), *Esox nobilior,* of North America, found chiefly in colder waters of the northern states and Canada, but occasionally as far south as North Carolina It is a slender species related to the pikes and pickerel and attains a length of eight feet and a weight of one hundred pounds Specimens over forty pounds are, however, rarely taken

The name is among the most abused of all fishes It is also spelled muscalonge, muskellunge, maskinongy, masquinonge, and occasionally in other ways (A W L)

MUSK DEER. Mammalia, Artiodactyla A small **deer,** *Moschus moschiferus,* of the Himalayas It stands twenty inches high Antlers are lacking and the upper jaw bears a pair of tusks which may project several inches in the males In northwestern China a second related species, *M sifanicus,* occurs (A W L)

MUSKEG. Swamp.

MUSK HOG. Peccary.

MUSKMELON. Gourd Family.

MUSK OX. Mammalia, Artiodactyla An animal, *Ovibos moschatus,* of Arctic America related to the sheep but resembling oxen It is about two thirds as large as the American bison and is clothed with long hair The horns are broad at the base but become rapidly narrower as they curve downward from the forehead over the sides of the head The more slender tips turn abruptly upward

Musk oxen are hunted by the eskimos for their hides and flesh (A W L)

MUSKRAT. Mammalia, Rodentia Moderately large amphibious **rodents** of North America They are stoutly built, short legged with partially webbed hind toes, and have a compressed tail They inhabit swamps and streams, making houses of sticks and also burrowing in the banks Two species are recognized, one a dark brown animal, *Ondatra rivalicia,* of the coastal part of Louisiana and the other an extremely variable species, *O zibethica,* found over most of the continent

Muskrat fur consists of a fine woolly undercoat and long glossy hairs. It is the best of the inexpensive furs and because of the ability of the animal to withstand extensive trapping is now the most important fur commercially Approximately fifteen million pelts are taken annually in North America, many of them from fur farms The natural colors of the fur are beautiful and many pelts are made up in this state, but many also reach the market as Hudson seal after being plucked, clipped and dyed black

The muskrat has also been introduced successfully into Europe (A W L)

MUSQUASH. The **muskrat.**

MUSSEL. Mollusca, Lamellibranchiata. A name applied to many **bivalve** mollusks, both marine and fresh water species Used to some extent as a synonym of clam, especially in reference to the fresh water species Most of the marine forms are normally called either mussels or clams, the species of the family Mytilidae bearing the former name They include the edible mussel of both American coasts and Europe

Fresh water mussels are eaten but they are not an important source of food They are taken in large numbers from the larger rivers of the country for their shells, which are used in making buttons, and for the pearls which they contain As many as fifty thousand tons of shells have been marketed in a single year, chiefly from the Mississippi River (A W L)

MUSTANG. Mammalia, Perissodactyla Western American **horses** descended from stock introduced by the Spanish conquerors Also known as Indian ponies and bronchos They are noted for their endurance, agility and spirit (A W L)

MUSTARD. Brassica.

MUSTARD GAS Poison Gases.

MUTAROTATION. Carbohydrates.

MUTATION. A characteristic different from any in the ancestry of the individual displaying it, which breeds true Mutations are like sports in showing abrupt departure from the hereditary characters of the species to which they belong but they differ in being transmissible

Changes of this type have been important in the study of **heredity,** since they afford contrasts with existing hereditary characters They have usually been regarded as fortuitous changes issuing from the heritage but it has been found possible to increase their appearance by treating breeding stock with X rays, radium, heat, and other environmental factors They are a possible basis of evolutionary change (A W L)

MUTUAL INDUCTANCE. Inductance.

MUTUAL INDUCTION. Electromagnetic Induction.

MYALGIA Pain in a muscle or muscles usually due to injury or inflammation (R S M)

MYCELIUM. Basidomycetes and Fungi.

MYCETOZOA. Sarcodina. An interesting group of organisms formerly classed with the plants as **slime molds,** related to the fungi, and now included with the one-celled animals in the phylum **Protozoa.** They consist of a creeping mass of **protoplasm** containing many nuclei This plasmodium occasionally produces fixed reproductive bodies (sporangia) in which their resemblance to plants is at its height (A W L)

MYCORHIZAE Mycorhizae are, strictly speaking, **hyphal** threads of various **fungus** plants, growing in intimate association with some part of the higher plant, usually the root Two different kinds of mycorhizae are known In one kind, known as ectotrophic mycorhizae, the fungus hyphae form a close welt over the surface of the root with hyphal threads penetrating into the root between the **cortical** cells This kind is particularly common on the tips of tree-roots, and often causes swelling of the infected roots The fungus seems to take the place of root hairs, which are not developed in its presence Apparently the general welfare of the tree is not absolutely dependent on the presence of mycorhizae, though they may materially benefit the tree The other kind of mycorhiza is the endotrophic form, in which the fungus hyphae are found within the cells of the higher plants **Orchids** and **Heaths** are well known examples in which endotrophic mycorhizae are found The fungus enters the plant through the epidermis of the root, passes into the cells of the cortical **parenchyma** and lives there From these cortical cells the fungus may extend into all the tissues of the higher plant, even reaching the **ovary** Plants supporting endotrophic mycorhizae seem much more dependent on their presence than those with ectotrophic forms Indeed, the successful growing of orchids from seed may depend on the presence of the fungus associate which enters the orchid embryo.

Plants growing in bogs, regions in which there is usually a lack of sufficient nitrogen, almost always have mycorhizae Apparently the mycorhizae obtain the **nitrogen** necessary for the welfare of the higher plant

This association of mycorhizae with higher plants is often described as a case of symbiosis, a living together of two organisms for mutual benefit The higher plant receives a greater supply of nitrogen and so benefits, it is difficult to see just how the mycorhizae benefits from the higher plant (R M W)

MYDRIATIC Any **drug** that causes dilation of the pupil of the eye Such drugs are **atropine, belladonna, cocaine,** etc (R S M)

MYELITIS This term refers to general or local involvement of the spinal cord by inflammation or softening, resulting from infection, injury, or certain poisons or toxins Infective myelitis may occur as a complication in many diseases, of which the most common are **influenza, tuberculosis, syphilis, diphtheria, gonorrhea,** and the various forms of **meningitis**. Toxic myelitis may be due to poisoning by **carbon monoxide, gasoline, chloroform** and other chemicals Traumatic myelitis may be due to direct or indirect injury about the spine The disease may be acute or chronic

Symptoms occurring in myelitis depend on its cause and on the extent of the spinal cord involvement The usual symptoms are weakness, paralysis, pain and other sensory findings The disease is serious and the mortality is high varying according to the extent and degree of involvement of the spinal cord (R S M)

MYLONITE. The term proposed by Charles Lapworth in 1885 for a massive **chert**-like rock occurring at the contact of the shear planes associated with the low-angle **overthrusts** of the North West Highlands of Scotland Mylonite is therefore developed through the process of **dynamic metamorphism** and derives its name from the Greek, meaning to crush (R M F)

MYNA. Aves, Passeriformes Indian birds (**Aves**) closely related to the starlings (A W L)

MYOCARDITIS. An acute or chronic inflammation of the muscular wall of the **heart.** Acute myocarditis is almost always secondary to any of the acute infections such as acute rheumatic fever, diphtheria, malaria, scarlet fever, erysipelas, septicemia, etc It may result from direct invasion of the heart muscle by the infective organism or, on the other hand, from the toxins liberated by the organs and carried to the heart by the blood stream It is most common in childhood and early life Often it complicates an acute and infectious disease which masks the symptoms, and makes the diagnosis difficult or impossible Acute myocarditis may be very mild and permit an early and complete recovery or be so severe that death results within a few days Chronic myocarditis is a term used to describe those conditions in which there is a chronic inflammatory process in the heart muscle and should not include those conditions resulting from degenerative diseases of the heart muscle such as hardening of the arteries (**arteriosclerosis**), fatty degeneration and degeneration in hypertensive and renal disease—diseases which accompany advancing age

The chronic inflammatory process causing the condition of myocarditis may develop as a late stage of the acute process or may appear without any previous evidence of the acute form It often follows the same diseases previously mentioned as causing the acute form It is always associated in some degree with endocarditis and often is the direct cause of death in this disease. Syphilis is one of the most frequent causes of myocarditis Chronic focal infection in the teeth, sinuses, tonsils, gall bladder, etc, may occasionally be the cause

The symptoms of chronic myocarditis may not be noticeable On the other hand sudden death may occur from this cause in an apparently healthy individual. Breathlessness following exertion, sense of suffocation, pressure over the heart region, cardiac pain and palpitation are often present as symptoms The electrocardiograph is a great aid in diagnosing this form of cardiac impairment (R S M)

MYOCARDIUM. The muscular layer which makes up the greater part of the wall of the vertebrate **heart.** It is lined with the thin endocardium and covered with a thin epicardium, continuous with the lining of the pericardial cavity (A W L)

MYONEME. Fine contractile filaments in the cytoplasm of one-celled animals (A W L)

MYOPIA. Short sight or **near-sightedness** due to too great an increase in the refractive power of the **eye** so that images from distant objects are focused in front of the **retina.** (See **Vision**) (R S M)

MYRIAPODA A class of the phylum **Arthropoda,** now obsolete It has been subdivided to form the four classes, **Chilopoda, Diplopoda, Pauropoda** and **Symphyla.** (A W L)

MYRIENTOMATA. Protura.

MYRMECOPHILE. An animal which makes its home in the nests of ants Among the insects that have become adapted to this mode of life are **crickets, beetles,** and larval flies In most cases that have been observed the myrmecophiles seem to feed at the expense of the ants, which may in turn eat secretions produced by their guests (A W L)

MYRRH. Commiphora myrrha. Burseraceae **Resins.**

MYRRH. *Commiphora myrrha* Burseraceae Myrrh is obtained from a spiny tree of small size, which grows wild in northeastern Africa and Asia Minor It has trifoliate leaves, in which the lateral leaflets are very much smaller than the terminal, and small red flowers borne in the axillary buds of the leaves of the previous year These flowers are **dioecious.** The fruit is a small **drupe.** A **resin** exudes from the stem of the tree, collecting in small lumps This is myrrh, long known for its fragrance It is used in perfumes and incense, and in medicine, and was one of the substances used by the Egyptians in embalming their dead Several

other species of the genus yield similar resins, also called myrrh (R M W)

MYSIDACEA. Crustacea.

MYSTACOCETI. The whalebone **whales,** an order of marine mammals including the largest living animals of this class They are characterized by the presence in the mouth of plates of baleen or whalebone whose fringed ends serve as a sieve through which water is strained to remove the small animals contained in it The order includes the fin whales or rorquals, the humpback whale, the pigmy whale of the southern hemisphere, the gray whale, the sulfur-bottom whale, and the right whales (A W L)

MYXEDEMA Thyroid Gland (R S M)

MYXINOIDEA Cyclostomata The hag fishes.

MYXOMYCETES. Slime Molds.

MYXOSPONGIDA Demospongiae.

MYXOSPORIDIA. Sporozoa.

N

N SERIES. X-ray spectra.

NACELLE. Nacelle is a term descriptive of certain parts of **aircraft** structures, particularly those appendages to, or parts of the principal structure which are concerned with enclosing or supporting equipment or passengers Both aerostatic and aerodynamic aircraft have been equipped with nacelles The suspended basket of the free balloon, or the car of the semi-rigid, have been called nacelles, and cockpits of aircraft not formed definitely by the principal fuselage structure have similarly been defined The cockpit type nacelles are found principally on bombing airplanes

The large modern multi-engined **airplane** has engine nacelles which support the engine from the aircraft structure, usually the wing or interplane bracing, and provide housing for certain of the engine auxiliaries Streamlining of the nacelle, and interference effects between it and adjacent lifting surfaces have been very carefully studied in research laboratories, so that the position adopted, and the shape of the nacelle on the latest types of planes represent the application of the best scientific information as to the shape and position which will result in the least interference with the airstream about the lifting surfaces, and at the same time give maximum effectiveness to the propeller (F T M)

NACRE. Mother-of-pearl

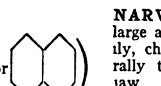
NADIR. Horizontal Coordinate System.

NAIAD. An aquatic insect larva **Hemimetabola. Larva.**

NAKONG. Mammalia, Artiodactyla One of the larger harnessed **antelopes** of Africa This species differs from most harnessed antelopes in its uniform grayish brown color The horns are long and spiral Also called the sititunga (A W L)

NANNOPLANKTON. The portion of the floating and drifting aquatic animals (**plankton**), including minute species, which pass through ordinary nets and must be secured by centrifuging (A W L)

NAPE The back of the neck

NAPHTHALENE. Naphthalene ($C_{10}H_8$ or ) is a colorless, odorous (odor of "moth balls"), solid, melting point 80° C, boiling point 218° C, sublimes, insoluble in water, slightly soluble in cold alcohol, soluble in hot alcohol or in ether Naphthalene reacts (1) with oxidizing agents, e g, **sodium** dichromate, plus **sulfuric acid,** to form 1,4-naphthaquinone, (2) with oxygen of the air, in the presence of **vanadium** pentoxide as a **catalyzer** at 425° C, orthophthalic acid is formed, with **chlorine** in **chloroform,** to form naphthalene tetrachloride ($C_{10}H_8Cl_4$(1,2,3,4), white solid, melting point 182° C, (3) with concentrated **sulfuric acid,** to form various naphthalene sulfonic acids This reaction is important on account of the ease of transforming the sulfonic acid group (—SO_2OH) into the hydroxyl group (—OH) by heating with **sodium** hydroxide, and because of the solubility in water of the sulfonic acids (See **Thioalcohols and Related Compounds**) With **mercuric** salt present as a catalyzer sulfuric acid forms orthophthalic acid, (4) with concentrated **nitric acid,** to form alpha-nitro-naphthalene ($C_{10}H_7NO_2$(1)), yellow solid, melting point 59° C, (5) with **picric acid** ((1)HO C_6H_2 $(NO_2)_3$(2,4 6)), to form yellow crystalline naphthalene picrate, melting point 149° C

Naphthalene is obtained from coal tar in the fraction **distilling** between 180° C and 200° C, from which the crystals are separated by **filtration** after cooling The product is purified by treatment with concentrated **sulfuric acid,** and subsequent **sublimation** Naphthalene may be detected by appearance of a carmine red color on heating with **mellitic acid** anhydride Naphthalene is used (1) as an insecticide, (2) in the preparation of **phthalic acid,** (3) in the preparation of azo-**dyes** and indigotin, which is the chief constituent of the dyestuff **indigo** (R K S)

NAPHTHOLS Phenols

NAPIERIAN LOGARITHMS. Logarithms.

NAPOLEONITE. Corsite.

NAPPE A great overfold of the "crust" of the earth including a thick **stratigraphic** series of formations frequently representing one or more geologic periods of the earth's history Under great continued compressional stress the overfold may be faulted and ride forward so as to produce a profound and relatively horizontal translocation of the earth's "crust" Some thrust masses of this type are supposed to have traveled as much as two to three hundred miles from the region in which the rocks were originally formed The type locality of nappes is the Swiss Alps, where they form the principal structural features of this highly deformed and structurally complex mountain system (R M F)

NARCOMEDUSAE. Hydrozoa.

NARCOTINE Alkaloids.

NARS. Terminal orifice of the nasal passages The external openings are the external or anterior nares and the openings at the communication of these passages with the **pharynx** in air-breathing **vertebrates** are the posterior or internal nares (A W L)

NARWHAL. Mammalia, Odontoceti A moderately large animal, *Monodon monoceros,* of the **dolphin** family, characterized by the single long straight tusk, spirally twisted, which extends forward from the upper jaw The tusk is a single tooth, usually that of the left side Its mate in the male and both of these teeth in the female are rudimentary The narwhal has no other teeth except a few irregular rudiments The tusk attains a length of eight feet and the animal reaches twelve to sixteen feet (A W L)

NASAL BONE One of a pair of small bones forming the bridge of the human **nose** and the corresponding portion of the skull in other vertebrates (A W.L.)

NASO-LABIAL GROOVE A groove extending from the nostril to the mouth in some of the fishes (**Pisces**) and **amphibians** (A W L)

NASTIES Movement in plants.

NATRIUM. Sodium.

NATROLITE. The mineral natrolite, one of the **zeolites,** is a **sodium aluminum silicate** corresponding to the formula $Na_2Al(AlO)(SiO_3)_3$ $2H_2O$. It is **orthorhombic,** crystallizing in slender prisms of nearly square

cross-section which are terminated by flat pyramids There are also fibrous to compact varieties Natrolite is a brittle mineral, hardness, 5–5 5, specific gravity, 2 2, luster, vitreous, color, red, yellow, white, or colorless, transparent to opaque Natrolite is found with other zeolites in fissures and cavities in basaltic and related rocks Czechoslovakia, France, Italy, Norway, Scotland, Ireland, Iceland, Greenland, and South Africa contain well-known localities for natrolite In the United States it is found in the Triassic **traps** of New Jersey Its name natrolite refers to its soda content (E S C S)

NATURAL GAS. Petroleum.

NATURAL LOGARITHMS. Logarithms.

NATURAL NUMBERS. Number.

NAUPLIUS. A form of **larva** occurring in some of the **crustaceans** It is the first stage to hatch from the egg and is a minute ovoid creature, unsegmented, with three pairs of appendages (A W L)

NAUTICAL ASTRONOMY. The term nautical astronomy is applied to those problems in the transformation of **spherical coordinates** and in the solution of the **astronomical triangle** which are of particular importance to the navigator Among such problems may be cited the determination of **latitude, longitude,** and **azimuth** from a single **altitude** of a celestial object as taken with a **sextant** (W K G)

NAUTICAL MILE This is the fundamental unit of distance used in navigation and, for purposes of convenience, has been defined as 6080 feet Rigorously the nautical mile was defined as the length of one minute of arc on a great circle drawn on the surface of a sphere with the same area as the earth In accordance with this rigorous definition the length of the nautical mile is 6080 27 feet

The nautical mile is frequently confused with the geographical mile, which is defined as the length of one minute of arc on the earth's **equator** The geographical mile has a length of 6087 15 feet

Owing to the fact that the earth is an oblate spheroid and flattened at the poles the length of one minute of arc measured along a **meridian** varies in different latitudes It is shortest at the poles and longest at the equator, having an average length of 6076 82 feet

With sufficient accuracy for most navigational purposes the minute of arc on the meridian, the minute of arc on the equator, and the nautical mile may all be considered as 6080 feet It will be noted that such an assumption will never introduce an error greater than 0 8% (W K G)

NAUTILUS Mollusca, Cephalopoda The name of a genus of marine **mollusks**, also anglicized as a common name The animal lives in the last and largest chamber of a shell which is coiled in a flat spiral The three or four existing species are found in shallow to moderately deep water in the tropical oceans They are eaten by the natives of some of the Pacific islands

The paper nautilus, *Argonauta*, is not a true nautilus, but is more closely related to the octopus (See also **Invertebrate Paleontology**) (A W L)

NAVEL. The scar on the abdomen of mammals where the **umbilical cord** was attached during prenatal life (A W L)

NEANDERTHALOIDS. Paleontology of man.

NEAR-SIGHTEDNESS (MYOPIA). This is a condition of the **eye** due to a lens that is too convex, or to an eyeball that is too deep Parallel rays of light focus too soon to register the image clearly on the retina A concave lens is used to correct this condition See **Vision.** (R S M)

NEBULA. The term nebula (stella nebulosa) was originally applied by astronomers to distinguish any luminous spot which remained fixed among the stars Before the application of the telescope to astronomy probably the only objects of this character that were observed were certain of the galactic star **clusters,** although in the tenth century an Arabian observer gives a reference to the great **spiral** in Andromeda Following the application of the telescope, many more nebulous objects were discovered, and it was recognized some of them could be resolved into individual stars At present the term nebula is applied to any nebulous object which remains approximately fixed among the stars and which cannot be resolved into stars Nebulae may be divided into two major classifications the galactic nebulae and the extra-galactic nebulae This article will be limited to the galactic nebulae, while the extra-galactic nebulae will be treated under the title of **spirals**

The galactic nebulae receive their name from the fact that they are all members of our own **galactic system** and show the same general distribution relative to the galactic plane as is the case for the stars They may be conveniently discussed under three headings the dark nebulae, the diffuse nebulae, and the planetary nebulae.

The dark nebulae are, as their name implies, dark objects and can only be detected by the absorption which they produce Thus far, they have only been found in the **milky way,** for it is in this region of the sky that the stars are the most numerous, and hence the effects of an absorbing medium would be most noticeable Whether or not they exist in other portions of the sidereal universe is still a debatable question Examination of a good photograph of the milky way in the constellation of Ophiuchus will indicate at once the dark regions Barnard, in an extensive study of long exposure photographs of the entire milky way, lists nearly three hundred and fifty such markings They range in size from very small spots up to the huge rift that extends nearly a third of the way around the milky way, from **Cygnus** to Centaurus, and is clearly visible to the unaided eye In a few cases the dark nebulae are associated with stars and diffuse nebulae and the distances of these objects have been estimated as of the order of magnitude of 400 **light years** For very obvious reasons, comparatively nothing is known regarding the physical character of the dark nebulae It may be demonstrated that the total obscuration of the huge cloud in Ophiuchus could be produced by a total mass equivalent to twelve suns, provided the particles of the mass were of an optimum size

The so-called diffuse nebulae are similar to the dark nebulae in that they have no particular shapes at all, but appear much like clouds of vapor in space They differ from the dark nebulae in the important respect that they are luminous and can be extensively studied They are usually associated with stars and it has been conclusively shown that the material of which the nebula is composed is excited to luminescence by these stars Hubble has shown that there is a direct correlation between the brightness of the associated stars and the extent to which the diffuse nebulae are luminous, i e, the brighter the star the more extensive is the luminous nebula Furthermore, the characteristics of the spectrum of a luminous diffuse nebula are directly correlated with the spectral class of the associated star If the star is B-type or hotter, the spectrum of the nebula shows bright lines, if the star is cooler than B-type, the spectrum is of the dark line type, suggesting that the nebula is shining principally by reflected star light In the few cases where diffuse nebulae are associated with **variable stars,** the characteristics of the nebula change with the changes in the light from the associated stars

The density of the diffuse nebulae must be exceedingly low Dynamical studies of the huge diffuse nebula in **Orion** indicate a density of less than one-billionth that of air. It is apparently a more perfect vacuum than is produced in a laboratory, yet its immense size indicates

that its total mass may be comparable with that of the average star

The planetary nebulae receive their name from the fact that they have much the same appearance in a telescope as a small planet Detailed studies indicate that these objects are probably ellipsoidal masses of gas Studies with the spectroscope have indicated that the planetary nebulae are in rotation about the minor axis and that there is also a complicated internal motion in many of the objects The apparent disk is brighter at the edges than at the center and hence some of them appear as rings of light and are known as annular nebulae

In most cases the planetary nebulae have a star at their center, and this star is of the hot, blue **spectral class** There can be little doubt that the radiation from the nebulous material is directly associated with the central star Several attempts have been made to introduce the planetary nebulae into the evolutionary sequence for the stars, but without success

The spectra of the planetary nebulae and those bright diffuse nebulae that are associated with stars of spectral type B, or hotter, are characterized by bright lines of gaseous radiation These bright lines are identified with hydrogen, oxygen, helium, carbon, and nitrogen A number of the bright lines in the gaseous spectrum of the nebulae have never been reproduced in the laboratory For many years they were supposed to be produced by an unknown element which was called "nebulium," but research on the spectrum of oxygen has proved that they are due to this element under the unusual conditions existing in the nebulae In addition to the bright line spectrum, continuous and absorption spectra are observed, indicating that there must be some dust material in the nebulae which is reflecting the light from the associated stars (W K G)

NEBULIUM. Nebula.

NECK. In zoology, a slender region connecting two other parts of a body Particularly the region between the head and trunk of many vertebrates The vertebrate neck contains a series of cervical vertebrae, respiratory and food passages, and part of the central nervous system, but it is not invaded by the body cavity It varies greatly in relative length, a long neck usually compensating for long legs to enable the animal to reach the ground

In geology, a volcanic conduit of plug-like character consisting of lava and other volcanic products, which has been exposed by erosion (A W L, R M F)

NECROPSY. An autopsy examination of the body after death to discover or verify the cause of death (R S M)

NECROSIS Death of a portion of any tissue. (R S M)

NECTARY. Flower.

NECTOCALYX. A modified **medusa** occurring in coelenterates of the order **Siphonophora. Hydrozoa** (A W L)

NECTONEMATOIDEA. Nematomorpha.

NEGRO BUG. Insecta, Hemiptera Small shining black **bugs** with a smooth convex upper surface They resemble beetles superficially Most of the abdomen is covered by a greatly enlarged sclerite of the thorax which also conceals most of the wings (A W L)

NEKTON. The portion of a population made up of animals which are capable of directive locomotion through a fluid medium Usually applied only to aquatic animals, including the fishes, although flying creatures constitute a similar part of the terrestrial fauna and may be called an aerial nekton (A W L)

NEMATHELMINTHES. The roundworms, a major division of the animal kingdom containing both free-living and parasitic species, many living in the human body The most widely known species are the intestinal worms of man and the domestic animals, the hookworms, the spiny headed worms, and the horsehair worms

The phylum is characterized as follows 1 The body is not segmented and is usually cylindrical, tapering at the ends 2 The ectodermal covering is noncellular and secretes an elastic cuticle 3 The body wall includes an inner layer of muscle cells divided into contractile and noncontractile parts 4 The alimentary tract is a slender tube In some species it is tubular for only part of its length and in some it is completely lacking 5 The excretory system consists of two lateral tubes 6 The nervous system includes a ring around the esophagus and longitudinal cords extending through the body A dorsal and a ventral cord are the chief nerve tracts 7 The space between the body wall and the gut is filled with large cells containing many **vacuoles**, which join extensively and form an apparent body cavity

The phylum is divided into three classes which differ enough to be segregated by some biologists

Class **Nematoda** Without a spiny proboscis Intestine present The typical roundworms The **hookworms, eelworm,** and **Guinea worm** are among the species parasitic in man Some species attack plants and some live in earth or water

Class **Nematomorpha** (Gordiacea) The **hairworms** or horsehair worms No spiny proboscis Body cavity lined with epithelium Alimentary tract present Adults free in water, larvae parasitic in insects or crustaceans

Class **Acanthocephala** With a spiny proboscis No gut Parasitic in the intestine of vertebrates (A W L)

NEMATOBLAST. A term proposed by Becke, in 1903, for pseudo-**porphyritic** minerals of fibrous habit developed in **metamorphic** rocks (R M F)

NEMATOCYST A structure discharged by the stinging cells of coelenterates (**cnidoblast**) It consists of a flask-shaped body bearing barbs and a long slender filament (A W L)

NEMATODA. The threadworms A class of the phylum **Nemathelminthes** containing worms of many habits, some parasitic in man and the domestic animals The body lacks a spiny proboscis and is marked by slender longitudinal lines along the sides These lateral lines follow the excretory tubes

Two orders are recognized

Order Hologonia Genital tract an unbranched tube Both large and small species, parasitic in man and domestic animals Trichinella (**Trichina**), a serious parasite sometimes taken into the human body in insufficiently cooked pork, is a member of the order

Order Telogonia Genital tract of female with two or more branches Most nematodes belong in this order, including free-living, plant-feeding, and parasitic forms The **Guinea worm, eelworm,** and **hookworm** belong here (A W L)

NEMATOMORPHA. The **hairworms** or **horsehair worms,** a class of the phylum Nemathelminthes These worms receive their popular name from the old belief that horsehairs soaked in water turn into them Their abrupt appearance in watering troughs and small pools is, in fact, due to their living in the bodies of insects and crustaceans as larvae and emerging when they take on the adult form to live in the water

They differ from the true **nematodes** in the absence of lateral lines and in the presence during adult life of a limited body cavity lined with epithelium In appearance they are very long and slender, bluntly rounded at the anterior end and blunt or forked at the posterior end.

They have also been called Gordian worms from their

occasional massing in tangled clusters reminiscent of the famous Gordian knot

The class includes two orders

Order Gordioidea Fresh water and terrestrial species.

Order Nectonematoidea Marine species only (A W L)

NEMERTEA. Marine worms with a flattened body, often long and ribbonlike in form They are unsegmented and have no body cavity, hence they are sometimes included with the flatworms as a class of the phylum **Platyhelminthes** More often they are made a separate phylum because the alimentary tract is a tube opening with an anterior mouth and a posterior anus Like the free-living flatworms, they have ciliated (**cilia**) integument They are also provided with an eversible proboscis associated with but not derived from the alimentary tract No common name is available save nemertean or nemertine worms

These worms live among seaweed or at the bottom of the ocean and prey on living animals or eat dead ones They are not economically important A few freshwater species and a few parasitic forms are known

The phylum is divided into four orders

Order Paleonemertea Long and slender Mouth behind brain Outer muscles of body wall circular Marine species

Order Heteronemertea Long and slender Mouth behind brain Outer muscles of body wall longitudinal Marine

Order Hoplonemertea Either long and slender or short and thick Mouth in front of brain Marine, freshwater, terrestrial, and parasitic species, the last living on crabs

Order Bdellonemertea Short, flat, and broad, with a sucker at the posterior end Three species which live in the gill chamber of marine and fresh-water mollusks (A W L)

NEODYMIUM. Symbol Nd Atomic number 60. Atomic weight 144 27 Density 6 96 Melting point 840° C Type of compound Nd_2O_3, blue Color of salts rose-red Discovered by Welsbach in 1885 A member of the **cerium** sub-group of the rare earth metals (R K S)

NEOLITHIC. Paleontology of man.

NEON Symbol Ne Atomic number 10 Atomic weight 20 183 Density 0 9004 gram per liter, 0° C, 760 mm, or 0 696 when air equals 1 000 Melting point —248 7° C Boiling point. —245 9° C Isotopes 20 (90 0%), 21 (0 27%), 22 (9 73%), have been separated by **diffusion**, identified and quantitatively estimated by the mass **spectrograph**

Neon is a colorless, odorless gas, of negative chemical properties with ordinary materials Discovered by Ramsay and Travers in 1898

Neon is present in ordinary **air** to the extent of 1 part neon in about 65,000 air In a vacuum electric discharge tube neon shows a crimson glow, and is widely used in advertising illumination One of the early elements to be discovered having the property of **isotopism** (R K S)

NEOPITHECUS. Paleontology of man.

NEOPLASM. Any new or abnormal overgrowth of cellular tissue A neoplasm is a cellular **tumor** and may be either benign or malignant (R S M)

NEOSALVARSAN. A modified form of "salvarsan" (**arsphenamine**) used in the treatment of **syphilis.** (R S M)

NEOTENY. The retention of characteristics of immature stages during adult life Neoteny and **paedogenesis** are difficult to distinguish in some cases The latter is the attainment of sexual maturity by structurally immature animals Both are illustrated by distinct cases among the insects, where immature and adult life are marked by distinct stages The **larvae** of some **gall gnats** produce young, sometimes for a series of several generations, but the fact that some individuals become winged adults marks the condition as paedogenesis On the other hand, the females of some **beetles** (Phengodidae), when they have attained the stage corresponding to the winged adult males, still retain the form of the larva and are called glow worms This is a distinct case of the persistence of larval characters in adult life, or neoteny Among the vertebrates the phenomenon of neoteny has been most extensively studied in the **axolotl.** (A W L)

NEPENTHES. Insectivorous plants.

NEPHELINITE A dense, sometimes **porphyritic** rock made up almost wholly of **nephelite** and **augite** If olivine is present the rock is then classified as a nephelite **basalt** (E S C S)

NEPHELITE-SYENITE. A coarse crystalline **igneous rock** composed chiefly of alkali-**feldspars**, **nepheline**, and **femic** minerals, such as the soda-**pyroxenes** and **amphiboles** Accessory minerals are other soda-**feldspathoids**, **zircon**, **apatite**, and **sphene** Nepheline syenites occur in Canada in the provinces of Quebec, Ontario, and British Columbia The principal foreign localities are Norway, Greenland, Sweden, the Ural Mountains, the Pyrenees, Italy, Brazil, China, and the Transvaal region (R M F)

NEPHRIDIUM. The excretory tubule in **annelid** worms It consists typically of a convoluted tubule with a ciliated (**cilia**) opening called the nephrostome at the inner end, communicating with the body cavity At the outer end it empties by a minute pore on the surface of the body True nephridia are associated with the **coelomoducts** in the excretory systems of annelids (A W L)

NEPHRITIS. Inflammation or injury to the **kidney**, involving in varying degrees the cellular, intercellular, and blood vessel tissue of the kidney The term does not include the pus-producing infections which may involve the kidney

Nephritis is a common cause of death, ranking third or fourth as a leading cause How often it is a contributing factor in deaths primarily due to other causes is not known, except that it is a very common factor

Nephritis may be divided generally into acute and chronic forms

Various systemic, local diseases, and infections are frequently the cause of acute nephritis Of these disorders, those most commonly causing nephritis are upper respiratory infections, tonsilitis, and scarlet fever Certain chemicals, most often mercury compounds, can cause acute nephritis Syphilis can cause nephritis but it is not a common cause

Symptoms of acute nephritis often begin insidiously after some acute infection There is usually malaise, headache, some fever, swelling of ankles and other parts of the body, nausea, and vomiting These symptoms may be mild or severe, depending on the amount of kidney involvement The urine may be small in amount, abnormal in color, and its examination shows **albumin** to be present Microscopic examination shows red blood cells and casts Toxic symptoms are frequently present, producing delirium in some cases, or, rarely, convulsions **Uremia** may develop and **anemia** may occur

The outlook in acute nephritis is good with suitable treatment The mortality during the acute attack is low Some patients recover completely, others continue to show varying degrees of permanent kidney damage, occasionally chronic nephritis develops Future infection must be guarded against

A less acute form of nephritis occurs in which the prognosis is poor, with death usually resulting in one or two years Due to the inability of the kidney to secrete water and salt, swelling (edema) of the dependent portions of the body is marked Weakness is progressive and anemia is marked in the latter stages of the disease

Chronic nephritis is believed to be caused in many cases by antecedent infection, although this has not been proven Degenerative changes in the blood vessels are also believed to play a considerable part in the cause of this disease Alcohol does not seem to have any causal relationship

Chronic nephritis occurs in two forms chronic nephritis with edema, and chronic nephritis without edema

Chronic nephritis with edema occurs with a gradual onset, and many patients succumb after four or five years The most striking symptom is the edema Some patients actually drown from the accumulation of fluid in their lungs The legs may become tremendously swollen from the fluid which the kidneys are unable to secrete The bodily cavities fill up with fluid, and when discomfort occurs from it the fluid must be removed by inserting a needle into the chest or abdominal cavity Besides the edema there is progressively increasing malaise, anemia, digestive symptoms and often headache The blood pressure is elevated Uremia may develop as a terminal event, but usually some intercurrent infection causes death Chronic nephritis without edema is the most common form, and in practically every case there are changes of a degenerative character not only in the kidneys, but in the systemic blood vessels (vascular system) and heart The blood pressure is always increased and is usually very high, the systolic pressure being commonly over 200 The symptoms vary Most commonly there is a gradual loss of well-being with elevated blood pressure and other signs of hardening of the arteries (arteriosclerosis) Often uremia or a stroke are the first warnings of this insidious disease The urine and eye grounds usually give the first diagnostic signs during the course of a physical examination Loss of weight, increasing irritability, tiredness, nocturia, headache, and cardiac symptoms are common symptoms Anemia may be quite marked

Uremia occurs most commonly in this form and may develop suddenly or gradually Acidosis occurs in the latter stages Indigestion and other gastric symptoms are common and often severe Many cases die without the condition being suspected and the cause of death popularly is said to be due to a stroke or "acute indigestion"

Patients with this form of nephritis do not recover, death occurring in several months or years Life often can be prolonged, made useful and more comfortable Drugs do not play a part in treatment The main measures taken concern regulation of physical and mental activities, diet, prevention of infection, and, of course, removal of any diseased condition of the body where deemed feasible (R S M)

NEPHROMIXIUM. An excretory organ of segmented worms formed of the united **nephridia** and **coelomoducts** (A W L)

NEPHROSTOME. The ciliated (**cilia**) opening of the excretory tubules of segmented worms and vertebrates which communicates with the **coelom** It is characteristic of the primitive form of tubule in both groups but is lacking in many species The connection with the body cavity is then supplanted by an association of the excretory organs with the **circulatory system** (A W L)

NEPTUNE (c f tables of planetary data, page 865) Possibly the most interesting feature of the **planet** Neptune is the circumstance which led to its discovery After Uranus was discovered an orbit was computed, and, by reckoning backwards, it was found that the planet had been observed as a star on several occasions many years previous to its announcement as a planet The **orbital** elements computed from the observations made shortly after the discovery did not satisfy the old observations accurately, and, what was worse, the planet soon began to deviate from the computed path Even the introduction of **perturbations** by all of the then known planets failed to completely remove the deviations, and after a prodigious amount of computing, Leverrier, a young French astronomer, and Adams, an Englishman, both predicted that a new planet would be found in the **constellation** of **Aquarius** Search was made in this vicinity by the German astronomer Galle on the basis of Leverrier's prediction, and by Challis at Cambridge, England, using Adams' prediction Challis observed the new planet first, but failed to recognize it until after Galle had announced the discovery on September 23, 1846 The discovery of Neptune can safely be regarded as one of the greatest successes of the Newtonian gravitational theory and the methods of orbit computation

Neptune itself is a planet slightly less than four times the diameter of the earth, and a mass slightly greater than seventeen times that of the earth Its mean density is only 0 29 times that of the earth, and this low value, coupled with the high value of the **albedo** (0 52), indicates that the planet probably has a thick layer of atmosphere

Neptune is invisible to the naked eye, having a stellar **magnitude** of about 7 7, but can be readily observed in any telescope with aperture greater than 1 inch In small instruments it can only be distinguished from the stars by observing the change in position from night to night, but with larger instruments it appears as a small greenish disk Observations indicate that the disk is apparently circular and that there are no distinguishable surface markings Hence, telescopic observations tell nothing regarding the rotation period In 1928 Moore and Menzel, at the Lick Observatory, found from spectroscopic observations, employing the **Doppler** principle, that the planet has a rotation period of slightly less than sixteen hours, and that the planet is rotating in the same directional sense as the majority of the other members of the solar system

Neptune has one **satellite**, discovered by Lassell very shortly after the discovery of the planet Telescopically the object is very faint and can only be observed with large instruments From the brightness it is estimated that the satellite is similar to our own **moon** in size The orbit of the satellite is inclined at about 20° to the plane of the planet's equator and the satellite revolves about the planet in the direction opposite to that of the majority of the members of the solar system. (W K G)

NERNST EFFECT. If heat is flowing through a strip of metal and the strip is placed in a magnetic field perpendicular to its plane, a difference of electric potential develops between the opposite edges This phenomenon, discovered by Nernst in 1886, is analogous to the **Hall effect**, but with a longitudinal flow of heat replacing the longitudinal electric current If, to one looking along the strip in the direction of the heat flow, and with the magnetic field directed downward, the transverse potential drop is toward the right, the Nernst effect is said to be positive (But Nernst at first used the opposite convention) Bismuth, in which the phenomenon was first observed, shows the positive effect, iron the negative See also **Ettingshausen** and **Righi-Leduc effects.** (L D W)

NERNST HEAT THEOREM **Entropy.**

NEROLI OIL. **Volatile oils.**

NERVE A slender cord made up of nerve fibers (**neuron**). In the **vertebrates** the nerve is surrounded by

loose connective tissue called the epineurium. Each small bundle of fibers within the epineurium is surrounded by a thin compact perineurium, and from this layer thin septa, the endoneurium, run between the irregular groups of fibers within the bundle

Nerves form the communicating paths between the central **nervous system** and the various parts of the body, as well as the connections between ganglia They have been given special names according to their anatomical distribution, and a few functional properties have been indicated by descriptive terms Thus sensory or afferent nerves carry impulses from sense organs to the central nervous system and motor or efferent nerves lead out to muscles and other effectors Most nerves of the body contain fibers of each kind and so are mixed nerves Nerves arising from the brain in the vertebrates are called cranial nerves and those connected with the spinal cord are spinal nerves Typically all of these main nerves of the vertebrate are supposed to be based on the form of the spinal nerves, which connect with the cord by two roots The dorsal root bears a spinal ganglion and carries all the sensory fibers and the ventral root lacks a ganglion and is motor All sensory nerves bear a ganglion or arise from a sensory layer such as the retina of the eye and no purely motor nerves have ganglia

The motor components of these nerves grow out from cells in the central nervous system and the sensory components grow into the central system from ganglia or from sensory cells and also out from the ganglia toward the periphery of the body (A W L)

NERVE IMPULSE A progressive transfer of a condition of excitation along a **nerve** fiber, initiated by a stimulus acting upon a sensory organ, by a cell within the **nervous system**, or experimentally by direct stimulation of the nerve fiber

The nature of a nerve impulse is not wholly understood It is accompanied by electro-chemical changes, and according to recent reports may result in the formation of a minute amount of material at the end of the nerve fiber

The impulse activates some organ of the body or enters the nervous system, where it is relayed to other parts (A W L)

NERVOUS COORDINATION. The attainment of harmonious action of all component parts of the animal and the adjustment of its behavior to environmental conditions by communication and regulation through the **nervous system** All coordinative processes are of this type or of the type carried on by the secretion and distribution of **hormones** Nervous coordination has the advantage of rapidity, since the **nerve impulse** travels much more rapidly than materials can be transported It is responsible for the immediate adjustment of the animal to fluctuating conditions, while chemical coordination is extensively involved in the maintenance of the normal organic processes which are a more uniform part of the animal's activity Coordination in general is, however, due to close interaction of the two types, neither is wholly independent of the other

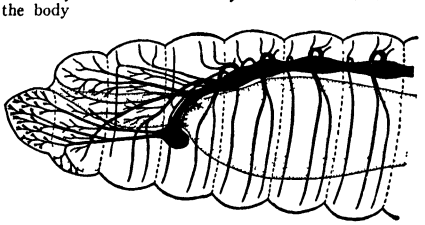
The process of coordination through the nervous system is based on the general sensitiveness of **protoplasm** known as irritability and on the property of conductivity by which some result of stimulation passes rapidly through the adjacent substance All living **cells** are irritable to some extent They respond to some stimulus with characteristic activity Sensory organs possess this property to a high degree and in addition are specialized to receive a certain kind of stimulus **Nervous tissue** is specialized for ready activation and for the rapid conduction of the impulse generated within it

The organs which receive stimuli as a special function for the benefit of the animal, whether relatively simple cells or extremely complex organs like the human **eye**, are known as receptors They have special nerve endings, often associated with other structures, and are connected by afferent or sensory nerves with other parts of the nervous system or, in very simple animals, with some organ capable of acting in response to the condition from which the stimulus arose Organs of the latter category are muscles, glands, electric organs, light organs, and some pigment cells, and are known collectively as effectors Usually one or more cells of the nervous system intervene between the sensory cell associated with the receptor and the motor cell which communicates directly with the effector The more complex this nervous chain, the more intricately may nerve impulses be relayed through different paths in the body, but in all cases the net result is the same All adjustments are due to the reception of stimuli by sense organs, both internal and external, followed by appropriate reaction of other parts of the body (A W L)

NERVOUS SYSTEM An organic system specialized for the ready reception of stimuli and the rapid transmission of a resulting change in its substance called the **nerve impulse** to other parts of the body The function of the nervous system is the regulation and coordination of the various parts of the body known as **nervous coordination**

All animals except **protozoans** and **sponges** have a nervous system derived from the ectoderm In the **coelenterates** it consists of scattered cells associated in a network which extends through the body without marked centralization In the flatworms the network persists, but in it nerve cells are massed near the anterior end of the body to form a cerebral ganglion or **brain**, and definite longitudinal paths can be traced from this center back through the body This centralization is associated with the change from radial to bilateral **symmetry** and persists in all bilaterally symmetrical animals With the attainment of radial symmetry by the echinoderms it is again lost The departure from the nerve net is marked by the attainment of synaptic organization In the nerve net impulses pass in either direction over nerve fibers and in the synaptic system they pass over the synapse in only one direction The ends of the fibers of different cells are closely associated in the **synapse** through which the impulse in one fiber acts as a stimulus to the others

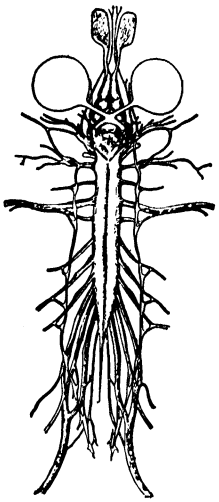
In all of the more complex nervous systems a major center, the **brain**, is present as a part of the central nervous system and supplementary centers called ganglia, each containing a small number of nerve cells, are scattered through the outlying parts of the system All of these parts are connected by nerve cords or **nerves** and are joined in the same way with other structures of the body



Nervous system of the earthworm Drawing showing a lateral view of the arrangement of the larger nerve trunks in the left half of the anterior segments of the earthworm

The most common type of nervous system among invertebrates consists of a small brain lying above the alimentary tract near the anterior end of the body It is connected by cords passing down around the sides of the gut with a ventral nerve cord In the **annelid** worms this cord is a chain of ganglia, one lying in each segment Conclusive evidence from **embryology** and

minute anatomy shows that the primitive cord was a paired structure and that each segment contained a pair of ganglia connected by transverse nerves as well. In most existing species the adult shows no visible evidence of the paired condition.

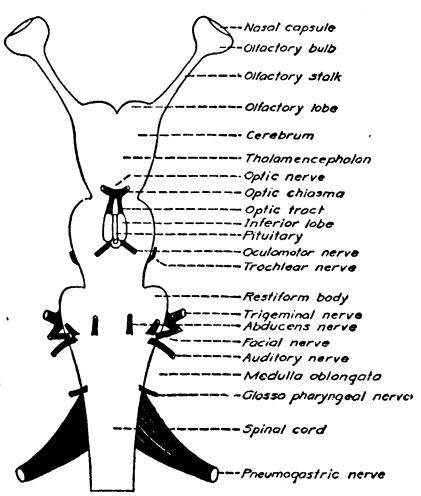


Ventral view of the nervous system of frog. (After Woodruff. *Foundations of Biology*, from Ecker. Courtesy of the Macmillan Co.)

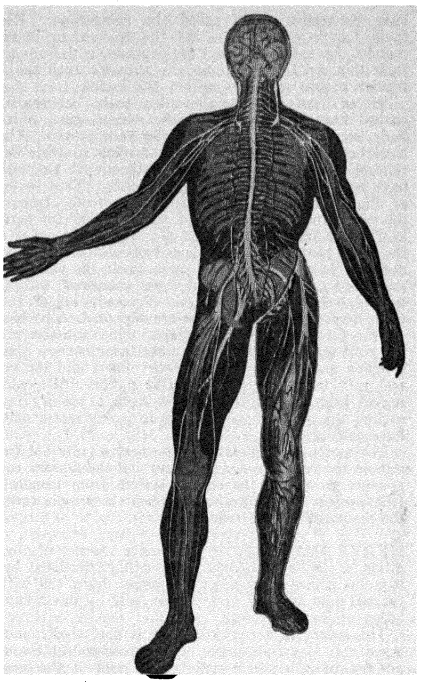
In the **arthropods** a concentration of ganglia in some species has resulted in one large ganglionic mass near the **anterior** end of the ventral cord.

Many **mollusks** have a number of pairs of ganglia of about equal size as nerve centers, although the cephalopods have a concentrated brain equal to any other invertebrates.

In the **vertebrates** the entire central nervous system lies above the alimentary tract. The brain is large and complex in most classes. From it a **spinal cord** runs back along the axis of the body. Both brain and spinal cord bear nerves which extend throughout the animal. Below the spinal cord two chains of ganglia connected by slender nerves with each other and with the spinal nerves constitute the sympathetic chains of the autonomic nervous system. Nerves of this system supply the viscera and are widely distributed elsewhere in the body. They control the functions which cannot be deliberately regulated by individual desire, such as the movements of the alimentary tract. (A.W.L.)



Ventral view of dogfish brain, showing cerebral nerves. (Drawn by W. J. Moore.)



Nervous system of man.

NERVOUS TISSUE. Nervous tissue proper is composed of cells specialized to a high degree in the properties of irritability and conductivity. These cells are called **neurons**. With the exception of a portion of the nervous system of echinoderms, which is said to be mesodermal, all nervous tissue originates from the ectoderm. More complex nervous systems such as that of the vertebrates also contain a supporting tissue called **neuroglia**, chiefly from the same source.

The bodies of nerve cells in most animals are concentrated in the central nervous system and in ganglia, while **nerves** are composed wholly of fibers and accessory sheaths. Even in the central system the tissue is not uniform, for some parts are fiber tracts and others are **nuclei** containing cell bodies or more extensive cellular layers like the cerebral cortex. Various regions, moreover, contain cells of special forms. Cells of the cortex, for example, include several forms with rounded to pyramidal bodies and a moderate number of processes, while in the cerebellum (**brain**) one form of cell is small, giving the tissue a granular appearance, and another, known as a Purkinje cell, bears a single process at one pole and numerous branching processes of mossy appearance at the other. In ganglia, too, the cells have characteristic forms. All nervous tissue, however, is composed of no more than the two components, neurons and neuroglia. (A.W.L.)

NEST. A place chosen or a structure built by an animal for shelter or concealment, usually for the reception of the eggs or young and as a home for the young during their early development.

The nest may be no more than a favorable spot on the ground or on the bottom of a body of water. Such spots are sometimes modified slightly, as in the shifting

of stones by fishes preparatory to depositing their eggs, or they may be used as found In other cases animals seek a more elaborate home such as a cave or a hollow in a tree, and often the retreat sought has already been prepared and used by another animal Birds illustrate all of these habits Not only do they deposit their eggs on the bare ground or in burrows, hollows, and nests prepared by other species, but also construct some of the most elaborate nests known Most species build a characteristic nest of sticks, fibers, or some other material Some are expert weavers and others merely pile their materials together The use of a salivary secretion by some of the swifts in the construction of their nests is widely known from the use of the nests in the Orient as an article of food

Many insects also build nests for the rearing of their young, and here, too, the nest may be only a burrow or a crevice, or it may be an elaborate structure such as the paper or mud nest of a wasp and the waxen combs of the honey-bee (A W L)

NETTLE Mint Family.

NETTLE CELL. Nematocyst

NETTLE HAIR. A form of hair-like scale found on some **caterpillars** which causes an irritation of human skin resembling that of nettles Caterpillars of the Io and the brown-tail moths have larger poisonous spines of similar properties The irritation caused by some species is very mild but others are much more severe (A W L)

NEURAL CREST. A strip of tissue formed from the ectoderm between the outer layer of the **neural fold** and the **neural tube** The two strips later fuse and then separate and divide into longitudinal series of masses, metamerically arranged, from which are formed the ganglia of the dorsal roots of the spinal **nerves**, the sympathetic ganglia, nerve sheath cells, and a part of the mesenchyme (A W L)

NEURAL FOLD. A longitudinal fold of tissue in the vertebrate embryo which contributes to the formation of the **neural tube** A pair of these folds arise along the dorsal surface, flanking the median line, very early in development (A W L)

NEURALGIA. Pain in a **nerve** or along the course of a nerve It is difficult to differentiate sharply between neuralgia and neuritis But, if there is a distinction, the term neuritis should be confined to acute and chronic inflammation of the peripheral nerves, while neuralgia is due to acute and chronic inflammation of the pathway stations (ganglia) lying along the course of nervous pathways The pain in neuralgia is usually of a sharp, shooting, intermittent type and accompanied by increased sensitivity of the skin supplied by the nerve Many varieties of neuralgia are differentiated according to the part effected Some of the common forms are (1) Trigeminal neuralgia, a very severe form marked by agonizing pain over branches of the trigeminal nerve in the face Palliative relief is obtained by injections of alcohol into the ganglion of the nerve and permanent and instantaneous relief by cutting the sensory root of the nerve, (2) Intercostal neuralgia—may be mistaken for pleurisy as the intercostal nerves, after leaving the spinal cord, run around each side of the chest between the ribs It may be accompanied by shingles, (3) Morton's neuralgia—pain in the joint of the third and fourth toe caused by pinching of a nerve in this region, (4) Cardiac neuralgia—angina pectoris, (5) Sciatic neuralgia (See **Sciatica**) (R S M)

NEURAL TUBE The embryonic structure from which the entire central **nervous system** of the **vertebrates** and much of the peripheral system are developed Early in embryonic life the ectoderm thickens along the upper surface of the body in the middle line On each side of this thickened strip the tissue rises in folds which finally approach each other and fuse, leaving the median strip in the form of a tube, now lying inside the body The further differentiation of the tube produces the central nervous system of the adult and the growth of other structures from it is the source of the motor nerve roots and the sympathetic system (A W L)

NEURASTHENIA (PSYCHASTHENIA) A condition marked by numerous related mental and physical symptoms produced by fatigue of the **nervous system** This is probably based on a disorder of **metabolism** of nervous tissue in conjunction with an unbalance of the endocrine gland system There are patients without number who are treated by stomach specialists for indigestion, constipation, or diarrhea, by cardiac specialists for rapid and palpitating hearts, by genito-urinary specialists for urinary and sexual complaints, and by surgeons and gynecologists for various pains and functional disabilities, when the real source of their troubles is abnormal fatigue of rather weak nervous systems, unable to stand the strain of present-day life Present-day life is one of overstimulation and even the physically robust may not always be able to stand the pace Even the young, under twenty years of age, are exposed to adverse conditions under the guise of smartness or "the thing to do," i e, late hours, drinking, and smoking, which are now almost universal, and begin at a much younger age than formerly These factors, plus overwork and worry, later in life, any physical disorder or disease that weakens the vital forces, or any poison as alcohol, or any exhausting factor, such as excessive sexual indulgence, all tend to produce the neurasthenic state The changes producing such a condition in the nervous system probably result from changes of chemistry in the nerve tissue and in the endocrine glands, each of which is independent of the other Anemia is often present in these cases, although it may only be of slight degree

The symptoms of this disorder are many and some of the common ones only will be mentioned The physical symptoms are tremor of the fingers, rapid heart and palpitation, dilated pupils, indigestion, pain in any or all parts of the body, especially the head and spine, spots before the eyes, dizziness, and ringing in the ears The mental symptoms are characterized by a general feeling of apprehension, with all the usual fears, phobias, and panics which show themselves on the slightest provocation Concentration is difficult Insomnia may be present, as may be irritability, imperative thoughts and obsessions

The most successful procedure in the treatment of this condition is, first a careful physical examination of the entire body, making sure to discover any organic disease or weakness, and, second, attempt should be made to improve the nutrition of the nervous system Third, it is helpful to change the patient's scene, climate, etc A change of environment, with new faces and interests, does more for this condition than anything else Fourth, suggestion plays an important part and really depends on the faith of the patient in the physician Psychoanalysis is dangerous and frequently the condition is changed from neurasthenia to **hypochondriosis** – from bad to worse—as a result of too much introspection In other words, the treatment is based on both the physical and mental, and if only one of the two is treated, failure is the result (R S M)

NEURITIS. An inflammation of a **nerve**, either chronic or acute Mononeuritis or localized neuritis is the term used when one nerve is involved When several or many nerves are involved the term multiple neuritis is used Localized neuritis develops from injury infection, chilling, chronic intoxication, or metal poisoning Chilling as a cause has been greatly overemphasized, however Neuritis either localized or multiple complicates

many of the infectious diseases, such as typhoid, diphtheria, tuberculosis, smallpox, etc Focal infection, as of teeth, tonsils, etc, may be the cause of both forms Other causes include pressure on a nerve by a tumor or calcium deposits in osteoarthritis, etc

Multiple neuritis —In addition to the causes mentioned above, **vitamin** deficiency, especially of vitamin B, can cause this disorder Beri-beri is an example, and the multiple neuritis so often seen in chronic alcoholics is most often due to the lack of vitamins because of the habit of substituting alcohol for the greater part of their diet It is often cured by giving adequate vitamin dosage, even though the drinking of alcohol cannot be stopped Many poisons cause multiple neuritis, such as arsenic, lead, coal tar products, mercury, copper, silver, zinc, and carbon monoxide The symptoms vary in both forms, but the most common are pain over the affected nerves and pain on motion Paralysis, weakness, and sensory changes often develop (R S M)

NEUROGLIA. Supporting **cells** of the central **nervous system**, derived, with the possible exception of microglia, like the nervous tissue from the ectoderm The cells are of various forms A common form in the vertebrate nervous system is the astrocyte, which has many fine processes radiating in all directions from the cell body In some astrocytes the processes are fibrous They form a network among the nerve cells and fibers (A W L)

NEURON. A **nerve** cell with all of its processes The processes include the dendrites which carry impulses to the **cell** body and the axon which carries an impulse from the cell body to some other nerve cell or to an organ such as a muscle At the end the processes branch This part of the axon is called the terminal arborization. The axon may also bear branches nearer to the cell body, called collaterals

Many nerve fibers in the central system and in peripheral nerves are surrounded by a sheath consisting of a fatty material called myelin, and in the nerves a cellular neurolemma or sheath of Schwann invests the whole The latter sheath ends before the terminal arborization and the myelin some distance before that (A W L)

NEUROPODIUM The ventral part of the **pseudopodium** of segmented worms

NEUROPTERA **Insects** of varied form and habits, including the **dobson fly**, the golden eyes or **lacewings**, the **alder flies**, and the **ant lions** The order is characterized by the four membranous wings, usually with a large number of branching veins which are united in some species to form a network The mouth is formed for biting but in some larvae the **mandibles** and **maxillae** fit together to form a piercing and sucking organ The insects are predacious

Neuroptera are of little economic importance save as food for fishes The larvae of lacewings prey on **aphids**, hence they are of some assistance in holding these pests in check

The order contains about 1200 species (A W L)

NEUROPTERIS **Paleobotany.**

NEUROSIS. A nervous disease due to a functional disorder of the nervous system It is a disorder of the nervous system not dependent on any discernible lesion The principal neuroses are hysteria, traumatic neurosis, shell shock, **neurasthenia.** (R S M.)

NEUROSYPHILIS. **Syphilis** involving principally the *central* nervous system The common forms are locomotor **ataxia**, syphilis of the spinal cord, and paresis, syphilis of the brain Neurosyphilis is one of the late stages of untreated syphilis **occurring** many years after the primary infection. (R S.M.)

NEUROTIC. According to its derivation this term refers to a person who is subject to a **neurosis;** more commonly the term has been used to describe a nervous individual in whom reason is subject to emotional domination (R S M)

NEUTRAL AXIS. The line of intersection of the **neutral plane** and any normal cross-section of a structural member is called the neutral axis When a straight bar of homogeneous material (rectangular for sake of illustration) is bent the fibers which are nearer the axis of flexure will shorten and those on the opposite side will lengthen There is one plane within the bar, parallel to its edges, in which there is no **deformation** of the fibers, this plane is known as the neutral surface The **flexure** theory shows that the neutral axis passes through the center of gravity of the cross-sectional area of any member (C W C)

NEUTRAL WIRE. The neutral wire of a 220–110 volt **direct current** system is one which is supplied from the midtap of the **balancer coil** While the voltage across the brushes, which rest on the **commutator,** is 220, the voltage from either of these to the neutral wire is 110 volts The neutral wire is also a feature of three-wire a-c circuits of the 220–110 volt type The neutral wire is brought out from the transformer at ground potential and 110 volts are obtained between either of the outside wires and the neutral, while 220 volts exist between the outside wires Three-wire service of this type is supplied where electric ranges or 220-volt motors are required in addition to lights and other apparatus commonly operated on 110 volts A three-phase **alternator** is usually connected so that a neutral wire can be brought out from the generator The neutral of Y-connected generators and **transformers** is usually grounded, either solidly or through grounding resistors. (F T M)

NEUTRALIZATION. **Acid, Bases, and Salts.**

NEUTRON. The neutron, like an un-ionized atom, is a neutral body, and has nearly the same mass as the atom of ordinary **hydrogen** That it is not a hydrogen atom is shown by its behavior and by the manner of its occurrence Neutrons were first recognized by Chadwick as the result of the impacts of alpha rays from radium upon the element beryllium (Many other elements yield neutrons upon bombardment, but less copiously) That they are neutral is shown by their great penetrating power in solids and by their not being deflected in a magnetic field Their mass has been deduced (not very accurately) from the recoil of the atoms of gases from which they are bombarded, and their speeds from their ranges in air Neutrons have proved effective as bombarding particles in producing **artificial disintegration.** Another type of neutron, having very much smaller mass, and called a neutret or neutrino, has recently been recognized (L D W)

NÉVÉ. **Glacier.**

NEWARK SERIES. This is a geological term, discussed under **Triassic.**

NEWT. Amphibia, Urodela Air-breathing **salamanders** which are at least partially aquatic in habits The many species are found chiefly in the northern hemisphere (A W L)

NEWTON (1642–1727) Isaac Newton was born at Woolsthorpe, Lincolnshire, England, on Christmas day, 1642 His father, a small freehold farmer, had died the previous October Upon his mother's second marriage in 1645 Isaac went to live with his grandfather When his step-father died in 1656, young Newton returned to Woolsthorpe to live with his mother and he attended the grammar school in Grantham for two years He

was removed from school and set to work on the farm, but, not being a successful farmer, he went to live with an uncle, who was rector of a small parish and a graduate of Trinity College, Cambridge The uncle, recognizing in his nephew a promise of a brilliant future, arranged for him to return to school and thence to Trinity College, Cambridge, where he matriculated in 1661 He proceeded in due course to the degree of Bachelor of Arts, and was elected a Fellow of Trinity College in 1667

During his early years at Cambridge the mathematical brilliancy of Newton began to make its appearance During 1665 Newton discovered what is now known as the **Binomial Theorem.** In 1666 he was at work on the development of what he called Fluxions, but which is now known as the **integral calculus.** In the same year, 1666, he began to theorize regarding the possibility of gravity extending out beyond the earth to the **orbit** of the **moon** Tradition states that his attention was directed to the study of gravitation by the fall of an apple while he was resting under a tree on the family farm at Woolsthorpe, to which place he had fled to escape the plague No matter what truth there may be in this legend, his first proof of the extension of the force of gravity beyond the surface of the earth came by comparing the force which the earth exerted on a falling body with the force necessary to hold the moon in its approximately circular orbit about the earth Nothing was published regarding his gravitational theory until eighteen years later It is said that the delay was caused by his attempt to extend his reasoning from the moon traveling about the earth to the earth traveling about the sun in which case he could not get satisfactory results, not because his theory was wrong, but rather because the distance of the earth from the sun was very imperfectly known at that time

During the years 1665 and 1666 Newton began his experiments on light and color His important contribution in that field was presented in a paper to the Royal Society in February, 1672, one month after his election to that notable organization In this paper he proved that sunlight is made up of a variety of different colors which may be dispersed by passage through a prism Previous to Newton's time it had been thought that the prism produced the colors Unfortunately, Newton made one serious error in his reasoning He asserted that the amount of **dispersion** was directly proportional to the deviation of the middle ray and was independent of the material of which the prism was constructed This statement, coming from one with the reputation which Newton had acquired, seriously delayed the invention of the **achromatic lens** His assertion was questioned by many other workers in optics and a controversy arose which became so heated that in 1675 Newton asserted "I was so persecuted by discussions that I blamed my own imprudence for parting with so substantial a blessing as my quiet to run after a shadow" The discussions bore fruit for Newton was forced to continue his studies and eventually developed what is now referred to as the **corpuscular theory of light** During the progress of the discussions Newton constructed his first reflecting telescope working along lines suggested by Gregory in 1663

While the discussion regarding the theory of light was raging, another group of members of the Royal Society, among whom was Edmund Halley, was attempting to explain the **Keplerian laws of planetary motion** on the basis of an inverse square law for gravitation In December, 1684, Halley went to Cambridge to discuss the matter with Newton and found to his amazement that Newton had been working on the same problem off and on for nearly twenty years and had reached some very definite conclusions, some of which were written out in form for publication Halley urged Newton to continue the work and present the material for printing. The result was that in mid-summer 1687, a series of three books, now commonly referred to as the Principia, were published, partly by the aid of funds supplied by Edmund Halley himself During his work on moving bodies Newton discovered independently the so-called laws of motion which had previously been stated by **Galileo** These laws of motion form the basis of the Newtonian or, as it is sometimes called, the Galileo-Newtonian system of mechanics

The Principia was received with great acclaim and the edition was sold out almost immediately The fame of Newton spread rapidly and with the fame came the numerous attacks that are always directed against any successful worker Hooke and Wren both claimed priority for much of the material in the Principia These claims were not entirely without foundation for certain of the ideas had been drifting about in Hooke's mind for some time Eventually that discussion was amicably settled Then, upon the publication of the theory of fluxions, Newton became involved in a bitter dispute with the German mathematician Leibnitz Among other vexations, Newton was elected to Parliament which he attended but there is no record of his ever having spoken In the midst of all the acclaim over the remarkable scientific work of Newton, it was suddenly discovered that he was poor and was forced to teach for a living Accordingly, in 1701, Newton was appointed Director of the Mint at a good salary and resigned from Cambridge to take up his duties in London In 1703, during his residence in London, he was elected President of the Royal Society, a position to which he was re-elected annually until his death In 1705 Queen Anne visited Cambridge and Newton was knighted He died in London in 1727 and his body lay in state in Jerusalem Chamber after which it was buried in Westminster Abbey (W K G)

NEWTONIAN POTENTIAL FUNCTION Potential

NEWTON'S LAW OF COOLING. From experiments upon the cooling of bodies, Newton concluded that, over moderate temperature ranges, the rate of cooling is proportional to the difference between the temperature of the cooling body and that of the surrounding medium This may be expressed as a differential equation, the solution of which for the temperature T as a function the time t is

$$T = T_m + (T_o - T_m)e^{-At}$$

in which T_m is the air temperature and T_o is the value of T at the beginning of the time interval t A is a constant depending upon the size, shape, material, and surface of the body While the law is only roughly approximate, it is nevertheless very useful for calorimeter corrections, etc See **Thermal Radiation** and **Stefan-Boltzmann Law.** (L D W)

NEWTON'S LAWS OF DYNAMICS. The classical or Newtonian **dynamics** rests upon certain propositions first enunciated in systematic form by Sir Isaac Newton, which he set forth as three "Laws" of force and motion

The first Law states, in effect, that bodies of matter do not alter their motions in any way except as the result of **forces** applied to them A body at rest remains at rest, or if in motion it continues to move in the same direction with the same speed, unless a force is impressed upon it It is quite conceivable that Newton's interpretation of "force" was the primitive concept which we all have, based on muscular effort, and that he regarded this statement as the expression of a natural law connecting force with motion On the other hand he may have recognized in this first Law, as we now do, an objective definition of force, namely, that which is capable of altering bodily motions in the face of an opposition called **inertia** whose nature is even now not fully understood

The second Law is made up of two distinct parts (a) When different forces are allowed to act upon free

bodies, the rates at which the **momentum** changes are proportional to the forces applied, (b) the direction of the change in momentum caused by a force is that of the line of action of the force Part (a) may now be regarded, from the more rigorous viewpoint of **dimensional analysis**, as a definition of the standard measure of force Two forces are judged equal if they produce change of momentum at equal rates, one force is twice as great as another if it changes the momentum at twice the rate, etc The absolute or Gaussian force units, such as the **dyne**, so much used in dynamic theory, are based upon this system of measure Part (b) emphasizes the **vector** character of force, and points out that no single force, acting alone, can cause a change of motion in any direction save that of its own line of action If the effect is apparently in some other direction, as when a string operates over a pulley, the force is always combined with one or more auxiliary forces, the **resultant** of all of them being in the direction of the observed change of motion

The third Law asserts the equality of "action and reaction" In the case of forces acting on bodies at rest, the principle is easily illustrated When a steel truss rests on a pier and presses downward upon it with a force of 100,000 pounds, the pier exerts an upward thrust or "reaction" against the truss, also of 100,000 pounds, and this thrust, tending to bend the truss upward, is a most important factor in computing the stresses in the truss members The Law also applies to forces acting upon bodies free to yield and to receive acceleration, a fact not explicitly stated by Newton, and discussed more fully elsewhere as **d'Alembert's principle.**

These propositions constituted the unquestioned foundation of dynamics until about the beginning of the twentieth century So far as practical operations with bodies of ordinary size are concerned, they still answer every purpose It is only when we consider motions with velocities comparable to that of light, or attempt to analyze the mechanics of bodies of the atomic and electronic order of magnitude, that the Newtonian dynamics breaks down and must be replaced by a system founded upon the postulates of **relativity** and the concepts of the **quantum theory.** (L D W)

NEWTON'S METHOD FOR SOLUTION OF EQUATIONS Let $x = a$ be a first approximation to a real **root** of an **equation** $f(x) = 0$, found by trial or by graph or otherwise Then a second approximation to the root is given by the formula

$$a' = a - \frac{f(a)}{f'(a)}$$

A new approximation may be obtained by substituting a' for a in this formula again, and so on until the desired degree of accuracy is attained The formula is based upon finding the point where the tangent at $x = a$ to the curve cuts the X-axis (L L S)

NEWTON'S RINGS An interference phenomenon, easily observed by laying a slightly convex lens upon a flat glass plate When the lens and plate are arranged so that monochromatic light is reflected at a suitable angle to the observer's eye, the point of contact is seen to be surrounded by a series of concentric, alternately bright and dark rings, which become closer together with increasing radius The rings are due to the interference of light at the film of air between the glass surfaces, which film increases in thickness with increasing distance from the contact point If the radius of curvature of the convex surface is R, and if, counting the central contact-spot as the zero ring, we number the rings in order, both bright and dark, from the center out, the radius of the Nth ring in monochromatic light of wave length λ is approximately

$$a = \sqrt{\frac{N R \lambda}{2}}$$

With white light, the bright rings become colored spectra, the overlapping of which at larger values of N causes the system to become indistinct and disappear (L D W)

NEW ZEALAND FLAX. Flax.

NICCOLITE. A **nickel arsenide** mineral, NiAs, crystallizes in the **hexagonal** system but is usually found massive Color, light copper red, hardness, 5 0-5 5, specific gravity, 7 33-7 67, luster, metallic, opaque Found in several European localities and in the Province of Ontario, Canada, in the United States at Franklin, New Jersey, and Silver Cliff, Colorado It is used as an ore of nickel (E S C S)

NICHOLS' RADIOMETER. The apparatus used by Nichols and Hull for the measurement of **radiation pressure** (1901) consisted of a pair of small, silvered glass mirrors suspended, in the manner of a **torsion balance**, by a fine quartz fiber within an enclosure in which the air pressure could be regulated The torsion head to which the fiber was attached could be turned from outside the enclosure by means of a magnet A beam of light was directed first on one mirror and then on the other, and the opposite deflections observed with mirror and scale By turning the mirror system around so as to receive the light on the unsilvered side, the influence of the air in the enclosure could be ascertained This influence was found to be a minimum, and to have an almost negligible value, at an air pressure of about 16 millimeters of mercury The radiant energy of the incident beam was deduced from its heating effect upon a small, blackened silver disk, which was found more reliable than the **bolometer** at first used With this apparatus the experimenters were able to obtain an agreement between observed and computed radiation pressures within about 0 6 of one per cent (I D W)

NICKEL. Symbol Ni Atomic number 28 Atomic weight 58 69 Density 8 9 Melting point 1452° C Boiling point 2900° C (Isotopes page 238)

Nickel is a silver-white metal, harder than **iron**, capable of taking a brilliant polish, malleable and ductile, magnetic below 345° C Compact nickel is not oxidized on exposure to air at ordinary temperatures, soluble in **nitric acid**, does not react with **alkalis**; becomes passive in concentrated nitric acid Finely divided nickel dissolves 17 times its own volume of **hydrogen**, and is extensively used as a **catalyzer** in the **hydrogenation** of oils Discovered by Cronstedt in 1751

Nickel is used (1) in **electroplating**, as a protective and ornamental coating for less resistant metals, especially iron and steel, (2) in coins of small denominations (25% Ni, 75% **copper**), (3) in nickel steel "invar" (26% Ni, 64% iron) of low coefficient of thermal expansion for standards of length, "permalloy" (80% Ni, 20% iron) for sheathing electric **cables**, (4) in monel metal (about 62% Ni and 31% copper), nichrome or chromel wire (50%–80% Ni, 11%–25% **chromium**, remainder iron) of high electrical **resistance** for heating units, german or nickel silver (10%–30% Ni, 50%–65% copper, remainder **zinc**), (5) in the alkaline (Edison) storage battery (See **Accumulator**), (6) extensively in corrosion resistant apparatus

Nickel occurs as sulfide (**pentlandite**) (NiS 2FeS) in Sudbury, Ontario, the ore averaging 3% nickel and 1 5% copper along with iron and some precious metals and as silicate carrying 4%–8% Ni and no copper in New Caledonia The Sudbury ore is roasted, and then treated in a **blast furnace** to obtain nickel and copper sulfides (25% metals), then in a **converter**, the product being composed of about 56% nickel, 24% copper and 20% **sulfur.** This is roasted to form nickel and copper oxides, and the copper oxide removed by dilute **sulfuric acid.** The residue is reduced to metallic nickel by heat-

ing with water gas (**hydrogen** and **carbon monoxide**), and the metal treated at 50° C. with **carbon monoxide** (Mond process), to form volatile nickel carbonyl, a very poisonous gas, which is then decomposed at 200° C. on nickel shot, nickel depositing on the shot and carbon monoxide being regenerated and used again.

Acetate: nickel acetate, nickelous acetate ($Ni(C_2H_5O_2)_2$), green solid, soluble.

Carbonyl: nickel carbonyl ($Ni(CO)_4$), liquid, melting point −25° C., boiling point about 43° C., by the reaction of carbon monoxide and nickel metal at about 50° C., and decomposed at 200° C. to nickel and carbon monoxide.

Chloride: nickel chloride, nickelous chloride ($NiCl_2 \cdot 6H_2O$), green crystals, soluble.

Cyanide: nickel cyanide ($Ni(CN)_2$), greenish-yellow precipitate by nickel salt solution and **potassium** cyanide solution; nickel potassium cyanide ($K_2Ni(CN)_4$), soluble, by excess of potassium cyanide with nickel salt solutions. Unchanged in boiling solution, and recovered by crystallization as reddish-yellow solid.

Hydroxide: nickel hydroxide, nickelous hydroxide ($Ni(OH)_2$), light green precipitate by reaction of nickel salt solution and **sodium** hydroxide solution; nickelic hydroxide ($Ni(OH)_3$).

Nitrate: nickel nitrate, nickelous nitrate ($Ni(NO_3)_2 \cdot 6H_2O$), green crystals, soluble.

Oxides: nickel monoxide, nickelous oxide (NiO), green to grayish green (yellow when hot) solid, by heating nickelous hydroxide or carbonate; nickel sesquioxide (Ni_2O_3), black solid, by heating nickelous nitrate, but the identity of this oxide is questioned; trinickel tetroxide (Ni_3O_4), gray solid, by heating the sesquioxide in **hydrogen** at 190° C.; nickel dioxide or its hydrate ($NiO_2 \cdot nH_2O$), black solid, by reaction of nickel salt solution and **sodium** hypochlorite solution, but the identity of this hydrate is questioned.

Sulfate: nickel sulfate, nickelous sulfate ($NiSO_4 \cdot 6H_2O$), green crystals, soluble.

Sulfide: nickel sulfide, nickelous sulfide (NiS), black precipitate by reaction of nickel salt solution with **ammonium** sulfide solution, relatively insoluble (after precipitation) in **hydrochloric acid.**

Dimethylglyoxime or diacetylglyoxime yields a characteristic red precipitate with nickel salts, of delicacy sufficient to detect one part of nickel in 400,000 parts of solution.

Nickel salts are green in solid or solution. (R.K.S.)

NICOL PRISM. One of the best known devices for producing plane-**polarized light.** It consists of two

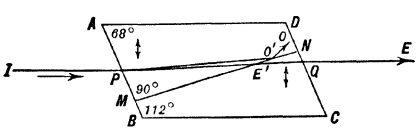


Diagram of Nicol prism. Double-headed arrows indicate direction of optic axis.

pieces of Iceland spar (pure calcium carbonate) cut as shown in the figure. The optic axis of each is approximately indicated by the double arrow, and they are cemented together with colorless Canada balsam along the plane *MN*. If the incident beam *IP* is unpolarized, it suffers **double refraction** at *P*, dividing into an ordinary component *PO'* and an extraordinary component *PE'*. The refractive index of Iceland spar for the ordinary ray (sodium light) is 1.658 and for the extraordinary it is 1.486, while that of Canada balsam for both is 1.53. The ordinary ray therefore encounters at *O'* a less refractive medium, and, the incidence being at an angle larger than the critical angle, it is totally reflected (*O'O*); while the extraordinary ray incident at *E'* encounters a more refractive medium, therefore cannot suffer total reflection and most of it passes on along *E'Q*, emerging along *QE* completely plane-polarized with its vibration plane in the plane of the paper. Modifications of this prism, having different shapes and using other cements, have been designed for special purposes. The use of such polarizers is somewhat limited by the scarcity and costliness of large Iceland spar crystals of suitable quality. (See also **Petrographic Microscope.**) (L.D.W.)

NICOTINE. **Alkaloids.**

NICTITATING MEMBRANE. The third **eyelid** of vertebrates.

NIDAMENTAL GLAND. Glands of the female reproductive system of **cephalopod** mollusks which secrete an elastic envelope about the egg. (A.W.L.)

NIGHTHAWK. Aves, Caprimulgiformes. **Nightjars** or **goatsuckers** of the New World. They have a very short beak and wide mouth, adapted for taking insects in flight, and are on the wing late in the day. Their flight is easy and powerful and their long dives, terminating in a peculiar hollow boom, are a memorable exhibition.

Nighthawk. *Chordeiles virginianus.* Mottled blackish brown and reddish; lighter below, with wavy brown bars. A large white patch on each wing; the male has white on throat and tail also.

The common nighthawk, *Chordeiles virginianus,* is widely distributed in North America and winters far into South America. A second species, the Texan nighthawk, *C. acutipennis,* enters the southwestern United States. (A.W.L.)

NIGHTINGALE. Aves, Passeriformes. A **warbler,** *Luscinia megarhyncha,* of western Europe, noted for its song. Farther east two other species, the eastern (*L. pheilomella*) and Persian (*L. hafizi*) nightingales, are found. (A.W.L.)

NIGHTJAR. Aves, Caprimulgiformes. Birds (**Aves**) with mottled plumage, a wide mouth and a short beak. They are insect eaters, flying chiefly at twilight. Every continent has some of the numerous species except Australia.

In North America the **nighthawk** and **whip-poor-will** are the most widely known representatives of the group, with the **poor-will,** chuck-will's widow (*Antrostomus carolinensis*) and Merrill parauque (*Nyctidromus albicollus*) as less widely distributed species.

Also called goatsuckers. (A.W.L.)

NIGHTSHADE. **Potato Family.**

NILGAI. Mammalia, Artiodactyla. An Indian **antelope,** *Boselephas tragocamelus,* of moderate size. The male has small horns, only slightly curved. (A.W.L.)

NIOBIUM. **Columbium.**

NIPPLE. The outlet of the breast which is composed of erectile tissue. Normally this protrudes but defects of development may produce an inverted nipple. (R.S.M.)

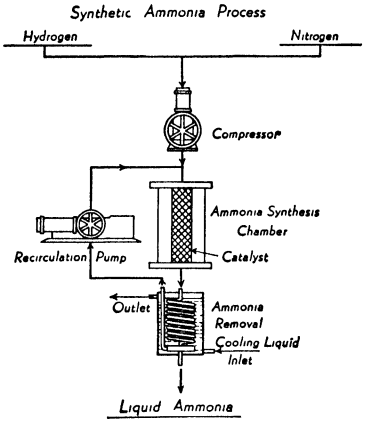
NITRATES. See each element for inorganic and organic nitrates; see also **Nitric Acid.**

NITRE. Nitre or saltpeter is a naturally occurring mineral form of **potassium** nitrate, KNO_3. It is found

only in small amounts as **orthorhombic** crystals or crystalline masses or crusts in limestone caverns or in soils. It is not an important mineral (R M F)

NITRIC ACID AND NITRATES. Nitric acid (HNO_3) is a colorless solution, commercially of strength 36° Baumé (specific gravity at 60° F, water at 60° F, 1 330, 52 30% HNO_3), specific gravity 1 42 (approximately 69% HNO_3) Sometimes colored yellow to brown by nitrogen tetroxide Higher strengths of nitric acid than 69% HNO_3 are used as "fuming nitric acid" (85% to 95% HNO_3) "Mixed acid" is a mixture of nitric and **sulfuric acids.** There is a maximum constant boiling point 120 5° C (760 mm) at 68% HNO_3 (distillate) for mixtures of nitric acid and water A commonly used strength for dilute nitric acid is 31 5 grams HNO_3 per 100 milliliters of solution (5 normal)

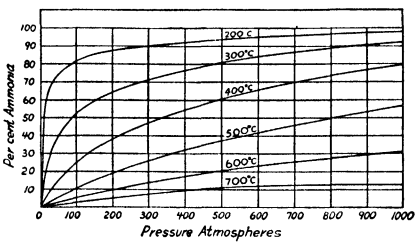
Dilute nitric acid reacts (1) with many hydroxides, e g, **sodium** hydroxide, to yield the corresponding nitrate, e g, sodium nitrate, solution, (2) with many ordinary oxides, e g, **magnesium** oxide, to yield the corresponding nitrate, e g, magnesium nitrate, solution; (3) with many carbonates, e g, **calcium** carbonate, to yield the corresponding nitrate, e g, calcium nitrate, solution plus **carbon dioxide** gas, (4) with some sulfides, e g, **copper** sulfide, to yield the corresponding nitrate, e g, copper nitrate plus **hydrogen sulfide gas,** (5) with



Diagrammatic representation of the manufacture of ammonia from hydrogen and nitrogen

many metals, e g, **copper,** to yield the corresponding nitrate, e g, copper nitrate, solution plus **nitric oxide** gas, (6) with cold freshly prepared solution of **ferrous** salt, when carefully stratified by concentrated sulfuric acid beneath, to yield a brown boundary layer of solution (nitrates react similarly)

Higher strengths of nitric acid react similarly in kind in the cases of (1), (2), (3), (6) above, but not, in general, in the remaining cases, (4) **sulfides** react to yield the corresponding nitrates, but accompanied by **sulfate** or **sulfur,** (5) reactions with metals depends upon the metal and the strength of nitric acid **Copper** and concentrated nitric acid yield copper nitrate and **nitrogen tetroxide. Iron** is made passive by concentrated nitric acid, so that when dipped into copper sulfate solution copper metal is not deposited (on nonpassive iron a deposit of copper metal forms) **Tin** and **antimony** yield stannic and antimonic oxides respectively



Graph showing ammonia equilibria

Concentrated nitric acid is (7) thus a powerful oxidizing agent and further examples of its action are the oxidation of **sulfur** to **sulfuric** acid, of **hydrogen sulfide** to sulfur, of **hydriodic acid** to **iodine,** and of cane sugar (sucrose) to **oxalic acid,** (8) a powerful nitrating agent (the reacting nitric acid usually reduced to nitrogen tetroxide or nitric oxide), thus **phenol** is nitrated to nitrophenols (mono- ortho- or para-, di- 2,4-nitro, tri-2,4,6-nitro), (9) an esterification agent, e g, **glycerol** esterified to glyceryl nitrates (mono, di, trinitrate)

In order to obtain nitric acid, (1) sodium nitrate is heated with the proper amount of sulfuric acid, whereupon nitric acid is **distilled** and condensed, with some accompanying loss due to formation of nitrogen oxides, (2) free nitrogen of the air is "fixed" by combination with hydrogen to form ammonia (Graph above) which may then be mixed with air or oxygen at a suitable temperature and passed over a **catalyzer,** which is usually smooth compact **platinum** in the form of very fine wire gauze in order to expose a maximum surface for the weight used The resulting nitrogen oxides—nitric oxide and nitrogen tetroxide—are absorbed in water, and the dilute acid obtained is subsequently concentrated by distillation Nitrogen oxides are also obtained by passing air (oxygen and nitrogen) through an electric arc This is the "arc" process for fixing nitrogen

The uses of nitric acid have been suggested by the chemical reactions previously cited, and the largest quantities are used in nitration and esterification of organic substances for explosives, plastics and dyes, and as an acid to prepare nitrates

All nitrates are soluble in water A few are decom-

REPRESENTATIVE ESTERS OF NITRIC ACID

Methyl nitrate	(CH_3ONO_2) explodes at 65° C
Ethyl nitrate	($C_2H_5ONO_2$), boiling point 88° C
Glycol dinitrate	($C_2H_4(ONO_2)_2$), explodes at 114° C
Glycerol alpha-mononitrate	($CH_2OHCHOHCH_2ONO_2$), melting point 58° C
Glycerol beta-mononitrate	(CH_2OH $CHONO_2$ CH_2OH), melting point 54° C
Glycerol 1,2-dinitrate	(CH_2OH $CHONO_2$ CH_2ONO_2), explosive
Glycerol 1,3-dinitrate	(CH_2ONO_2 $CHOH$ CH_2ONO_2), boiling point 148° C at 15 mm pressure.
Glyceryl trinitrate (nitroglycerine)	(CH_2ONO_2 $CHONO_2$ CH_2ONO_2), melting point 13° C, explosive at 260° C.
Cellulose trinitrate	$(C_{12}H_{10}(OH)_7(ONO_2)_3)$
Cellulose tetranitrate	$(C_{12}H_{10}(OH)_6(ONO_2)_4)$
Cellulose pentanitrate	$(C_{12}H_{10}(OH)_5(ONO_2)_5)$
Cellulose hexanitrate (guncotton)	$(C_{12}H_{10}(OH)_4(ONO_2)_6)$

posed by water with the formation of insoluble basic nitrates, e g, **bismuth** nitrate ($Bi(NO_3)_3$) to bismuth oxynitrate ($BiONO_3$), which are dissolved by excess nitric acid Most nitrates (distinction from basic nitrates) are less soluble in nitric acid than in water, e g, **lead** nitrate Metallic nitrates, when heated, behave in an individually characteristic manner, e g, **potassium** nitrate, melting point 333° C, evolves oxygen gas at high temperatures, leaves a residue of nitrite, **ammonium** nitrate, melting point 170° C, evolves nitrous oxide gas at somewhat higher temperatures, **copper** nitrate melts upon heating and at higher temperature evolves nitrogen dioxide and oxygen gases leaving a residue of cupric oxide, **silver** nitrate, melting point 212° C, at 320° C decomposition begins into oxygen and silver nitrite, at high temperatures the residue is silver

A common test for nitrates is as follows An aqueous solution of the nitrate is carefully mixed with an equal volume of concentrated **sulfuric acid,** cooled and a layer of **ferrous** sulfate is carefully poured down the side of the test tube to form two layers in the tube A brown ring at the interface indicates presence of nitrate (R K S)

NITRIC OXIDE. Nitrogen.

NITRILES. Hydrocyanic Acid and Cyanides.

NITRITES See each element, see also **Nitrous Acid,** for inorganic and organic nitrites

NITRO- AND NITROSO-COMPOUNDS. Nitro-compounds contain the nitro-group (—NO_2) attached directly to **carbon** atom, nitroso-compounds contain the nitroso-group (—NO) similarly attached A very important member of this group is nitrobenzene, which upon reduction yields a variety of products, important in the synthesis of drugs and dyes

ALKYLNITRO-COMPOUNDS

Primary	Secondary	Tertiary
CH_3CH_2 NO_2	$(CH_3)_2CH$ NO_2	$(CH_3)_3C$ NO_2
Nitroethane	Nitrodimethylmethane (2 nitropropane)	Nitrotrimethylmethane

ISOMERIC NITRITES

CH_3CH_2 ONO	$(CH_3)_2CH$ ONO	$(CH_3)_3C$ ONO
Ethyl nitrite	Isopropyl nitrite	1,1-dimethylethyl nitrite

ALKYLNITROSO-COMPOUNDS

CH_3CH_2 NO	$(CH_3)_2CH$ NO	$(CH_3)_3C$ NO
Nitrosoethane	Nitrosodimethylmethane	Nitrosotrimethylmethane

NITRATES

CH_3CH_2 ONO_2	$(CH_3)_2CH$ ONO_2	$(CH_3)_3C$ ONO_2
Ethyl nitrate	Isopropylnitrate	1,1-dimethylethylnitrate

NITROSAMINE

$(C_2H_5)_2N$ NO

Diethylnitrosamine

Upon reduction, nitro- and nitroso- compounds form the corresponding **amine;** nitrites and nitrates form the corresponding **alcohol;** nitrosamines form the corresponding **hydrazine.**

Upon oxidation, nitroso-compounds form the corresponding nitro-compounds

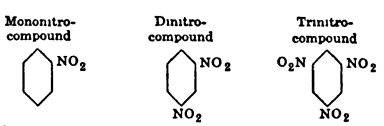
Upon treatment with **sodium** hydroxide solution, nitrites and nitrates form the corresponding alcohol plus **sodium** nitrite and nitrate, respectively Primary and secondary nitro-compounds, with **sodium** methylate ($NaOCH_3$) in alcohol form salts of isonitro-compounds, $CH_3CH_2NO_2$ yielding CH_3CH NO(ONa), and $(CH_3)_2$ $CHNO_2$ yielding $(CH_3)_2C$ NO(ONa) These salts are derived from an acid form $\left(-CH\ N\begin{matrix}O\\OH\end{matrix}\right)$ of the pseudo-acid $\left(\text{true nitro-compounds } \left(-CH_2\ N\begin{matrix}O\\O\end{matrix}\right)\right)$

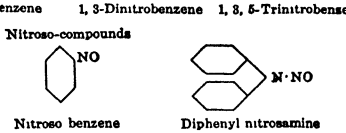
Upon treatment with **nitrous acid,** primary nitro-compounds form nitrolic acids, e g, nitroethane (CH_3CH_2 NO_2) yields ethylnitrolic acid $\left(CH_3C\begin{matrix}NOH\\NO_2\end{matrix}\right)$, which dissolves in **sodium** hydroxide to form $\left(CH_3C\begin{matrix}NONa\\NO_2\end{matrix}\right)$ red color, secondary nitro-compounds form pseudo-nitrols, e g, 2-nitropropane ($(CH_3)_2CHNO_2$) yields 2,2-nitrosonitropropane $\left((CH_3)_2C\begin{matrix}NO\\NO_2\end{matrix}\right)$ 2, colorless, solid but on fusion or in solution changes to blue color, tertiary nitro-compounds are unaffected

Upon treatment with **sodium** hypobromite (or hypochlorite) primary and secondary nitro-compounds form bromo- (or chloro-) nitro-compounds, thus, nitroethane CH_3CH_2 NO_2) yields 1-bromo-1-nitroethane (CH_3CHBr NO_2), and 1,1-dibromo-2-nitroethane (CH_3CBr_2 NO_2), 2-nitropropane ($(CH_3)_2CH$ NO_2) yields 2-bromonitropropane-2 ($(CH_3)_2CBr$ NO_2), tertiary nitro compounds are unaffected

Alkylnitro-compounds are made (1) by reaction of the alkyl iodide (See **Iodine**) and **silver** nitrite Higher alkyl members yield increasing proportions of nitrite along with the nitro-compound, but these frequently may be separated by fractional **distillation.** Tertiary alkyl iodides do not behave in this manner, (2) by reaction of alpha-substituted halogen acids and **sodium** nitrite, followed by loss of **carbon dioxide,** e g, chloroacetic acid (CH_2Cl COOH) yields nitroacetic acid (CH_2NO_2 COOH) and then nitromethane plus **carbon dioxide,** (3) by reaction of the higher **hydrocarbons** with **nitric acid,** e g, normal-decane ($C_{10}H_{22}$) plus fuming nitric acid furnishes a 30 per cent yield of normal-1-nitrodecane ($C_{10}H_{21}$ NO_2)

BENZENOID NITRO- AND NITROSO-COMPOUNDS.





Under the proper conditions of concentration of **nitric acid** and of temperature, **benzene** forms mainly nitrobenzene, nitrobenzene forms mainly 1,3-dinitrobenzene, and 1,3-dinitrobenzene, mainly 1,3,5-trinitrobenzene

When nitrobenzene is treated (1) with **zinc** and **calcium** chloride or ammonium chloride solution, beta-phenylhydroxylamine (C_6H_5NHOH) is formed, and from this by treatment with **chromic acid** or **ferric** chloride nitrosobenzene is formed, (2) with **tin** or **iron** and **hydrochloric** acid, **aniline** ($C_6H_5NH_2$), is formed and from this by treatment with **nitrous acid** followed by treatment with **stannous** chloride plus **hydrochloric acid phenylhydrazine** (C_6H_5NH NH_2) is formed (For other reactions of nitrobenzene see **Azo-, Diazo- and Related Compounds.**)

Mono-or poly substituted nitro-compounds are changed in whole or in part to the corresponding amino-compounds by proper choice of reducing agent and temperature, e g , in acid medium 1,3-dinitrobenzene yields 1,3-phenylendiamine ($C_6H_4(NH_2)_2(1,3)$), and with ammonium sulfide yields 3-nitraniline-1 ((1)$H_2NC_6H_4NO_2(3)$) When diphenylnitrosamine is reduced, 1,1-diphenylhydrazine ($(C_6H_5)_2N\ NH_2$) is formed

SELECTED REPRESENTATIVE NITRO–COMPOUNDS

	Nitro-Compounds	Formula	Melting Point, ° C	Boiling Point, ° C
1	Nitrobenzene	$C_6H_5\ NO_2$	6	211
2	1,2-Dinitrobenzene	$C_6H_4(NO_2)_2$ 1,2	116	319
3	1,3-Dinitrobenzene	$C_6H_4(NO_2)_2$ 1,3	90	302
4	1,4-Dinitrobenzene	$C_6H_4(NO_2)_2$ 1,4	172	299
5	1,2,3-Trinitrobenzene	$C_6H_3(NO_2)_3$ 1,2,3	127	
6.	1,2,4-Trinitrobenzene	$C_6H_3(NO_2)_3$ 1,2,4	61	
7	1,3,5-Trinitrobenzene	$C_6H_3(NO_2)_3$ 1,3,5	121	decom
8	2-Nitrotoluene	(1) $CH_3C_6H_4(NO_2)$ (2)	−11	222
9	3-Nitrotoluene	(1) $CH_3C_6H_4(NO_2)$ (3)	15	231
10	4-Nitrotoluene	(1) $CH_3C_6H_4(NO_2)$ (4)	51	238
11	2,4-Dinitrotoluene	(1) $CH_3C_6H_3(NO_2)_2$ (2,4)	70	300
12	2,6-Dinitrotoluene (Five others)	(1) $CH_3C_6H_3(NO_2)_2$ (2,6)	61	
13.	Trinitrotoluene ("T N T " (Three others)	(1) $CH_3C_6H_2(NO_2)_3$ (2,4,6)	81	240 expl.
14	2-Nitrophenol	$HOC_6H_4\ NO_2$ (2)	44	214
15	3-Nitrophenol	$HOC_6H_4\ NO_2$ (3)	96	194 (70 mm)
16	4-Nitrophenol	$HOC_6H_4\ NO_2$ (4)	113	
17	2 4-Dinitrophenol (Five others)	$HOC_6H_3(NO_2)_2$(2,4)	114	
18	2,4,6-Trinitophenol (picric acid) (Three others)	$HOC_6H_2(NO_2)_3$(2,4,6)	122 expl	>300
19	2-Nitrobenzaldehyde	$C_6H_4(CHO)(NO_2)$ (1,2)	41	153 (23 mm)
20	3-Nitrobenzaldehyde	$C_6H_4(CHO)(NO_2)$ (1,3)	38	
21	4-Nitrobenzaldehyde	$C_6H_4(CHO)(NO_2)$(1,4)	58	164 (23 mm)
22	2-Nitrobenzoic acid	$C_6H_4(COOH)(NO_2)$ (1,2)	147	
23	3-Nitrobenzoic acid	$C_6H_4(COOH)\ (NO_2)$ (1,3)	140	
24.	4-Nitrobenzoic acid	$C_6H_4(COOH)\ (NO_2)$ (1,4)	240	subl
25	2-Nitrobenzyl alcohol	$C_6H_4(CH_2OH)(NO_2)$ (1,2)	74	270
26	3-Nitrobenzyl alcohol	$C_6H_4(CH_2OH)\ (NO_2)$ (1,3)	27	175 (3 mm)
27	4-Nitrobenzyl alcohol	$C_6H_4(CH_2OH)\ (NO_2)$ (1,4)	93	185 (12 mm)
28	1-Nitronaphthalene	$C_{10}H_7(NO_2)$ (1)	59	304
29	2-Nitronaphthalene	$C_{10}H_7(NO_2)$ (2)	79	165 (15 mm)
30	2-Nitro-1-naphthol	$C_{10}H_6(OH)(NO_2)$ (1,2)	128	
31	4-Nitro-1-naphthol	$C_{10}H_6(OH)(NO_2)$ (1,4)	164	
32	1-Nitro-2-naphthol	$C_{10}H_6(NO_2)(OH)$ (1,2)	103	
33.	9-Nitroanthracene (nitrosoanthron)	$C_{14}H_9\ NO_2$ (9)	146	>360
34	1-Nitroanthraquinone	$C_6H_4(CO)_2C_6H_3(NO_2)$ (1)	230	subl
35	2-Nitroanthraquinone	$C_6H_4(CO)_2C_6H_3(NO_2)$ (2)	185	270 (7 mm)
36	Nitromethane	CH_3NO_2	−28	101
37	Dinitromethane	$CH_2(NO_2)_2$.		
38	Trinitromethane (nitroform)	$CH(NO_2)_3$	15	126
39	Trichloronitromethane (chloropicrin)	CCl_3NO_2		112
40	Tetranitromethane	$C(NO_2)_4$	13	
41	Nitroethane .	$CH_3CH_2NO_2$	<−50	115
42	Dinitroethane	$CH_3CH(NO_2)_2$		
43	1-Nitropropane (norm)	$C_3H_7NO_2$		131
44	1-Nitrobutane (norm)	$C_4H_9NO_2$		151
45.	1-Nitropentane (norm)	$C_5H_{11}NO_2$		172
46	1-Nitrohexane (norm)	$C_6H_{13}NO_2$		193
47.	Nitroethyl alcohol	$CH_3OHCH_2NO_2$	<−80	194
48	Nitrobromoform (bromopicrin)	NO_2CBr_3	10	Expl
49	Nitrochloroform (chloropicrin)	NO_2CCl_3	−64	112
50	Nitrofurane	$C_4H_3O\ NO_2$	28	
51.	Nitrourea. . .	$OC(NH_2)(NHNO_2)$	155 dec.	
52	Nitroguanidine .	$HNC(NH_2)(NHNO_2)$.	246	
53.	1,2-Nitroaniline	$C_6H_4(NO_2)(NH_2)$ (1,2)	72	
54	1,3-Nitroaniline	$C_6H_4(NO_2)(NH_2)$ (1,3) .	114	>285
55	1,4-Nitroaniline	$C_6H_4(NO_2)(NH_2)$ (1,4)	146	

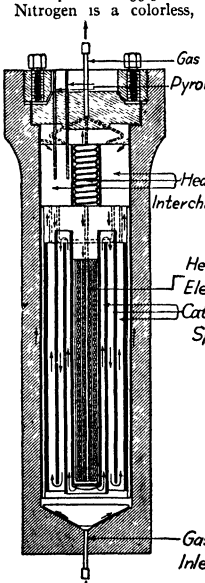
SELECTED REPRESENTATIVE NITROSO-COMPOUNDS

	Nitroso Compounds	Formula	Melting Point, ° C	Boiling Point, ° C
1	Nitrosobenzene	C_6H_4NO	68	58 (18 mm)
2	2-Nitrosotoluene	$C_6H_4(CH_3)(NO)$ (1,2)	72	
3.	3-Nitrosotoluene	$C_6H_4(CH_3)(NO)(1,3)$	53	
4	4-Nitrosotoluene	$C_6H_4(CH_3)(NO)$ (1,4)	48	
5	4-Nitrosophenol (4-quinoneoxime)	$C_6H_4(OH)(NO)$ (1,4)	125	144 dec.
6	4-Nitrosonaphthol-1 (4-naphthaquinoneoxime)	$C_{10}H_6(OH)(NO)$ (1,4) or $(C_{10}H_8(O)(NOH)$ (1,4)	193	
7	2-Nitrosonaphthol-1	$C_{10}H_6(OH)(NO)$ (1,2)	163 dec	
8	1-Nitrosonaphthol-2	$C_{10}H_6(OH)(NO)$ (2,1)	109	
9	4-Nitrosoaniline (Quinoneimideoxime)	$C_6H_4(NH_2)(NO)$ (1,4) $(C_6H_4(NH)(NOH)$ (1,4))	173	
10.	N-Nitrosomethylaniline	$C_6H_5N(CH_3)(NO)$	13 appr	128 (20 mm)
11.	4-Nitrosophenylaniline	$C_6H_5NH\ C_6H_4NO$	145	
12	1-Nitrosonaphthylamine-2	$C_{10}H_6(NH_2)(NO)$ (2,1)	151	
13	Diphenylnitrosamine	$(C_6H_5)_2N\ NO$	66	
14	Dimethylnitrosamine	$(CH_3)_2N\ NO$		153 (774 mm)
15	Diethylnitrosoamine	$(C_2H_5)_2N\ NO$		177 (RKS)

NITROBENZENE. Nitro and Nitroso Compounds. NITROCELLULOSE. Explosives.

NITROGEN. Symbol N Atomic number 7 Atomic weight 14 008 Density 1 2505 grams per liter, 0° C, 760 mm or 0 967 when air equals 1 000 Formula of nitrogen gas N_2 Melting point — 209 86° C Boiling point — 195 8° C Critical temperature — 147 1° C. Critical pressure 33 5 atmospheres

Nitrogen is a colorless, odorless, tasteless, non-toxic gas, found free in the **atmosphere** (78 03% by weight nitrogen) mixed with **oxygen, argon, carbon dioxide,** and water vapor Nitrogen was recognized as a simple gas by Lavoisier about 1776, although previously isolated by Rutherford in 1772 Isotopes 14 (99 7%), 15 (0 3%) The free gas nitrogen is among the least reactive substances chemically, but many of its compounds display marked reactivity, eg, **nitric acid,** glyceryl nitrates, **cellulose** nitrates, nitrotoluene, **picric acid,** the last four being important explosives Nitrogen occurs combined locally in Chile as **sodium** nitrate, and as a constituent of many plant and animal proteins (See **Aminoacids**) In the atmosphere nitrogen serves as a diluent for the oxygen in the processes of burning and respiration. Nitrogen is an important element in plant nutrition, eg, in the form of nitrates, in animal nutrition, eg, in the form of **proteins,** and many of its compounds are important **explosives, dyes,** and **drugs.** The fixation of atmospheric nitrogen is accomplished in nature by certain **bacteria** of the soil Several processes have been exploited for the commercial fixation of nitrogen of the atmosphere Of these, one of the first was the combination of nitrogen and oxygen into nitric oxide by means of the electric spark, developed in Norway, another was the formation of **aluminum** nitride and thence **ammonia,** but the process which has survived practically to the displacement of all others is the combination of nitrogen and **hydrogen** gases in the **catalytic** reaction to form ammonia (See **Chemical Changes,** also **Nitric Acid.**)



Bomb for the manufacture of ammonia from nitrogen and hydrogen under pressure and in the presence of a catalyst (Designed by the Fixed Nitrogen Research Laboratory)

Nitrogen, mixed with about 1 per cent **argon,** may be obtained from the air by passing the latter over heated **copper** or **iron** to remove the **oxygen,** or pure by fractional **distillation** of liquid air whereby the nitrogen distills off before the oxygen Pure nitrogen may also be obtained by heating such compounds as **ammonium** nitrite, **ammonium** dichromate, and collecting the gas Mixed with **carbon monoxide** in producer gas, nitrogen may be utilized without separation by first making methyl alcohol from carbon monoxide and hydrogen and then using hydrogen and nitrogen for ammonia When nitrogen at low pressure is subjected to the silent electric discharge, activated nitrogen is produced Activated nitrogen displays a golden yellow afterglow upon cessation of the current, increased by cooling and decreased by heating This form of nitrogen is very active with **phosphorus,** with alkali metals (forming **azides**), with the vapor of **zinc, mercury, cadmium, arsenic** (forming nitrides), with many metallic chlorides (forming a green fluorescence), and with **hydrocarbons** (forming **hydrocyanic acid** and cyanides) The transformation of nitrogen to activated nitrogen is partial, and its return to ordinary nitrogen takes place rapidly, in about one minute

Acids Nitrogen is a constituent of several acids In increasing order of oxidation the following are those without carbon **hydrazoic** acid (HN_3), **hydroxylamine** (H_2NOH), **hyponitrous acid** ($H_2N_2O_2$) **nitrous acid** (HNO_2), **nitric acid** (HNO_3), those which contain **carbon: hydrocyanic acid** (HCN), **cyanic acid** (HCNO), **fulminic acid** (HONC), **uric acid** ($C_5H_4N_4O_3$)

Bases Nitrogen is a constituent of several bases In increasing order of oxidation the following are those which do not contain carbon **ammonia** (NH_3), **hy-**

drazine (N_2H_4), **hydroxylamine** (H_2NOH); **those** which contain carbon **amines**, such as methyl amines, phenyl amines, **hydrazines**, such as phenyl hydrazine, **pyridine; ureas; semicarbazides; guanidines.**

Chlorides nitrogen chloride (NCl_3), yellow volatile oil, odor of chlorine, very explosive in light, on heating, or with various substances, such as turpentine With water yields **ammonia** and **hypochlorous acid;** formed by reaction of **ammonium** chloride concentrated solution with excess **chlorine;** nitrosyl chloride (NOCl), orange yellow gas, boiling point $-5°$ C, formed by distilling **sodium** nitrite plus **phosphorus** pentachloride

Hydrides **ammonia** (NH_3), **hydrazine** (N_2H_4), **hydrazoic acid** (HN_3)

Iodide nitrogen iodide (NI_3), reddish solid, very explosive by slight mechanical shock, in light, or on warming

Nitrides **magnesium** nitride (Mg_3N_2), yellow solid, boron nitride (BN), white solid, trisilicon tetranitride (Si_3N_4) Formed by reaction of certain elements (or their oxide plus carbon) and nitrogen (or ammonia) upon heating

Oxides· nitrous oxide, nitrogen monoxide (N_2O), colorless gas, boiling point $-90°$ C, of pleasant odor, of sweetish taste Used as an anaesthetic in minor operations—when used as such extreme caution must be exercised to avoid the presence of poisonous oxides of nitrogen Made by heating ammonium nitrate, and collecting and purifying the gas, nitric oxide (NO), colorless gas, boiling point $-152°$ C, reactive with air or oxygen forming brown nitrogen tetroxide, and in early times used thus to test "the goodness of air" Made (1) by the reaction of dilute **nitric acid** and **copper,** (2) by the catalytic oxidation of **ammonia** and air, (3) in the electric arc process of nitrogen-oxygen (air) fixation; nitrogen trioxide (N_2O_3), brown gas, behaving at ordinary temperatures as if a mixture of nitric oxide and nitrogen tetroxide, boiling point $-27°$ C, the anhydride of nitrous acid, and with water forms nitrous acid, nitrogen tetroxide, nitrogen dioxide, nitrogen peroxide (N_2O_4), brown gas, color deepens with increase of temperature to 140° C when there is present nitrogen dioxide (NO_2) only Made by reaction of concentrated nitric acid and **copper;** nitrogen pentoxide (N_2O_5), white

SCHEME SHOWING THE INTERRELATIONSHIPS OF NITROGEN-CONTAINING SUBSTANCES

Ammonia Ammonium compounds Metallic ammines Organic amines	NITROGEN In the atmosphere	Nitrous oxide Hyponitrous acid Metallic hyponitrites	Nitric oxide Hydronitrous acid	Nitrogen trioxide Nitrous acid Metallic nitrites Organic nitrites	Nitrogen dioxide Nitrogen tetroxide	Nitrogen pentoxide Nitric acid Metallic nitrates Salt peter in nature Organic nitrates
Hydrazine Organic hydrazines Hydrazoic acid Metallic azides Organic azides	Hydroxylamine Metallic hydroxylamates Organic hydroxylamines					
Cyanogen Hydrocyanic acid Metallic cyanides Organic cyanides		Cyanic acid Metallic cyanates Organic cyanates Urea				
	Proteins In Plant and Animal Substances					
Pyrrole Pyridine	Tetrapyrroles Chlorophyll In green leaf chloroplasts Haemoglobin In red blood corpuscles					

to yellowish solid, melting point 29 5° C, the anhydride of nitric acid, and with water forms nitric acid Formed by dehydrating nitric acid with **phosphorus** pentoxide, and recovered from the mixture by volatilizing in a current of dry air

Other compounds of nitrogen are discussed as follows

Acridines See **Pyridine and Related Compounds.**
Alkaloids.
Amines.
Aminoacids.
Aminoazo-compounds See **Azo- and Related Compounds.**
Aminoguanidines See **Amines and Amides.**
Ammines
Ammonia.
Ammonium compounds
Anilides See **Amines and Amides**
Azides See **Hydrazoic acid and Azides.**
Azines See **Pyridine and Related Compounds.**
Azo-compounds.
Azoles See **Pyrrole and Related Compounds.**
Azoxy-compounds See **Azo- and Related Compounds.**
Biuret See **Amines and Amides.**
Carbamic acid See **Amines and Amides.**
Carbazoles See **Pyrrole and Related Compounds.**
Chlorophyll See **Pyrrole and Related Compounds.**
Cyanamides.
Cyanates See **Cyanic Acid and Cyanates.**
Cyanic acid.
Cyanides See **Hydrocyanic Acid and Cyanides.**
Cyanogen.
Cyanuric acid See **Cyanic Acid and Cyanates.**
Diazines See **Pyridine and Related Compounds.**
Diazoles See **Pyrroles and Related Compounds**
Diazoamino compounds See **Azo, Diazo and Related Compounds.**
Diazo-compounds See **Azo-, Diazo, and Related Compounds.**

SCHEME SHOWING INTERRELATIONSHIPS OF NITROGEN-FUNCTION ORGANIC COMPOUNDS

Related to	$H-N(H)-H$ Ammon a	H_2N-NH_2 Hydrazine	H_2N-OH Hydroxylamine	$HO-N=O$ Nitrous acid	$HO-NO_2$ Nitric acid
$\rightarrow CH$ of benzene	Pyrrole and derivative Pyridine and derivative				
$-CH_2OH$ $>CHOH$ $\rightarrow COH$ of alcohols, and phenols	Amines Primary Secondary Tertiary Quaternary ammonium compounds	Hydrazines Mono Unsym di Sym di (Hydrazo comp [1])	Hydroxylamines Mono N Di N	Nitrites Nitroso compounds (Nitrosamines) (Diazo and Azo compounds[1])	Nitrates Nitro compounds
$-CHO$ $>CO$ of aldehydes, ketones, and quinones		Hydrazones (Osazones)	Oximes		
$H-COOH$ Carboxylic acids	Cyanides Isocyanides Amides (Anilides) Aminoacids (Polypeptides) (Proteins)				
$HO-COOH$ Carbonic acid	Cyanates Isocyanates Fulminates Cyanamides Carbamates[2] Ureas[2] (Ureides)[3] Semicarbazides[2] Semicarbazones[4] Guanidines[2] Aminoguanidines[2]				

Footnotes: [1] Hydrazo, Azo and Azoxy comp form a series [2] See **Amines and Amides.** [3] Includes Purine comp [4] From aldehydes and ketones, similar to hydrazones and oximes

$H-N(N)-N$
Hydrazoic acid
Metallic Azides
Organic Azides

(R K S)

Esters See corresponding acids
Fulminates See **Cyanic Acid and Cyanates.**
Fulminic acid See **Cyanic Acid and Cyanates.**
Guanidines See **Amines and Amides.**
Hydrazines.
Hydrazo-compounds See **Azo- and Related Compounds, and Hydrazines.**
Hydrazoic acid.
Hydrazones See **Hydrazines, Hydrazones and Osazones.**
Hydrazoates See **Hydrazoic Acid, Hydrazoates, and Azides.**
Hydrocyanic acid.
Hydroferricyanic acid.
Hydroferricyanides See **Hydroferricyanic acid and hydroferricyanides.**
Hydroferrocyanic acid
Hydroferrocyanides See **Hydroferrocyanic acid and hydroferrocyanides**
Hyponitrites See **Hyponitrous acid and Hyponitrites.**
Hyponitrous acid.
Hydroxyazo-compounds See **Azo-, Diazo- and Related Compounds.**
Hydroxylamines.
Imides See **Amines and Amides.**
Imines See **Amines and Amides.**
Indazoles See **Pyrrole and Related Compounds.**
Indigo See **Pyrrole and Related Compounds, Dyes.**
Indoles See **Pyrrole and Related Compounds**
Isocyanates See **Cyanic acid and Cyanates**
Isocyanic acid See **Cyanic acid and Cyanates.**
Isocyanides See **Hydrocyanic acid and Cyanides.**
Isonitriles See **Hydrocyanic acid and Cyanides**
Isoquinolines See **Pyridine and Related Compounds.**
Lactams See **Aminoacids, Polypeptides, and Proteins.**
Lactims See **Aminoacids, Polypeptides, and Proteins.**
Nitrates See **Nitric acid and Nitrates**
Nitric acid.
Nitriles See **Hydrocyanic acid and Cyanides.**
Nitrates See **Nitric acid and Nitrates**
Nitro-compounds
Nitrolic acids See **Nitro- and Nitroso-compounds**
Nitroso-compounds See **Nitro- and Nitroso-compounds.**
Nitrous acid
Nucleic acids See **Proteins.**
Osazones See **Hydrazine, Hydrazones, and Osazones; Carbohydrates**
Oxazoles. See **Pyrrole and Related Compounds**
Oximes See **Hydroxylamines.**
Phenylhydrazones See **Hydrazines and Hydrazones.**
Piperidines See **Pyridine and Related Compounds**
Polypeptides See **Aminoacids, Polypeptides and Proteins.**
Porphyrans See **Pyrrole and Related Compounds**
Porphyrins See **Pyrrole and Related Compounds**
Proteins See **Aminoacids, Polypeptides, and Proteins.**
Purines.
Pyrazoles See **Pyrrole and Related Compounds.**
Pyridines.
Pyrroles.
Pyrrolidines See **Pyrrole and Related Compounds.**
Quinolines See **Pyridine and Related Compounds.**
Semicarbazides See **Amines and Amides**
Semicarbazones See **Amines and Amides.**
Tetrazoles See **Pyrrole and Related Compounds.**
Triazoles See **Pyrrole and Related Compounds.**
Ureas See **Amines and Amides**
Ureides See **Purine and Uric Acid Compounds.**
Urethanes See **Amines and Amides**
Uric Acid See **Purine and Uric Acid Compounds.**
Note Sulfur-nitrogen organic compounds are listed under **Sulfur.**

NITROGEN CYCLE. Bacteria.

NITROGLYCERIN. Explosives.

NITROLIC ACIDS. Nitro- and Nitroso-Compounds.

NITROSYL CHLORIDE. Nitrogen.

NITROUS ACID AND NITRITES. Nitrous acid (HNO_2) is a blue solution, unstable, the blue color soon disappears, especially on warming, with the formation of brown nitrogen tetroxide (See **Nitrogen**) and **nitric acid** in solution Nitrous acid reacts in some cases as an **oxidizing** agent, in other cases as a **reducing** agent, and is unusually interesting on that account As an oxidizing agent, nitric oxide is usually formed, e g , with **ferrous** salt solution changed to ferric, with **hydrosulfuric acid** to **sulfur, sulfurous acid** to **sulfuric acid, hydriodic acid** to **iodine; nitrogen** is formed with **urea**, with **ammonia** and with **formaldehyde**, ammonia with ammonium in **sodium** hydroxide medium As a reducing agent, nitric acid is formed, e g , with **potassium** permanganate changed to manganous, with dichromate to **chromic**, with chlorate to **chlorine**, with bromate to bromine, with iodate to **iodine**, with **hypochlorite** in **sodium** hydrogen carbonate medium to **chloride**

Prepared by reaction (1) of **nitrogen** trioxide (or nitric oxide plus **nitrogen** dioxide) and water, (2) **barium** nitrite solution and **sulfuric acid**, and filtering off barium sulfate, (3) sodium nitrite solution and an acid

Sodium nitrite is formed (1) by heating sodium nitrate solid and **lead**, with stirring, preferably in an iron dish, and upon cooling, dissolving the nitrite and filtering off lead oxide, (2) by reaction of nitric oxide plus nitrogen dioxide with **sodium** hydroxide or carbonate solution

Silver nitrite is insoluble, and formed as a precipitate by reaction of sodium nitrite solution and silver nitrate solution

With numerous organic substances characteristic colors are developed Nitrous acid is (1) used in organic chemistry as an important reagent, e g , with **amines**, and (2) the color developed in dilute solutions is used as a method of quantitatively estimating nitrous acid, e g , **sulfanilic acid** plus alpha-naphthylamine develops a red color A complex nitrite, potassium cobaltinitrite, yellow insoluble, is important in the detection of **potassium** in salt solution, soluble sodium cobaltinitrite is used as the reagent

Esters methyl nitrite (CH_3ONO), boiling point —12° C , ethyl nitrite (nitrous ether) (C_2H_5ONO), boiling point 17° C

Indication of the presence of a nitrite is given by the appearance of brown fumes on treatment with dilute **sulfuric acid** in the cold (R K S)

NITROUS OXIDE. This is one of the most common **anesthetics** Its chemical and physical properties are discussed in the article on **nitrogen** It is called laughing gas because occasionally, when inhaled in small quantities, it produces hilarity As an anesthetic it is very safe in expert hands and produces, very rapidly, a full degree of unconsciousness, but not a complete muscular relaxation Diethyl **ether** is usually combined with it as the two together produce the desired state of unconsciousness with any desired degree of muscular relaxation The gas is not given pure but is combined with **oxygen** It is not used for the very young, the aged, or cardiacs (R S M)

NOCTILUCA. Protozoa, Mastigophora A genus of **protozoans** with one phosphorescent species This minute form is sometimes so abundant in the ocean that the water appears luminous at night (A W L)

NOCTULE. Mammalia, Chiroptera A **bat** found in Europe, Asia, the Oriental region, and northern Africa. It has a wing spread of more than a foot. (A W L)

NOCTURIA. Increased urination at night (R S M)

NODDY. Aves, Charadriiformes A group of birds (**Aves**) related to the terns They are chiefly tropical. (A W L)

NODE. The significance of this term in physics is treated in the article on **interference**

In astronomy, the line of intersection of any two planes in space is referred to as the **line of nodes**, and the points where the line of nodes meets the **celestial sphere** are known as the nodes

In botany, a node is that part of a **stem** at which a leaf arises The "joints" of a stem are the nodes

In medicine, a hard rounded swelling or protuberance Often, in chronic infections of the joints (certain types of **arthritis**), hard protuberances appear about the **joints**, especially in the fingers Lymph nodes—small round or oval glandlike structures arranged in groups throughout the body These are connected with the lymph vessels, into which they drain In this way they act as safety barriers, localizing or temporarily stopping an infection or cancer invasion that is spreading through the lymphatic vessels They are found in the neck, groin, axilla, in the chest around the lungs, and in large numbers in the abdomen Often when hopelessly diseased, as with tuberculosis, and when involved with cancer, whole groups of these nodes are removed surgically (W K G, R M W, R S M)

NOISE AND VIBRATION The two chief characteristics of vibration are **frequency** and **amplitude** A mechanical vibration which is felt as a shake or tremor differs from one which manifests itself to the senses as noise or sound only in the value of its frequency When the frequency is low, say less than 15 oscillations per second, vibration is felt as a shake or tremor, and then is only perceptible to the senses if its amplitude amounts to 016 inch or more When the frequency lies between 15 and 30 oscillations per second, the shake or tremor is accompanied by noises such as clicks and rumbles For example, all major earthquakes are accompanied by a rumble, so deep that observers usually differ as to whether the sensation it produces is felt or heard When the frequency lies about 30 oscillations per second, vibration passes into the range of sound The limits of frequency for musical sounds are usually given as 40 to 4000 oscillations per second, although the upper limit of audibility extends to 15,000 oscillations per second For a vibration of given frequency, the intensity is proportional to the amplitude, or linear magnitude, of the disturbance Thus in the case of sound, the amplitude of vibration determines the loudness while the frequency determines the pitch For vibrations of low frequency which are felt as tremor or shake, various experiments have been made to determine the limiting amplitude and frequency at which they become apparent to the senses

The use of **insulation** for localizing vibration in structures is only one phase of the complicated problem of vibration control The general problem, whether considered in relation to structures or machinery, is a dynamic rather than a static one Probably it is for this reason that greater progress toward a solution has been made in mechanical than in structural lines The general problem of vibration control may be classified under several heads In the design of permanent machinery installations such as lighting and power units in office buildings and apartments, batteries of looms, printing presses, or machine tools in shops and factories, marine installations, automotive and aircraft power plants, etc, the first step consists in eliminating the unbalanced effects in rotating parts by means of dynamic balancing In general, however, this by itself is never completely effective In reciprocating machinery, where the power fluctuates, it is of utmost consequence to design parts affected by vibration so as to avoid critical speeds In buildings and other structures, critical speeds are those speeds of operation at which synchronous vibration is set up in one or more members of the structure If the design of the structure cannot be altered, synchronism may be destroyed by changing the speed of the machine causing vibration When vibration is due to outside sources such as street traffic, some other remedy, such as insulation, must be adopted

Mechanical insulators fall into two general classes· Those that are elastic and resilient, such as rubber, felt, and cork, and those which are almost entirely lacking in these qualities, such as sand, gravel, lead, and asbestos Properly speaking, there is no such thing as a vibration absorbent, since this implies dissipation of energy through internal work in the form of molecular friction, heat losses, etc Resilient materials store up energy like a spring and give this up again when released without appreciable loss, and their insulating properties depend on this feature, whereas non-resilient materials like sand and gravel serve mainly to destroy the rigidity, or interrupt the continuity, of otherwise rigid structures

The most general principle of vibration control is that vibration should be damped out as near as possible to its source When the source of vibration is under control, as in the case of a stationary machine in a building, this principle implies that the machine shall be of correct design, properly balanced, and with adequate foundation, thereby preventing so far as possible the occurrence of vibration, or reducing it to a minimum, before any attempt is made to introduce resilient supports or vibration dampers for short-circuiting residual vibration

When the source of vibration lies entirely outside control, as in the case of vibration in a building due to street traffic, the use of resilient dampers or isolators often becomes the chief remedy Also when the problem is to prevent vibration from affecting some particular object, such as a piece of delicate scientific apparatus, local insulation by the use of resilient supports is in general the most effective means of securing results

The sensation of **sound** is produced, in general, by compressional waves transmitted through the air from some vibrating source Sound may also be communicated to the ear through the medium of a solid body which transmits vibration directly to the bones of the skull, or by means of a metal plate held firmly between the teeth When the sound wave is periodic, a musical sound is produced, the pitch of which depends on the frequency of vibration When the sound wave is nonperiodic, the resulting sensation is what we call noise

The transmission of sound implies a transmission of wave energy The numerical amount of such wave energy measures what is called the **intensity** of the sound Sound intensity is thus a definite physical quantity, and is defined as the amount of energy transmitted per unit of time through a unit area of a plane, normal to the direction of travel of the sound wave

When a sound is transmitted through the air, it proceeds outward from the source in spherical waves, alternating between compression and rarefaction with the same frequency as its source When such a sound wave in air impinges on a surface, such as the wall of a room, part of its energy is reflected, part absorbed, and part transmitted through the wall, in proportionate amounts depending on the construction of the wall and the nature of its surface

Experiments on soundproofing structures, such as those carried out at the U S Bureau of Standards for a period of years on standard building construction and more recently on aircraft cabins, as well as somewhat similar but independent developments in connection with the insulation of sound stages of talking picture studios, have disclosed certain basic facts with regard to practical methods for preventing sound transmission

For ordinary building construction it has been found that in the case of solid walls such as those of brick or masonry, whatever tends to make the wall stiffer or heavier, tends to improve its sound insulating properties

However mechanical may be the age in which we live, the foundations of this or any nation's wealth is based

on human resources The nervous and muscular system which directs and controls human effort, whether mental or manual, is, in fact, a very highly organized machine, and from a purely mechanical standpoint its efficiency depends very largely on the prevention of fatigue and the restoration of used tissues through sleep and relaxed muscular and nervous tension With all forms of mechanical waste carefully guarded against by scientific management, authorities on industrial economics assure us that the greatest waste in industry today is that caused by nervous fatigue induced by excessive and incessant noise

In recent years there has become apparent in all branches of engineering a very definite trend of development from static to dynamic Until recently the topic of vibration, which is a dynamic phenomenon, was considered as belonging in the domain of physics, and was chiefly concerned with problems in light and sound With the development of modern electrical engineering, however, vibration became a subject of major importance Still more recently it has become of basic importance in many other branches of engineering These include such widely divergent lines as seismology in the oil fields, automotive engineering, machine design, steam turbine practice, radio engineering, noise abatement in offices, vibration control in tall buildings, acoustic correction of auditoriums, and vibration in railway tracks and bridges (This article has been prepared from material in "Noise and Vibration Engineering," by Stephen E. Slocum, Van Nostrand)

NOMENCLATURE. For **chemical nomenclature**, see article under that heading In the biological sciences, nomenclature is the names of species and the groups in which they are classified, and the procedure governing the selection of such names A part of **taxonomy**

All zoological nomenclature is dated from Linnaeus' Systema Naturae, Tenth Edition, 1758 The same scientist is credited with the establishment of the system of binomial nomenclature which applies to every species a name consisting of the name of the genus to which it belongs, followed by the name of the species The name of the author of the species or an abbreviation is also appended, and it is permissible, if the species is later removed to another genus, to place this author's name in parentheses and follow it with that of the author of the new combination

In modern zoology a series of International Rules of Zoological Nomenclature prepared by the International Commission on Zoological Nomenclature is regarded as the authoritative code for naming taxonomic divisions and for the regulation of certain other procedure of taxonomy Disputed points are submitted to the Commission and opinions on such points are published from time to time

A general provision is that all scientific names must be published in such form as to satisfy the Commission's definition of publication In addition a priority rule establishes the first valid application of a name, all names subsequently published to apply to the same unit becoming synonyms

The selection of names for species is practically unrestricted They are Latinized in their application to scientific uses but they may be derived from any language and may be descriptive or not Custom imposes a limitation in some groups, as in a family of moths with specific names ending in *-ana* and another with the ending *-ella* Names of species are written with a small initial letter and are italicized in text

The names of genera are chosen with equal freedom, but it is provided that no name shall be used a second time in the same kingdom. If this is inadvertently done, the second application is said to be preoccupied and is replaced by a new name when the duplication is discovered Names of genera are single words, written with an initial capital and italicized in text

Subfamily names are formed of the stem of the name of the type genus plus the ending *-inae*, family names of this stem with the ending *-idae*, and superfamily names with the ending *-oidea* These and all names of higher divisions are capitalized but are not placed in italics (A W L)

NONCALCAREA. A division of the **sponges** (Porifera) used by some zoologists to include the species without calcareous spicules Equivalent to **Hexactinellida** and **Demospongiae** of this work (A W L)

NONCONFORMITY. Unconformity.

NON-EUCLIDEAN GEOMETRY. A non-Euclidean geometry is a geometry in which not all the axioms and postulates of Euclid are assumed In particular, the classical non-Euclidean geometries are obtained by replacing the parallel postulate of Euclidean geometry by other assumptions

In the hyperbolic geometry, usually credited to the Russian mathematician Lobachevski, all of Euclid's axioms are accepted with the exception of the parallel postulate, which is replaced by the assumption that through any point there are two or more lines which do not intersect a given line in the plane In hyperbolic geometry, many theorems are the same as in Euclidean geometry, but many are different, for example, in hyperbolic geometry, the sum of the three angles of a triangle is less than two right angles

In elliptic geometry, the parallel postulate of Euclid is replaced by the assumption that through a given point there are no lines which do not intersect a given line in the plane (L L S)

NONPAREIL. Aves, Passeriformes The painted **bunting**, *Passerina ciris*, of the southern United States, a small bird brightly colored with red, blue, and green (A W L)

NORDMARKITE. The term proposed by Brogger, in 1890, for an **alkali syenite** containing free **silica** in the form of **quartz**, the principal **femic** minerals being **biotite** and **aegirine** This type locality is at Nordmaken, Norway (R M F)

NORITE. Gabbro.

NORM. For the geological significance of this term, see **Mode**

NORMAL FAULT Fault.

NORMAL LINE TO A PLANE CURVE Tangents and Normals to Plane Curves.

NORMAL LINE TO A SURFACE. Tangent Plane to a Surface.

NORMAL SOLUTION. Concentration.

NORTHFIELDITE The term proposed by Emerson in 1915 for an exceedingly quartz-rich **granite** containing 83% of **quartz** and 13% of **soda—orthoclase feldspar** The type locality is at Northfield, Mass (R M F)

NORTH POLAR SEQUENCE. Stellar Magnitude.

NORTH STAR. Polaris.

NOSE. A protuberance on the face of air-breathing **vertebrates** through which the respiratory passages lead It is also associated in these passages with the sense of smell through the presence of the sensory olfactory epithelium (A W L)

NO-SEE-'EM. Black fly.

NOSE LEAF. Complicated folds of skin, sometimes very extensive, on the snout of some **bats.** They are

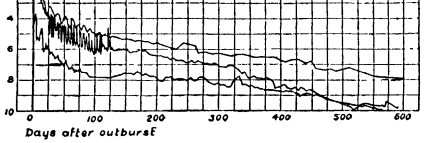
supposed to be provided with delicate sensory organs akin to the organs of touch (A W L)

NOSTRIL. The external orifice of a respiratory passage in the air-breathing **vertebrates** There are usually two nostrils, but in some of the whales the respiratory system opens by a single aperture, called the nostril or blow-hole External **naris** (A W L)

NOTOCHORD. A longitudinal stiffening rod found in all **embryonic** chordates and in the adults of some of the lower members of this phylum (**Chordata**) It lies between the central **nervous system** and the alimentary tract (**digestive system**) and is the axis around which the spinal column develops As the bony structure forms, the notochord is almost crowded out of existence In the human body small remnants of it form the nuclei pulposi in the intervertebral disks (A W L)

NOTOPODIUM. The dorsal portion of the **parapodium** of **annelid** worms (A W L)

NOVA. There is probably no class of stars that attracts so much popular attention as the novae or "new stars" These objects suddenly appear in the sky at unpredicted time and place, in some cases becoming the brightest object in the sky for a few days They then fade away and disappear from naked eye observation, but may be followed telescopically for indefinite lengths of time Many novae which do not attain naked eye brilliancy are discovered and studied telescopically It is impossible to give a definite estimate of the total number of novae which appear each year, for undoubtedly many escape detection Bailey has estimated that ten or more reach a brightness of the ninth **stellar magnitude** or greater each year During the first thirty-five years of the present century there were five novae which reached conspicuous brightness



Light Curves of Nova Aquilae, 1918, Nova Persei, 1901, and Nova Germinorum, 1912 They are designated in order of decreasing height (From Harvard College Observatory Annals)

In the accompanying figure we have represented the **light curves** of three of the bright novae of the present century The ordinate scale of brightness is expressed in stellar magnitude, and, since magnitude 6 is the limit of naked eye visibility, the length of time that each was visible to the naked eye may be determined from the time scale at the bottom These curves are characteristic of most novae, with the very rapid rise to maximum and then the relatively slow and irregular decline Examination of photographic records indicates that novae are not actually "new stars" at all, but rather are faint stars which, for some unexplained reason, suddenly increase in intensity An increase of ten magnitudes is by no means uncommon, and this represents an increase of light intensity amounting to 10,000 fold.

Coupled with the increase in light intensity of a nova there is a correspondingly remarkable change in **spectral characteristics** While the spectral changes in different novae vary to a considerable extent, nevertheless, there are certain stages of development which are more or less characteristic of them all During the period of rise, in the few cases where increasing novae have been detected in time for observation, the star is of the hot, blue, A-type, with the absorption lines displaced very strongly to the violet As the star starts to decline the color changes from white to yellow, and bright lines, particularly of hydrogen and ionized iron, appear The bright lines then broaden out to bands of irregular structure which soon completely mask the continuous spectrum of the star A few days later dark lines again make their appearance, and these are displaced far to the violet Soon bright lines again appear, frequently of the type which are characteristic of the gaseous **nebulae**, except that they are broad As the brightness of the star further decreases it eventually settles down to a peculiar O-type spectrum with bright lines superimposed on a continuous and dark line absorption spectrum

There has been a tremendous amount of research on the novae during the present century, but as yet there is no complete explanation available The best theory is that, for some completely unexplained reason, a relatively faint star explodes and blows off an outer shell of gaseous material Since this shell would rapidly expand after leaving the surface of the star, the displacement of the spectral lines to the violet may be explained as a **radial velocity** shift There is further confirmation of the possibility of the expanding shell of gas in the fact that a nebulous envelope has actually been observed in certain novae While the explosion and expanding shell hypothesis is by far the best of any thus far proposed, there is no explanation available as to what causes the terrific explosion necessary to drive the material out of the star against the enormous gravitational attraction Other theories for the formation of novae from the collisions or very close approach of two stars have been advanced In view of the approximately known distribution of stars in space and the average **space velocities** of the stars, the probability of a collision can be computed and is found to be far too small to account for the large number of novae which are observed

Novae have been observed telescopically in some of the **extra-galactic** nebulae such as the great spiral in Andromeda Since the distances of some of these objects are at least very approximately known, it is possible to get an approximation to the **absolute magnitudes** at maxima of the novae observed in them For these extra-galactic novae we find absolute magnitudes of the order of -4, a value which compares favorably with those determined for the few cases where the distance of a galactic nova is known (W K G)

NOVACULITE. The term proposed by Coldier, in 1868, for a fine-grained or **crytocrystalline, cherty, metamorphic** rock essentially composed of **quartz** and other forms of **silica** Accessory minerals are **feldspar** and **garnet** Used for whetstones (R M F)

NOVOCAINE. **Anesthesia**, and **Drugs.**

NOZZLES. A nozzle is a converging tube attached to the outlet of a pipe, hose, or pressure chamber, the purpose of which is to convert efficiently the pressure existing in a fluid into velocity Examples may be cited of nozzles for liquids, gases, and vapors It may or may not be necessary to take compressibility of the fluid into consideration Water in a hose or pipe at a pressure measured by a head of h feet should, theoretically, spout freely from the pipe with a velocity equal to $\sqrt{2gh}$, in which $g =$ **acceleration** due to gravity However, unless a nozzle were applied, there would be a tendency of the water to begin to increase in velocity far enough back in the pipe so that a great deal of the head would be consumed in overcoming friction A nozzle throttles the discharge down to a smaller stream, and allows a pressure to be carried in the pipe or hose adjacent to the nozzle The percentage of ideal jet velocity actually obtained in a nozzle is known as the velocity coefficient This coefficient ranges between 85 and 98 for nozzles of different shapes and designs The discharge of water from a nozzle needs to be further

corrected by allowing for the velocity of approach As the water moves through the converging section of the nozzle towards the tip, it is increased in velocity, resulting in some tendency to offset reduction by velocity coefficient Multiplying the computed velocity by

$$\sqrt{\frac{1}{1-\left(\frac{\text{tip diameter}}{\text{root diameter}}\right)^4}}$$

allows for this velocity of approach and gives the actual velocity at the tip of the nozzle

The flow of air through nozzles may or may not involve compression For example, compressed air jets used for cleaning have considerable expansion in the nozzles, from which high velocity is derived Another case of an air nozzle is the entrance cone of a wind tunnel, in which an airstream is restricted in cross-sectional area, and increased in velocity Here compressibility is not generally taken into account

Steam nozzles are very definitely based upon expansion of steam The nozzles of a steam turbine have to change the heat contained in steam into work, and direct the course of the steam onto the blades The liberation of heat during the adiabatic expansion which occurs in steam nozzles increases the velocity of flow Heat is liberated by a drop of pressure made possible by proper design of nozzle areas The velocity attained by steam through **adiabatic** expansion can be found by application of the law of conservation of energy The sum of the heat energy and kinetic energy in steam approaching a nozzle is equated to that leaving the nozzle, since there is no work done on the nozzle itself This yields the formula

$$V_2^2 - V_1^2 = 50{,}200H$$

Here the V's are the velocity of approach and emergence from the nozzle, and H is the heat released by adiabatic expansion When v cubic feet of steam are flowing with a velocity of V feet per second, they require a flow area of $\frac{v}{V}$, so at any point of a nozzle the area is determined by the density of the steam and its velocity, both of these being determined by the pressure The physical phenomena attending the variation in velocity and volume with change of pressure create a condition of a converging nozzle, that is, diminishing area, until the pressure becomes 58% (55% for superheated steam) of the initial pressure, after which the nozzle diverges The final velocity, that is, the velocity at the mouth of the steam nozzle, is slightly less than that given by the above equation, because (a) perfect adiabatic expansions are not possible, (b) there are frictional losses on the nozzle walls (F T M)

NUCELLUS. Flower.

NUCLEIC ACIDS Aminoacids, Polypeptides, and Proteins

NUCLEOLUS These are small rounded bodies found in the **nucleus** of the **cell** Generally each nucleus contains a single nucleolus, but in many cases there are several The function of the nucleolus is unknown It seems to be a mass of accumulated material which is used in the **metabolic** processes going on in the nucleus (R M W)

NUCLEUS. 1 **Cell** 2 A group of cell bodies in the central **nervous system** of vertebrates

Examples are the red nucleus in the mid-brain, through which impulses are routed for the control of subconscious muscular movements, and Deiter's nucleus, lying at the junction of the medulla with the hind **brain** Through this center impulses pass for muscular action involved in the maintenance of equilibrium (A W L)

NUDA. Comb jellies (ctenophores) of large size and ovate or conical form, without tentacles They constitute a class of this name in the phylum **Ctenophora.** It contains the single family Beroidae (A W L)

NUDIBRANCHIATA. Gasteropoda.

NULL METHOD Physical Measurements.

NUMBER. Historically, the various types of numbers of algebra were introduced gradually, step by step, as the need for them arose

In the early stages of the development of man, the process of counting gave rise to the natural numbers or positive integers, 1, 2, 3, 4, 5, etc These numbers serve to answer the question "How many?"

The process of measurement of quantities led naturally to the introduction of the positive rational fractions, examples of which are ½, ⅔, 5/7, etc These numbers are needed to assist in answering the question "How much?" From an algebraic viewpoint, the positive rational numbers were introduced in order to make division always possible Positive rational fractions can be expressed as quotients of positive integers.

The positive irrational numbers were introduced through the incommensurable quantities which occur frequently in Geometry, for example, the diagonal of a square is incommensurable with its side Examples of such numbers are: $\sqrt{2}$, $\sqrt[3]{2}$, $5+\sqrt{7}$, π, etc From an algebraic viewpoint, the positive irrational numbers were introduced in order to help to make the extraction of roots always possible

Quantities that could be measured in two opposite senses suggested the idea of the negative numbers, for example, temperature is measured above and below zero, and latitude is measured north and south of the equator Algebraically, the negative numbers were introduced in order to make subtraction always possible The negative numbers consist of several types the negative integers -1, -2, -3, -4, etc , the negative rational fractions, such as $-3/4$, $-8/5$, $-1/7$, etc , and the negative irrational numbers, such as $-\sqrt{3}$, $-\sqrt[3]{6}$, -1, $-\sqrt{2}$, etc

The number zero, 0, is often used to indicate absence of quantity Algebraically, zero is introduced to indicate the result of subtracting a number from itself

The positive integers, the negative integers, zero, the positive rational fractions, and the negative rational fractions are grouped together to form the system of rational numbers

The numbers of the rational number system together with the positive and negative irrational numbers are grouped to form the real number system

Comparatively late in the historical development of algebra, the pure imaginary numbers and the complex numbers were introduced in order to make the extraction of roots of negative numbers and the solution of certain types of equations always possible Examples of pure imaginary numbers are $\sqrt{-1}$, $\sqrt{-5}$, $-3\sqrt{-1}$, etc ; examples of complex numbers are $2+3\sqrt{-1}$, $-1-\sqrt{-2}$, $\frac{1}{2}-\frac{1}{2}\sqrt{-3}$, etc

The square of any real number is always a positive real number But the pure imaginary numbers have the property that their squares are negative real numbers, thus, the square of the imaginary number $\sqrt{-3}$ is -3. Any complex number may be expressed as an indicated sum of a real and a pure imaginary number, as for example $2+\sqrt{-3}$ The term "imaginary number" is sometimes used to mean complex number

An irrational number cannot be expressed as a quotient of positive integers nor as a quotient of rational fractions It may, however, be represented approximately by rational fractions, to any degree of approximation desired Thus, the irrational number $\sqrt{2}$ may be represented approximately by the rational numbers 1 4, or 1 41, or 1 414, or 1 4142, etc In fact, any irrational number can always be inclosed between pairs of rational numbers whose difference

are as small as we please. Thus, $\sqrt{2}$ lies between 1.4 and 1.5, between 1.41 and 1.42, between 1.414 and 1.415, etc.

The absolute value (or numerical value) of a positive number is the number itself, while the absolute value of a negative number is the number with its sign changed. The absolute value of a number a is denoted by the symbol $|a|$. Thus, $|5| = 5$, $|-8| = 8$.

Real numbers may be represented graphically by points on a straight line, whose distances from some arbitrarily selected origin are the corresponding real numbers.

An algebraic number is a number which satisfies a **polynomial equation** in one variable with integral coefficients. A transcendental number is a number which is not algebraic, i.e., is not a root of a polynomial equation in one variable with integral coefficients.

Irrational numbers are either algebraic, as $\sqrt{2}$, $\sqrt[3]{5}$, $1-\sqrt{3}$, etc., or transcendental, as π, e, etc.

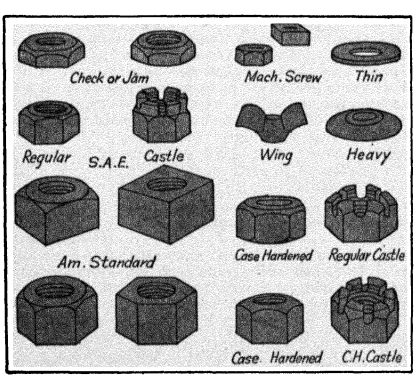
Any type of number may be regarded as contained in the complex number system. If in the complex number $a+bi$, we have $b=0$, the number is a real number a; if $a=0$, the number is purely imaginary. (L.L.S.)

NUMERICAL INTEGRATION. Approximation Integration.

NUNATAK. A topographic or physiographic term of Eskimo origin and meaning the top of a hill or mountain which projects above an ice sheet or continental glacier. (R.M.F.)

NUT. For the use of this term in botany, see **Fruit.**

In engineering, a nut is a small block of metal drilled and tapped with an internal thread which may be screwed over the external thread of a bolt or stud. The object of a nut is to retain the bolt in the bolt hole, and compress between nut and bolt head the parts thus gripped. Nuts are variously shaped and finished, as evidenced by the accompanying illustration, because of the many variations in the uses to which they are put. Some are rough and comparatively unfinished, some are



Common types of nuts.

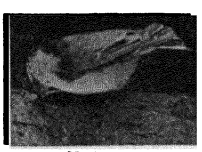
highly polished and plated and arranged with six or eight, instead of four, sides, so that they may be turned in close clearances, and some are intermediate between these extremes. A castle nut is one used with a bolt which has bored through the threads a small hole, through which is passed a cotter pin. The pin is locked through the castling of the nut, and prevents loosening under vibration. A jam nut is a thin nut which is screwed tightly against a standard nut in order to jam it more tightly against the thread of the bolt. (F.T.M.)

NUTATION. For the use of this term in botany, see **Movement in plants.**

Nutation in astronomy is a short periodic change in **precession.** Precession is caused by the attracting force of the sun and the moon tending to pull the equatorial bulge of the earth into the plane of the **ecliptic.** The amount of this force is changing throughout the year as the **declinations** of the sun and the moon change. For example, twice during each year both the sun and the moon are on the equator, and at those times their precessional forces are zero. The principal nutation is due to the periodic change in the plane of the moon's orbit, and has a period of about 19 years. Most of the nutation effects are periodic in character, but a complete account of them is beyond the scope of this work. (W.K.G.)

NUTCRACKER. Aves, Passeriformes. Birds (**Aves**) related to the crows and jays. The few species are confined to the northern parts of the northern hemisphere. The Clarke nutcracker, *Nucifraga columbiana*, lives principally at higher altitudes in the mountains of western North America. It is associated with coniferous forests. (A.W.L.)

NUTHATCH. Aves, Passeriformes. Small climbing birds (**Aves**) which cling in any position to the bark of trees as they search for food. They eat both insects and seeds. The most common North American species is the white-breasted nuthatch, *Sita carolinensis*, found throughout the United States east of the Rockies. The red-breasted nuthatch, *S. canadensis*, is more common in Canada and the mountains but migrates in winter as far as the southern states. The pigmy nuthatch, *S. pygmaea*, is a western species. Nuthatches are found on all other continents except South America, although in Africa they are confined to the north. (A.W.L.)



Nuthatch.

NUT LOCK. Many machines have important essential parts held together by bolts and nuts. The bolt and nut is perhaps the most common fastening of machinery. The failure of bolts or nuts through the loosening of the nut may be a matter of vital importance in certain key positions. The action between a nut and bolt is simply that of a body moving on an inclined plane, and it is easily possible for that body, in this case the nut, to slide or back off the inclined plane, especially when subjected constantly to vibration and shock. In practice, nuts are prevented from so loosening from their adjusted positions by several different types of nut-locking devices. Possibly the two most common are the castle nut and lock washer. A castle nut has a cotter **pin** passed through the castle, and a hole bored in the bolt. The pin retains itself, since its tips may be bent so that it is impossible for the pin to come loose, even when severely vibrated. Lock washers are spring type washers which exert a steady pressure against the nut so that even though the nut does loosen slightly, it will still be jammed against its threads by the expansion of the lock washer. The lock washer is not as positive a nut-locking device as the castle nut. Pins and set screws and spring wire locks perform the same services, as do also many special and patented forms of washers, the main idea of which is to create a locking action by seating a washer into recesses scored into the nut and shoulder against which the washer bears during the action of tightening. (F.T.M.)

NUTMEG. *Myristica fragrans.* Myristicaceae. Nutmegs are the fruit of a tree native to the Molucca Islands. The tree grows sixty feet tall, and has pointed **lanceolate** leaves. The trees are **dioecious,** pistillate (See **Pistil**) and staminate (See **Stamen**) flowers being borne on separate trees. Since the trees are frequently

grown in cultivation, especially in favorable localities, it is necessary to plant some of both sexes to insure cross-pollination and seed formation The flowers are pale yellow, the fruit a dark orange-colored berry containing a single large brown seed Surrounding the seed is a branched deep red **aril**, which on drying becomes pale brown The seed is the nutmeg of commerce, the aril is mace Both the seed and the aril contain an aromatic oil, but only poor quality fruits are used for the oil Both nutmeg and mace are well-known spices used in great quantities in the United States (R M W)

NUTRITION. The process of incorporating in the body the substances necessary for growth, repair, and energy Constructive **metabolism** Anabolism

In the usual sense the term designates certain aspects of the entire process of securing food and incorporating it in the body, hence words describing the manner of nutrition indicate fundamental relations of the animals involved All organisms which ingest animals or plants as food, as is true of most animals, carry on holozoic nutrition They are also described as zootrophic or heterotrophic organisms Those which have chlorophyll and are able to synthesize food from inorganic materials like the green plants and some one-celled animals, have holophytic nutrition, or are called autotrophic or phytotrophic organisms Animals which absorb dissolved organic materials have saprozoic nutrition and those which live in another organism and use its materials carry on parasitic nutrition No exact line can be drawn between parasitic and saprozoic animals for some parasites merely absorb food from the contents of the alimentary tract in which they live and so are, in the strict sense, saprozoic The bodily association and dependence of parasitism also enter into the definition of this condition (A W L)

NUX VOMICA. The dried ripe seed of *Strychnos Nux Vomica*, which grows in Austria, China, and India It yields several **alkaloids**, the principal one being **strychnine** It is used principally in the form of the Tincture of Nux Vomica as a tonic and as a bitter to promote flow of digestive juices, thus increasing the appetite (R S M)

NYALA. Mammalia, Artiodactyla An African harnessed **antelope**, *Tragelaphus angasi*, related to the bongo and nakong It is blue-gray with faint white stripes Found in swampy jungles of eastern Africa (A W L)

NYMPH An immature insect of the forms which have gradual metamorphosis (**Paurometabola**) Nymphs resemble adults but have wings in the developmental state (A W L)

NYMPHAEACEAE. Water-lilies.

NYMPHOMANIA. Abnormal sexual desire in the female (R S M)

NYSTAGMUS An involuntary rapid movement of the eyeball which may be from side to side, up and down, circular, or a combination of these movements It may be due to incoordination of the eye muscles, disturbances of the nerves of the eye, or to disturbances of the vestibular canals in the ear (R S M)

O

O SERIES. X-ray Spectra.

OAKS. *Quercus* sp Fagaceae The oaks are trees and shrubs of the north temperate region All the more northern species are **deciduous** plants Many of those in the southern part of the range have evergreen leaves, and are often called live oaks In Asia and the Pacific coast of North America, oaks are found in regions approaching tropical conditions

The 300 species of this genus have simple alternate leaves The flowers are of two kinds, borne on the same tree The pistillate (See **Pistil**) flowers are borne singly and are surrounded by an **involucre** of many scales beyond which the **stigmas** protrude The staminate (See **Stamen**) flowers are borne in long slender pendant **catkins** Pollination is by wind The fruit is an acorn, a **nut** of characteristic cylindrical shape, capped by the small persistent style-base, and seated in the scaly involucre, which forms a cup partially or almost wholly surrounding the nut

Many of the oaks are valuable trees, yielding woods which have a variety of uses In early times, before the day of the sawmill, oaks were much used in the construction of buildings Often the oaks used for this purpose were split into thin planks, a method of preparation which served well to bring out the attractive grain of the **wood** This grain is due partly to the numerous large vessels which are formed periodically every spring and appear as very evident dark lines or streaks in the wood, and partly to the large **vascular** rays which appear as irregular flakes, especially when the wood is split in a radial plane In modern construction oak is often used as paneling or flooring To obtain the best grain, the wood is quarter-sawed, that is, cut in such a way that the flat surfaces shall be as nearly radial as is possible Because of its beauty and also its durability, oak wood is also much used in furniture making In America the principal species used for wood is white oak, *Quercus alba* In Europe several species are used, among them the British oak, *Quercus Robur* Often these European oaks are trees of remarkable size, and are preserved because of their rugged beauty The wood is very strong and durable, and finds considerable use in ship construction Formerly much more was used for this purpose

Accidents sometimes cause the formation of oak wood of special properties and value The trunks of fallen trees may lie buried for long periods of time in bogs or elsewhere Sometimes, when removed, these logs are found to be perfectly sound and to have developed a rich dark brown or nearly black color, which makes them especially sought after for furniture making Such oak is known as bog oak Living trees frequently develop large irregular growths, known as burls, in which a very irregular much-contorted grain is found The custom of cutting back the top of the tree, causing the development of numerous **adventitious buds**, a practice known as pollarding, causes a similar irregular grain These burls are used for making **veneers** Another species of oak, *Quercus suber*, yields **cork**

Oaks are valuable sources of **tannin** In many species the bark is the source of the tannin, but in *Quercus Aegilops*, a native of eastern Europe and Asia, a tannin known as valonia is obtained from the cup and the young acorns

African oak, a strong, heavy wood, comes from African trees of other genera than *Quercus* This wood is rarely used, due to the difficulty of removing the heavy wood from its native forest (R M W)

OATS. *Avena sativa* Gramineae Oats are annual cereal grasses native in temperate regions of the Old World The several species of oat plants are characterized by their closed leaf-sheath, a wide-branched **panicle**, and by a special type of **inflorescence** In the **florets** of wild oat plants the **lemma** has the midrib prolonged as a prominent **awn**, the basal portion of which is spirally twisted In many cultivated forms this awn has been eliminated The grain of oats is not easily separated from the surrounding husk, composed of the lemma and **palea**, which are neither palatable nor digestible

Oats are principally adapted to growing in a climate having cool summers and abundant moisture However, the plants are very hardy and tolerant of adverse conditions Oats are used principally for grain The straw is used either for bedding livestock or as a rough cattle food The grain is an important article in horse feeding A comparatively small part of the total oat harvest is used for human consumption in the form of rolled oats and oatmeal In manufacturing rolled oats the grain is first carefully cleaned and graded according to size, then passed between two millstones so placed that by the revolution of one against the other the husks are removed and withdrawn by suction The cleaned grains are steamed, and in the case of "Quick Oats," partially cooked, and then passed between heavy rollers and dried, after which they are ready for the market (R M W)

OBESITY (Adiposity, Overweight) A state of the body in which excessive fat is stored in the tissues This is one of the most common disorders to which the human race is subject The prevention and treatment of obesity is important, not only for the sake of appearance, but also because it decreases human efficiency, shortens life and predisposes the subject to many chronic disorders

The fundamental cause of obesity is the absorption of a greater caloric value of food than necessary for the total amount of energy expended by the body It is also true that, while two persons may eat the same amount of food, one may gain and the other lose weight This difference is due to factors present regulating the amount of energy expended One who gains weight and who does not apparently eat to excess (such a person eats more than he realizes or admits) is usually phlegmatic, reacts slowly to outside stimuli, is not easily worried, dislikes exercise or expenditure of energy in any form, sleeps longer and more soundly, and relaxes more completely than either the thin or person of normal weight Many people that fall in the overweight group have disturbances of their endocrine glands, especially the thyroid or pituitary or both But the explanation of most obesity is due to the one factor of simply liking to eat large quantities of fattening food—carbohydrates, starches and fats

Marked obesity can cause shortness of breath and fatigue on slight exertion It also seems to predispose to other diseases or accentuate their symptoms A person with heart disease may develop heart failure sooner than a thin person with the same degree of cardiac disease **Arthritics** having pain in the legs or back notice considerable improvement in their symptoms, as a rule, with reduction in weight. Because of obesity the kid-

neys, pancreas, and liver carry an extra burden **Diabetes** is predisposed to and so is increased blood pressure **Pneumonia** at times is more serious in the obese.

Prevention of obesity is simpler than its treatment Treatment lies along two lines First, the amount of food must be reduced and at the same time a balanced diet adhered to The rapid loss of weight by radical diets is harmful and actually may cause death Second, increase in exercise, which unfortunately increases the appetite Those that suffer glandular troubles must also be treated along these lines (R S M)

OBJECTIVE. Optical Instruments; Telescope; Microscope, Camera.

OBJECTIVE PRISM In the ordinary laboratory **spectrograph** a collimating lens is necessary in order that the light from the narrow slit may be sent through the **dispersing** agent in a parallel beam At the principal focus of the camera lens the images of the slit in the different radiations are commonly known as the **spectral lines**

The stars are at such tremendous distances that they subtend infinitesimal angles and the light from them reaches the earth in parallel beams Hence the slit and collimating lens of the laboratory spectrograph are unnecessary and the dispersing agent, usually a prism, may be placed directly before the objective lens of the telescope or astrographic camera With such an instrument, commonly known as an objective prism, instead of single point images of the stars, there appear on the photographic plate a series of dots, each of them in some particular radiation from the stars, or, in other words, the **spectra** of the stars In order that the spectra may have appreciable width or that the spectral lines may have length instead of appearing as mere dots, the refracting edge of the prism is set parallel to the spherical coordinate of **right ascension** and the telescope driven a bit too fast or too slow, slightly "trailing" the images

The objective prism has certain important advantages over the slit spectrograph for astronomical purposes On each plate taken with the instrument we obtain spectra of a great number of different stars Furthermore, the loss of light at the narrow slot is obviated and the exposure time necessary to obtain a good spectrogram will be greatly diminished In contrast to the advantages in speed of the objective prism there is the serious disadvantage that it is impossible to obtain good comparison spectra with such an instrument, and the determination of accurate wave lengths of the different radiations is practically impossible

The objective prism is used primarily for the determination of the **spectral classes** of the stars and to determine the relative intensities of the different lines and regions of the spectra Within recent years attempts have been made to determine **radial velocities** of the stars by this method and results obtained are of sufficient accuracy for statistical purposes The **flash spectrum** is also obtained by use of the objective prism (W K G)

OBLIQUE COORDINATES IN A PLANE. Let any two non-perpendicular intersecting lines in a plane be chosen as reference axes, let P be any point in the plane, and through P draw lines parallel to the axes The distances, parallel to the axes, from the axes to the point P are called oblique coordinates of the point (L I S)

OBLIQUE TRIANGLES. Triangles.

OBSEQUENT STREAMS. Consequent streams.

OBSIDIAN VOLCANIC GLASS. Highly acidic lavas (those containing a preponderance of **silica**), when chilled very rapidly and congealed, without appreciable crystallization, into a rigid liquid solution Such a solid is called a glass to distinguish it from a crystalline substance Pure obsidian is hard, with conchoidal fracture and vitreous luster Thin chips appear smoky gray or red in transmitted light The exceptionally dark color of obsidian, as compared with chemically related crystalline rocks (**rhyolite** and **granite**) is due to the fact that a small amount of coloring matter is much more effective in a solution than when segregated in a few dispersed dark-colored minerals (R M F)

OBSTETRICS. The branch of medicine and surgery that has to do with the management of **pregnancy**, labor and the complications and disorders arising from them (R S M)

OCCIPITAL BONE. A bone of the vertebrate **skull** located at the posterior end of the dorsal wall It is a median unpaired bone (A W L)

OCCLUSION. Adsorption.

OCCULTATION. When the **moon** passes between a star and the earth, the light of the star is cut off and the star is said to be occulted The term **eclipse**, which is technically correct for this phenomenon, is reserved for circumstances involving the **sun**, **earth**, and moon, and for such things as **eclipsing binaries**, **satellites of Jupiter**, etc As the moon passes between the earth and a star in its revolution about the earth the star disappears behind the eastern edge of the moon and reappears again at the western edge The disappearance and reappearance are practically instantaneous, proving both that the moon has no sensible atmosphere and that the star appears sensibly as a point of light The interval between disappearance and reappearance depends fundamentally upon how closely the center of the moon appears to pass across the star

Since the disappearance and reappearance are practically instantaneous, the times of the phenomena can be determined with great precision Observations of the instants of occultation of stars by the moon may be used to determine the position of the moon with great precision A large number of such occultations are observed both by professional and amateur astronomers, and the results used to verify and correct the theory regarding complicated motions of the moon The differences in the time of occultation of a given star, as observed by widely separated observers, may be used both to determine the distance of the moon and also to determine the difference in terrestrial **longitude** of the two observers This method of determination of difference in longitude was the most accurate available before the development of modern methods for distribution of Greenwich **Time** (W K G)

OCCULT MINERALS. A term proposed by Iddings, in 1913, for mineral compounds which, because of the chemical composition of an **igneous rock**, should be either potentially or actually present, but which cannot be detected by the **petrographic** microscope (R M F)

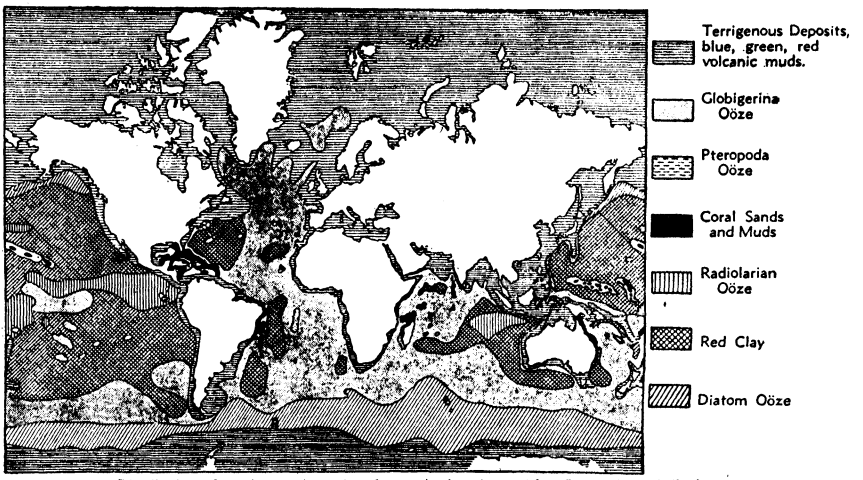
OCEANIC DEPOSITS The map on the facing page shows the distribution of the different types of deep sea or oceanic sediments (R M F)

OCELLUS. 1 The simple **eye** of **arthropods** Usually very small 2 An eyelike spot The wings of many butterflies and moths bear such markings (A W L)

OCELOT. Mammalia, Carnivora A moderately large South American **cat**, *Felis pardalis*, which ranges north to the Rio Grande It is tawny or reddish, marked with black spots and blotches

This species has been recorded from southern Texas. (A W L)

OCTAHEDRITE. The mineral octahedrite, **titanium** dioxide, TiO_2, is a rare mineral crystallizing in the **tetragonal** system It has the same chemical composi-



Distribution of marine-continental and oceanic deposits. (After Scott. After Collet.)

tion as **rutile** and **brookite**. It commonly occurs in **octahedral** crystals, either acute or obtuse, hence the name. (See **Rutile**.) (E.S.C.S.)

OCTANE RATING. Gasoline.

OCTOPUS. Mollusca, Cephalopoda. A genus of marine **mollusks** commonly called **devil fishes** but also known by the anglicized generic name. They have a large head bearing eight similar arms or tentacles, each with many suckers. The arms are webbed at the base, and in a related genus the webs unite them almost to the tips. (See also **Invertebrate Paleontology**.) (A.W.L.)

ODONATA. The **dragon flies** and **damsel flies**, an order of insects containing moderate to large species with slender bodies and four narrow net-veined wings. Their flight is powerful and they are well adapted to take their insect prey on the wing. The mouth is formed for biting. In the immature stages these insects are aquatic. Commonly called devil's darning needles. The order contains about 2700 species and is represented in all parts of the world. (A.W.L.)

ODONITE. The term proposed by Chelius, in 1892, for a basic **igneous rock** with a **porphyritic** texture whose **phenocrysts** are **labradorite** and **augite** in a matrix composed of **feldspar** and **hornblende**. (R.M.F.)

ODONTOCETI. The toothed whales, an order of marine mammals containing the **dolphins**, **narwhal**, **porpoises**, etc. A few species live in the large tropical rivers, including the Ganges and the Amazon. (A.W.L.)

ODONTOLITE. Turquoise.

OENOCYTE. A kind of large **cell** found in clusters associated with the **tracheae** and fat bodies of insects. Larval oenocytes have been interpreted as **endocrine glands** and those of adults are apparently for the storage of waste products. (A.W.L.)

OERSTED. The practical unit of magnetic intensity. The term oersted, prior to 1932, was used to designate the practical unit of magnetic reluctance (See **Magnetism**). By international agreement, however, it now replaces the term **gauss**, which formerly denoted a unit of magnetic field intensity; while the unit of magnetic reluctance is left without a name. The value of the oersted of magnetic intensity may be expressed in the same way as that used in defining the gauss of magnetic induction; but it is simpler to state that if a unit north magnetic pole is placed in a vacuum traversed by a magnetic field of intensity 1 oersted, the pole is urged in the direction of the field with a force of 1 **dyne**. (L.D.W.)

OERSTED EXPERIMENT. Electromagnetism.

OESOPHAGEAL GLAND. Glands associated with pouches on the sides of the **oesophagus** in earthworms. They secrete **calcium** carbonate. Also called calciferous glands. (A.W.L.)

OESOPHAGUS. A narrow portion of the alimentary tract (**digestive system**) behind the mouth. It serves only as a food passage in most species but in the earthworms bears a series of glandular pouches. In the vertebrates it is the part of the tract behind the pharynx, leading to the stomach. (A.W.L.)

OHM. The practical unit of electrical **resistance**. It is defined in two ways. The absolute ohm is that resistance which causes a potential drop of 1 absolute **volt** when a steady current of 1 absolute **ampere** flows through it; it is equal to 10^9 abohms (See **Electrical and Magnetic Units**). The international ohm is based upon a specified conductor; viz., it is the resistance of a uniform thread of mercury in a capillary tube of such diameter that the thread is 106.3 centimeters long and weighs 14.4521 grams, its temperature being 0° C. (This gives the thread a cross section of almost exactly 1 square millimeter.) Unfortunately the two units are not quite equal, the international ohm being larger by about 5 parts in 10,000. In more familiar terms: a No. 16 copper wire (0.05 inch in diameter), having a resistance of 1 ohm, would be about 264 feet long. The resistance of a 110-volt, 50-watt lamp in full operation is 242 ohms. Occasional use is made of the megohm (1,000,000 ohms) and the microhm (0.000001 ohm). (L.D.W.)

OHMMETERS. The accurate measurement of resistance is somewhat tedious, and various instruments have been devised to make direct readings in ohms. For example, one may send a current from a source of

known electromotive force E and known internal resistance R through an unknown resistance R_x, a voltmeter being placed across the terminals to register the resulting potential drop V From these the resistance can be calculated, for, using Equation 3 under **Electric Circuits** and substituting therein V *for* $V_A - V_V$, R_x for R_{AB}, $R_i + R_x$ for R, and zero for E_{AB} (since the terminals A, B are here the terminals of the unknown, inactive resistance R_x), we obtain

$$V = \frac{R_x}{R_i + R_x} E,$$

from which

$$R_x = \frac{VR_i}{E - V}.$$

Obviously, for a given, fixed electromotive force, the voltmeter scale might be graduated directly in ohms But the reliability of such an instrument requires a strictly constant electromotive force The more approved types of ohmmeter use the slide-wire **bridge** principle, with the slide-wire scale graduated in ohms These instruments, though accurate, are necessarily somewhat restricted in range A form of high-resistance ohmmeter, designed by Evershed, is graduated in megohms and is known commercially as a "megger" This is a type of differential, moving-coil galvanometer, in which part of the coil is in series with the unknown resistance, while another part, carrying current from the same generator, is independent of that resistance The galvanometer reading depends upon the relative currents in the two parts, and hence upon the unknown resistance (L D W)

OHM'S LAW. This very familiar law of **electric conduction**, stated by George Simon Ohm in 1827, is expressible in various forms, of which the following is typical The steady electric current in a metallic circuit is proportional to the constant total electromotive force operating in the circuit $I = KE$ The constant K, known as the "conductance" of the circuit, is the reciprocal of the **resistance** R, so that the equation may be written in the more usual form

$$I = \frac{E}{R}$$

Emphasis must be placed on the constancy of the electromotive force and the current For, if the current varies, the effects of **inductance** and **capacitance** set up extra electromotive forces, positive or negative, which render the law expressible in general only by a differential equation (See **Transients, Alternating Currents,** and **Electric Circuits**) Also there are certain kinds of conduction for which the law is not valid, notably that of **ionized gases, thermionic vacuum tubes** and **photoelectric cells** (L D W)

OIL. Volatile Oils, and **Fixed Oils,** and **Paints,** and **Hydrocarbons, Lubrication** and **Lubricants.**

OIL POOLS Petroleum.

OIL SANDS Petroleum.

OIL SHALE A general term applied to a group of fine black to dark brown **shales** rich enough in **bituminous** material (called kerogen) to yield **petroleum** upon appropriate distillation Oil shales are only of economic importance in those countries which are notably deficient in petroleum The United States has vast reserves of oil shales (R M P)

OIL WELLS Petroleum.

OILS, ESSENTIAL. Perfumes, and **Volatile Oils.**

OILS, FATTY. Esters.

OILS, PETROLEUM. Hydrocarbons.

OILS, VOLATILE. Volatile Oils.

OKAPI. Mammalia, Artiodactyla *Okapia* An African forest animal related to the giraffe but smaller and with shorter legs and neck They are dark brown with white stripes on the hind quarters (A W L)

OKRA. *Hibiscus esculentus* **Mallow Family.**

OLD MAN. 1 The great gray **kangaroo,** *Macropus giganteus* 2 Aves, Cuculiformes A Jamaican name for a **cuckoo,** also called the rain bird (A W L)

"OLD RED" SANDSTONE. Devonian.

OLD SQUAW, OLD WIFE Aves, Anseriformes A small **duck,** *Clangula hymenalis,* of the northern latitudes of the northern hemisphere, migrating into the United States in winter It is chiefly black and white and the male has a long slender tail Also called the long-tailed duck (A W L)

OLEFINE. Hydrocarbons.

OLEIC ACID AND OLEATES. Oleic acid ($H C_{18} H_{33} O_2$ or $C_{17}H_{33}$ COOH or $CH_3(CH_2)_7CH$ $CH(CH_2)_7$ COOH), is a colorless liquid, melting point 14° C, boiling point 286° C at 100 mm pressure, insoluble in water, miscible with alcohol or ether in all proportions Oleic acid differs from **stearic acid** chemically by possessing 33 instead of 35 hydrogen atoms in the radical ($C_{17}H_{33}$ COOH (oleic acid), $C_{17}H_{35}COOH$ (stearic acid)) It is possible to convert oleic acid and oleate esters into stearic acid and stearate esters by treatment with **hydrogen** gas in the presence of finely divided **nickel** as a **catalyzer** at 250° C under pressure as in the **hydrogenation** of oils and fats Either by careful oxidation, or by addition of ozone (See **Oxygen**) and splitting, oleic acid yields products of 9 carbon atoms, thus leading to the conclusion that the double bond is in the center of the carbon chain Oleic acid adds **bromine** or **iodine** in definite amounts to confirm the conclusion that one double bond is contained **Nitric acid** converts oleic acid into elaidic acid ($C_{17}H_{33}COOH$), melting point 51° C (oleic and elaidic acids are related, cis- and trans-, as maleic and fumaric acids)

Oleic acid may be obtained from glycerol trioleate, present in many liquid vegetable and animal non-drying oils, such as olive, cottonseed, lard, by **hydrolysis** The crude oleic acid after separation of the water solution of **glycerol** is cooled to fractionally crystallize the stearic and **palmitic acids,** which are then separated by filtration, and fractional distillation under diminished pressure Oleic acid reacts with **lead** oxide to form lead oleate, which is soluble in ether, whereas lead stearate or palmitate is insoluble From lead oleate oleic acid may be obtained by treatment with **hydrogen sulfide** (lead sulfide, non-volatile, formed) With sodium oleate, a soap is formed Most soaps are mixtures of sodium stearate, palmitate, and oleate

Representative esters of oleic acid are methyl oleate ($C_{17}H_{33}COOCH_3$) boiling point 100° C at 10 mm pressure, ethyl oleate ($C_{17}H_{33}COOC_2H_5$) boiling point 205° C at 10 mm pressure, glyceryl trioleate (triolein) ($(C_3H_5(COOC_{17}H_{33})_3)$) boiling point 240° C at 18 mm pressure

Oleic acid is used in the preparation of metallic oleates, such as aluminum oleate for thickening lubricating oils, for water-proofing materials, and for varnish driers As the glyceryl ester oleic acid is one of the constituents of many vegetable and animal oils and fats (R K S)

OLEO SHOCK ABSORBER. Shock Absorber.

OLEOTHORAX. Compression of a diseased tubercular lung by the injection of oil in the **pleural** cavity. (R S M)

OLFACTORY ORGAN. Organs of the sense of smell These organs are stimulated by minute quantities of material such as diffuse through the air in the form of gases or vapors. In a broad sense they sample materials in the animal's environment in the form of gases or vapors, although these substances probably dissolve in the body fluids before they act on the sensory ending. Like the organs of taste, olfactory organs are chemoreceptors, reacting to chemical properties, and in some animals it is difficult to distinguish accurately between the two senses The fact that they are activated by minute concentrations, sometimes as low as one part in one million of air, gives them a wider range of perception Whereas taste demands actual contact with a solid or liquid material, the volatile products may diffuse rapidly and over long distances from such a source and are readily carried by air currents

Sense organs of many lower animals which live in water are more logically interpreted as organs of taste or as more primitive chemoreceptors, since materials must reach them in solution Some aquatic insects and fishes, however, have olfactory organs enclosed in cavities which open to the exterior Whether reached by water or not, they are classed as olfactory organs from their resemblance to such organs in related terrestrial forms

The olfactory organs of insects are most abundant on the **antennae** They consist of blunt processes or flat plates, associated with sensory nerve endings In some cases they are grouped in the lining of depressions As many as 39,000 have been reported on a single antenna and five or six thousand are frequently present

In the **vertebrates** the olfactory cells lie in the epithelium lining a pair of olfactory pits which form in the embryo as depressions at the anterior end of the head These cells are connected with the brain by the fibers of the olfactory nerves, the most anterior pair of cranial nerves of known function In the air-breathing vertebrates the olfactory epithelium becomes part of the lining of the nasal passages.

The keenness of smell and its varied uses are well illustrated by dogs Man has very nearly abandoned the sense through depending more on vision for distant perception, although he is usually more aware of odors when he cannot see The sense is keener in man than we usually realize, but it is much less keen than in other animals (A W L)

OLIGOCENE. A geologic period of the **Tertiary**, of the Lower **Cenozoic** era of the **geologic time-scale** The term was proposed by Beyrich in 1854 Type locality near Paris, France Maximum thickness of strata in Italy This period began approximately 36,000,000 years ago and lasted for about 16,000,000 years In the United States marine sediments overlap the Cretaceous and earlier Tertiary sediments of the Atlantic border of South Carolina and the Gulf of Mexico Marine sediments also occur on the Pacific Coast Terrestrial sediments are well developed in the easterly Great Plains and Oregon (John Day Basin) The "Bad Lands" of South Dakota, eastern Wyoming, and North Dakota (Black Hills) are important collecting localities for the fossil mammals of this period In the Paris Basin occur fresh and brackish water deposits, which contain numerous **fossil vertebrates, invertebrates**, and plants (See **Paleobotany**) The Oligocene formations are also well developed in Germany, and in the Alps The marine invertebrates and fishes of the Oligocene are similar to those in the Eocene Among the mammals the true carnivores have replaced the **creodonts** The principal types of mammals are the Archaeotherium (giant pig), Poebrotherium (ancestor of the camels), Mesophippus (early horse), Hyracodon (cursorial rhinoceros), and Hoplophoneus (progenitor of the saber-toothed cats) (See also **Fossil Mammals**) For mineral resources of this period see the **Tertiary.** (R M F)

OLIGOCHAETA. **Chaetopoda.**

OLIGOCLASE. **Feldspar.**

OLIGOTRICHIDA. Ciliophora.

OLIVE. *Olea europaea* Oleaceae The olive is a small tree indigenous to the eastern Mediterranean region It has **lanceolate** evergreen leaves, small inconspicuous flowers, and a purplish **drupe**, the flesh of which is very bitter in the natural state Cultivation of the tree has continued through many centuries, gradually spreading not only to all Mediterranean countries, but abroad to suitable regions both in the Old and the New Worlds In the United States, olive growing is largely restricted to California, and even there it is not a major crop The wood of the tree is used to a limited extent

The principal product is the oil, which is expressed from the flesh of the fruit To obtain this oil the fruit is picked when ripe and usually allowed to dry a bit to remove some of the water contained in the flesh Pressing freshly picked fruits yields a much higher grade of oil Pressing is often done in a rather primitive machine The fruit is first crushed and then firmly pressed. The best grade of oil is known as virgin oil

Olive oil is widely used as a food or in the preparation of food, owing to its lack of objectionable taste Cheaper grades are used in soap-making Sardine packers require large quantities for packing their product In recent years olive oil has been much adulterated with cottonseed, sesamum, peanut, and other oils (R M W)

OLIVENITE. The mineral olivenite is a complex basic **arsenate of copper** with the formula $Cu_3As_2O_8 \cdot Cu(OH)_2$ It appears as prismatic, sometimes acicular **orthorhombic** crystals or may be fibrous to granular and earthy It is brittle, hardness, 3 , specific gravity, 4 1–4 4, luster, vitreous, color, usually some shade of green but may be brownish, less frequently yellowish or grayish, translucent to opaque Olivenite is a rare secondary mineral found associated with other copper minerals in various localities in France, England, South West Africa, and in the United States in the Eureka and Tintic mining districts of Utah The name olivenite is derived from its olive green color (E S C S)

OLIVINE. The mineral olivine is an **orthosilicate of magnesium** corresponding to the formula $(Mg,Fe)_2SiO_4$, in which the ratio of magnesium to **iron** is found to vary considerably Olivine crystallizes in the **orthorhombic** system in somewhat flattened forms but may occur massive or granular It has a conchoidal **fracture** and is rather brittle, the hardness is 6 5-7, specific gravity, 3 27-3 37, luster, vitreous, color, olive green, may be reddish from the oxidation of the iron It is transparent to translucent Olivine occurs both in **igneous rocks** as a primary mineral as well as in certain rocks of **metamorphic** origin It has also been discovered in **meteorites.**

Olivine crystallizes from **magmas** that are rich in magnesia and low in silica which form such rocks as **gabbros, norites, peridotites** and **basalts.** The metamorphism of impure **dolomites** or other sediments in which the magnesia content is high and silica low seems to produce olivine

Transparent olivines of good color are sometimes used as a gem, often called *peridot,* the French word for olivine, it is also called chrysolite from the Greek meaning gold, and stone Olivine occurs in the lavas of Vesuvius and Monte Somma and in the Eifel district of Germany Gem material comes from St John's Island in the Red Sea, Upper Burma, and from Minas Geraes, Brazil In the United States olivine localities are Orange County, Vermont, Webster and Jackson Counties, North Carolina. Arizona and New Mexico have also furnished some gem material (E S C S)

OLM. Amphibia, Urodela A European **salamander** with a long snakelike body, very small legs, and tufted

external gills It is found in subterranean waters, and in correlation with this habitat has rudimentary eyes (A W L)

OMMATIDIUM The structural unit of the compound eye of **arthropods.** (A W L)

ONAGER. Mammalia, Perissodactyla. A wild **ass,** *Equus onager,* of western India (A W L)

ONCHOSPHERE. An early embryo or **larva** of the tapeworm (**Cestoda**) It is a small rounded organism with six hooks which hatches from the egg after it is taken into the alimentary tract of a host After hatching the onchosphere lodges in various tissues, depending on the species to which it belongs, and develops into the bladder worm or another intermediate stage (A W L)

ONION. Allium.

ONYCHOPHORA. Small soft-bodied creeping animals, slightly like caterpillars in appearance They are of limited distribution in warm countries and have no common name The name of one genus, *Peripatus,* is sometimes applied indiscriminately to all members of the group

Peripatus.

These animals form a class of the phylum **Arthropoda** characterized as follows. 1 The body is metameric but segments are not distinctly marked externally 2 The head consists of three segments but is not distinctly separated from the body 3 The first segment bears a pair of **antennae** 4 The mouth is provided with a pair of jaws and a pair of oral **papillae** 5 Each segment of the body bears a pair of legs which are fleshy protuberances ending with a pair of claws 6 Each leg contains an excretory tubule 7 Respiration is carried on by air tubes or **tracheae** whose external orifices are irregularly placed 8 Unlike other arthropods, these animals have **cilia** in the alimentary tract and reproductive system

Onychophora are regarded as the most primitive of the terrestrial arthropods Their structure suggests the ancestral form of the insects (A W L)

ONYX. Agate.

ONYX MARBLE. A trade term for a variegated, crystalline **limestone** which resembles the cryptocrystalline variety of **quartz** called **onyx.** Not a true **marble** since it is not a **metamorphosed** limestone Onyx is usually formed as encrustations around springs which are particularly rich in **calcium** carbonate Much used for interior ornamental purposes (R M F)

OOECIUM A brood pouch in which the **embryo** develops in **bryozoans** Nourishment is supplied during this period by specialized cells in the walls of the ooecium Regarded as a modified **zooecium** and also called the ovicell (A W L)

OOGONIUM. Gamete.

OOLITE The term is from the Greek meaning egg and stone Oolites are well-rounded sand-like particles,

Different types of oölites *A* and *B* typical oölites, *C* probably the excrement of marine worms (Field, *Outline of Geology,* Princeton University Press)

originally formed of calcite but sometimes subsequently altered to either dolomite, or entirely silicified. Structure typically concentric about a nucleus, and often with radial lines In the accompanying figure, A and B (typical oolites) and C are probably the excrement of worms Oolites are relatively common constituents of limestones, often forming distinct beds Oolites are now forming on the shores of Great Salt Lake, but no authentic case is known of marine oolites being formed at the present time Coarse-grained oolites, in which the particles are about the size of pears, are called pisolites, from the Greek, meaning pea and stone (R M F)

OOLOGY. A division of biology which deals with the eggs of birds It is scarcely a science, but is rather a part of **ornithology.** (A.W L)

OOSPORE. An oospore is the **cell** formed by the union of two unlike **gametes.** It is the result of the union of an egg and a **sperm.** (R M W)

OOTYPE. A region of the genital passages of flatworms (**Platyhelminthes**) at the junction of the oviducts and vitelline ducts At this point the walls are thickened and a special secretion aids in forming the shell of the egg (A W L)

OOZE. Ooze is a general term used to designate the muds found on the ocean bottoms at abyssal depths and composed largely of the calcareous and silicified shells of minute surface living marine organisms, called **plankton.** (R M F)

OPAH. Pisces, Teleostei A beautifully colored Mediterranean and Atlantic fish (**Pisces**), *Lampris luna,* also called the sunfish. It reaches a length of four feet. (A W L)

OPAL. The mineral opal is amorphous hydrated **silica,** the water content being sometimes as much as 20% It has, of course, no crystal form, occurring as irregular **veins** and masses It has a conchoidal fracture, hardness 5 5–6 5, specific gravity 2 1–2 3, luster, vitreous or greasy to dull, color, very variable, colorless, white, milky blue, gray, red, yellow, green, brown and black Often a beautiful play of colors may be observed in the gem varieties These interference colors result from minute cracks in the opal which are filled with secondary silica It has also been suggested that this effect is due to the physical arrangement of thin lamellae in the opal during its solidification Besides the gem varieties which show the delicate play of colors, there are other sorts of common opal such as the milk opal, a milky bluish to greenish kind, resin opal, which is honey yellow with a resinous luster, wood opal, resulting from the replacement of the organic matter of wood by opal, and **hyalite,** a colorless glass clear opal sometimes called Muller's Glass Opal is a mineral gel, which is deposited at relatively low temperatures and may occur in the fissures of almost any type of rock Hungary, Australia, Honduras, Mexico and in the United States, Nevada and Idaho, have been the sources of gem opals. Hyalite comes from Czechoslovakia, Mexico, Japan and British Columbia Other common varieties of opal are widespread in their occurrence The word opal is derived from the Latin *opallus* (R M F)

OPEN-BILL. Aves, Ciconiiformes *Anastomus.* Birds (**Aves**) of Indian and African species related to the storks The upper **mandible** is straight and the lower curved, so that complete closure is impossible (A W.L.)

OPEN DELTA. Open delta is a way of connecting two single-phase **transformers** so as to become a three-phase transformer bank To accomplish this connection one side of a delta arrangement is omitted. (F.T M.)

OPEN HEARTH PROCESS. The open hearth process developed by Sir William Simens is the principal method for making steel in the United States This process is briefly described as follows A rectangular covered furnace is provided with a hearth in the shape of a large shallow dish in which is charged pig iron, scrap, and iron ore, together with limestone The charge is heated and melted at a very high temperature The source of this high temperature is the combustion of gaseous fuel, for which the air supply has been highly preheated The high temperature in the furnace, coupled with the oxidizing ores, and the presence of considerable excess air in the furnace, brings about the oxidation of part of the **carbon,** and of other elements which are to be removed from the **iron.** In this respect the action of the open hearth furnace is seen to be the same as the **Bessemer process,** which is one of oxidation The chemical reactions are under better control in the open hearth process, and a greater variety of steels can be produced than in the Bessemer furnace The loss of iron is lower, and the product is of higher quality For these and other reasons, the open hearth process is the leading method of steel making in the United States The secret of obtaining the high temperatures necessary for the successful operation of an open hearth furnace lies in the regenerative heating of the gas and air for combustion The furnace will be equipped with double ports at both ends, through which the preheated gas and air enter the melting chamber The furnace is fired from one end at a time, and the heated gases pass out of the ports at the other end, thence into heat exchange chambers, which are large brick chambers in which is set up a checker work of brick This checker work is heated by the burned gases which pass through it After about fifteen minutes' operation, firing from one end, the valves shift so that the furnace is fired from the other end, and preheated gas and air for combustion are drawn from the chambers containing the checker work of brick which has just been heated by the burned gases In the meantime the burned gases have been passed out through the other port into a corresponding checker work, which is being heated An open hearth furnace is fired alternately from either end, and there are two sets of heat exchanging, checker work chambers, at one of which air and gases are being heated and brick being cooled, while bricks are being heated in the other

There are two modifications of the general open hearth process which differ only in the kind of materials used for the charge and the **slag** produced The basic open hearth process uses materials high in sulfur and phosphorus which must be removed by the addition of a basic **flux.** The slag produced will be basic The acid open hearth process differs from the basic process in several respects The materials used are low in sulfur and phosphorus, the flux is omitted, consequently the slag will be acid, and the production time is shorter since there are less impurities to remove The furnace itself is made of brick having steel reinforcement on the sides and ends The hearth is made of basic or acid materials laid on a **concrete** foundation The type of materials will depend upon whether the furnace is to be used for the basic or the acid process The average open hearth furnace has a capacity of 50 to 100 tons of metal, is about 40 feet long by 15 feet wide, and the pool of metal will be about 2 feet deep The side walls are laid up with first quality silica brick, as is also the arched roof In addition to the ports previously mentioned, the walls are pierced by several charging doors, with slag holes, and by a tapping hole The slag holes are placed at the normal upper level of the bath, and the tap holes at the bottom so that all of the iron may be drained.

The manufacture of steel by this process requires, in addition to the furnace, a large amount of other equipment. There must be calcining cupolas to produce the calcined dolomite used for lining ladles and hearths; storage bins for limestone, ore, pig iron, scrap, conveyor systems, and machines for dumping measured amounts of the materials composing the steel into the furnaces, ladles and **cranes;** ingot molds, stripping machines, hot metal mixers, cupolas for producing the hot metal, and frequently, gas producer plants Natural gas, coke oven gas, and pulverized coal have been used, as well as producer gas

The actual making of steel by the open hearth process can be described as follows When the furnace is ready for the heat, the limestone is charged, then the scrap, ore, and cold pig iron The combustion is stepped up to its maximum rate, and the melting down of the charge begins If the heat is one in which some of the charge is molten iron which has been obtained from an auxiliary cupola, it is not added until the melting is nearly finished After a few hours the charge lies molten on the hearth, and the purification of the iron is carried out by oxidizing Due to the presence of the iron oxides, the limestone, and the excess oxygen in the combustion region, the action of the ore definitely precedes that of the limestone, and the reaction in the furnace has two definite stages, the one known as the ore boil, the other as the lime boil After several of these the slag is removed from the slag holes When the carbon is nearly burned out of the bath, the furnace men take samples of the metal, which are cast in small molds The test bars are broken, and the experienced melter can tell from the appearance of the fracture what the carbon content at that time was There are two methods of making steel One is to estimate the rate of elimination of the carbon and to tap the heat when the carbon content has dropped to that which is desired in the steel The other is to reduce the carbon content to about ten points and recarburize in the ladle with Spiegel or coal When the iron approaches the final state desired, the temperature of the pool of metal must be raised to that which is proper for pouring This should be possible by controlling the furnace carefully during the period just preceding the tapping, but sometimes it is necessary to add pig iron, whose carbon content will give some slight boil which will increase the temperature to that suitable for pouring (about 2900° Fahrenheit) The heat (molten metal) is then tapped into a large crane ladle, and additions of **manganese,** carbon, and other alloys in the ladle make the steel of the desired type Exceptions to this procedure are to be noted in the case of nickel and copper, both of which are added in the furnace After thus finishing the steel, the ladle is carried over the mold track, and a train of cars, each carrying an ingot mold, is brought up under it The molten steel is then teemed into the ingots one by one, after which the molds from the red hot ingots (F T M)

OPERA GLASS. Telescope; Binocular.

OPERCULUM. A flap covering an opening 1 An enlarged branch of a tentacle found in some of the marine **annelid** worms It closes the mouth of the tube when the animal is retracted 2 The margin of the **zooecium** of **bryozoans** which closes in when the body is retracted 3 A horny plate which fits into and closes the aperture of the shell of certain **gasteropod** mollusks when the body is retracted 4 A plate formed of a pair of rudimentary appendages which covers the external apertures of the genital ducts of **scorpions.** 5 A hinged flap on the side of the head in most fishes (**Pisces**). It covers the entire series of gill slits Also called the opercle (A W L)

OPHICALCITE. An old, but still consistently used term, proposed by Brongiart in 1813, for a variety of crystalline **calcite** and **serpentine.** Frequently used as a decorative **marble.** (R M F)

OPHITIC TEXTURE. A term proposed by Michel-Levy, in 1877, for the characteristic texture of **dolerites,**

in which the **pyroxene** crystals are penetrated by laths of **plagioclase** feldspar This type of texture differs from poikilitic in that in the latter type of texture the pyroxene crystals entirely enclose a number of laths of plagioclase (R M F)

OPHIURAE. Ophiuroidea.

OPHIUROIDEA. The brittle stars, a class of **echinoderms** resembling starfishes with a well marked disk and slender arms The class is distinguished chiefly by this sharp demarcation of disk and arms, which accompanies the restriction of visceral organs to the disk In addition the tube feet are without suckers and the madreporite lies on the oral surface (A W L)

OPHTHALMIA. Acute infection of the **eye** or the membrane around the eye Ophthalmia of the newborn is a very severe form caused by **gonorrhea.** Until measures were taken for applying **antiseptics** to the eyes of all infants directly after birth, it was one of the great causes of blindness (R S M)

OPHTHALMOSCOPE. An instrument made up of lenses, and producing a beam of light by means of which the interior of the eyeball (the eye ground) can be seen It is one of the valuable diagnostic instruments as in many diseases significant findings are present in the eye grounds (R S M)

OPIATE. Any **drug** derived from **opium** or, as the term is commonly used, any drug that produces sleep (R S M)

OPISTHOBRANCHIATA Gasteropoda.

OPISTHOSOMA. The abdomen of **arthropods.**

OPIUM. The dried milk-juice obtained from incising the unripe **poppy.** The principal opium-producing countries are in Asia Minor, India and China

Opium contains a series of nineteen closely related **alkaloids** At one end of the series is the principal constituent—**morphine,** which has the greatest narcotic power plus some tendency to stimulate the reflexes At the other end is thebain with no narcotic power but with an action similar to strychnine The principal drugs obtained from opium are morphine and **codeine**—two of the most valuable drugs in medicine Laudanum is the tincture of opium Paregoric is the camphorated tincture and is much weaker than laudanum Morphine is used as the sulfate Some combined forms of morphine marketed under their respective trade names are "Pantopon," "Dilaudid," "Papain," and "Magendie's Solution" This latter is simply a liquid form of morphine sulfate much employed in hospitals for hypodermic use

The smoking of opium is common in the Far East This is the least pernicious form of opium addiction (R S M)

OPOSSUM. Mammalia, Marsupialia Pouched **mammals** of moderate size, with long scaly tails and sharp noses With the exception of the water opossum they are arboreal animals which eat insects or a general diet The pouch is rudimentary in some species

The common opossum, *Didelphys virginiana,* ranges from the Great Lakes to the Gulf and westward to Oklahoma Other species range from Mexico to southern Brazil The water opossum or yapock, *Chironectes,* of this region is a swimming animal which lives on fishes and other aquatic animals (A W L)

OPPOSITION. Planetary motion.

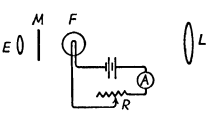
OPTIC AXIS. Double Refraction.

OPTICAL ACTIVITY. Isomerism; Polarized Light.

OPTICAL INSTRUMENTS. Optical instruments may be divided into two general classes· (1) those used for optical projection, such as the stereopticon and the **camera;** and (2) those used as an aid to natural **vision,** such as the **telescope** and the **microscope.** In the first class, a real image of the object to be represented is formed on a screen or photographic plate by means of a lens system or a mirror In the second, the eye of the observer is placed so as to view a virtual image formed by the optical system as a whole, which may or may not involve the formation of a real image in the interior of the instrument In either type there is an objective lens or mirror, and in the second class the final virtual image is formed by an **eyepiece** or ocular There are also usually one or more "stops," which are opaque screens with circular openings serving to limit sharply the field of view and incidentally to intercept stray light Some cameras and projectors have stops of adjustable diameter See **Geometrical Optics, Magnifying Power,** and **Vision.** (L D W)

OPTICAL LEVER A common device for amplifying and measuring small rotations The object rotated carries a small mirror, which, reflecting a beam of light, deflects it through twice the angle of rotation to be measured Light from a lamp is thus reflected as a bright spot moving along a scale, or the image of a fixed scale is viewed in the mirror by means of a reading telescope The most common applications are to **galvanometers, electrometers,** etc, using a torsion suspension, but the principle is also often adapted to devices such as that used for measuring Young's modulus, and in situations where a **micrometer** might otherwise be used (L D W)

OPTICAL PYROMETER. Several **pyrometers** have been devised, by means of which the temperature of a very hot surface is determined from its incandescent **brightness.** One commercial type is illustrated in the figure The hot body is viewed through a sort of telescope, whose objective *L* produces at *F* a real image of the glowing surface At this point *F* is placed a lamp filament, which is thus viewed through the eyepiece *E* against the hot surface as a background A monochromatic filter *M* is interposed before both, so that their brightness is compared in one spectral region only The current in the filament is so adjusted by means of the rheostat *R* that the filament becomes invisible against the bright background The ammeter *A* then gives the current, from which the temperature may be deduced, or the ammeter scale may be graduated to read temperatures directly In another type the balance is secured by keeping the current constant and introducing an absorbing wedge between the filament and the objective, as in a **wedge photometer.** In still others, the temperature is determined, not by the total brightness, but by the relative brightness at two selected wave lengths (L D W)



Arrangement of parts of optical pyrometer (Diagrammatic)

OPTICAL ROTATION. Polarized Light.

ORAL CAVITY. The cavity usually called the mouth. It is formed in the **vertebrates** of an embryonic depression, the stomodaeum, which forms in the ectoderm of the under side of the head and unites with the embryonic gut just behind its anterior end The depression is deepened by the growth of processes from the body wall at the level of the pharynx which form the upper and lower jaws Later the olfactory pits break through to join it and in this stage, which persists in the **amphibians,** the cavity is common to the **respiratory** and **digestive systems.** In a more advanced stage shelf-like partitions grow out from the lateral walls and join

to form the palate, which divides the cavity into respiratory and oral portions, as in man Also called the buccal cavity. (A W L)

ORAL FUNNEL The depression leading to the mouth in the lampreys (**Cyclostomata**) (A W L)

ORAL GROOVE. A shallow depression in the surface of the one-celled animals resembling *Paramecium* It is lined with cilia which create a current along it toward the cytopharynx at the rear, where food particles are gathered together to be taken into the body (A W L)

ORANG-UTAN Mammalia, Primates A large man-like **ape** found in Borneo and Sumatra It reaches a height of less than five feet and a weight of about 150 pounds The sharply depressed bridge of the nose accentuates the prominence of the rounded muzzle This feature, together with the weak legs, long arms, and prominent abdomen, gives the species a grotesque appearance

Orangs have been kept in captivity more successfully than gorillas but they also are delicate in the severe climates of Europe and America They have been found very intelligent, but they are less desirable subjects for study than chimpanzees because of their uncertain temper This is especially true of older males

The name is Malayan for man of the woods (A W L)

ORANGE Citrus fruits

ORANGITE. Thorite.

ORBICULAR STRUCTURE. The term proposed by Delesse, in 1849, for concentric shells of different minerals, frequently formed around a **xenotithic** nucleus, in **granites, diorites** and other granitoid, intrusive **igneous rocks.** Synonyms for orbicular (in the above sense) are spheroidal and nodular (R M F)

ORBIT In anatomy the orbit is the bony depression in the **vertebrate** skull in which the **eye** is seated

The path which a celestial object follows in its motions through space, relative to some selected point, is known as the orbit of the object The solution of the **two body problem** indicates that, in the case of two objects moving under the influence of their mutual gravitational attractions, the relative orbit of one to the other will be a **conic section.** The character of the conic will depend upon initial conditions In the case of members of the **solar system,** because of the relative very large mass of the sun in comparison with any of the other members, the orbits of the members may be conveniently represented as ellipses with the sun at one focus In the case of the satellites of the various members the orbits of the satellites may be represented as ellipses with the primary object at one focus Any deviations from the two body problem may be treated as departures of **perturbations** from the simple conic

To define completely the orbit of an object at any particular instant and to permit of the determination of

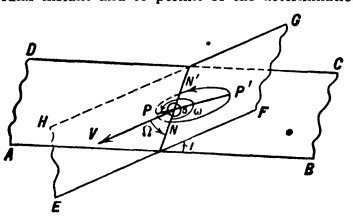


Diagram of orbit of member of solar system

the position of the object in this orbit at any future time, six quantities are necessary, known as the seven **elements** of the orbit In the accompanying figure we have a diagram of a planetary orbit about the sun The plane *ABCD* represents the plane of the **ecliptic,** and the plane *EFGH* represents the plane containing the orbit These two planes must intersect in a line, *NN'*, which must pass through the sun since both the earth (the plane of the ecliptic being the plane of the earth's orbit) and the planet are revolving about the sun The elliptical orbit of the planet is represented by *PNP'N'* with the direction of motion of the planet as indicated, *PP'* representing the major axis of the ellipse, and *P* the point where the object is closest to the sun (the **perihelion** point) The line *SV* represents, in the plane of the ecliptic, the direction to the vernal equinox We will assume that we are looking down on the plane of the ecliptic from the direction of its north pole The points *N* and *N'*, where the planet is on the ecliptic, are known as the nodes, the point *N*, where the planet is passing from south to north of the ecliptic, being the ascending node and the point *N'* the descending node To define the orbit plane the orbital element, i, the inclination, gives the angle between the orbit plane and the plane of the ecliptic, while the element, Ω (the angle *VSN*), gives the celestial **longitude** of the ascending node The size and shape of the orbit in its plane are given by the orbital elements, a, semi-major axis (usually expressed in **astronomical units**) and, e, the eccentricity of the **conic.** To locate the position of the conic in the orbit plane we use either ω (the angle *NSP* measured in the direction of motion of the planet), or, more commonly, ϖ, the longitude of **perihelion** which is the sum of the two angles, Ω and ω It should be noted that Ω, is measured in the plane of the ecliptic while ω is measured in the orbit plane so that ϖ is not strictly a longitude To locate the position of the object in its orbit the element, T, which is some epoch or date when the object is at perihelion and the rate at which the object is moving in the orbit are necessary Occasionally we find the rate of motion of the object given as an orbital element, but it is strictly not an independent element, since it may be derived from a Listing the six elements as defined above we have, i, Ω, a, e, ω, and T Unfortunately, several different systems of symbolic notation have been used by different authors and great care must be exercised in interpreting any symbolic description of an orbit

In describing the orbits of satellites the plane frequently used is the plane of the planet's orbit about the sun and the inclination, i, of the satellite orbit is referred to it Also, instead of locating the position of the orbit in the plane by perihelion, the point where the satellite is closest to the planet is used (in the case of satellites of Jupiter the point is known as perijove) In the case of **binary star** orbits, i gives the inclination of the orbit plane to the plane perpendicular to the line of sight, and instead of perihelion the point where the smaller star is closest to the primary, the periastral point, is used

The problem of orbit computation is far too complex to be included in a work of this character In general three observations of an object, giving the **spherical coordinates** of the object and the times of observation, are sufficient to compute a set of preliminary elements From these preliminary elements subsequent positions of the object may be computed and compared with observed positions From the differences between observed and computed positions the preliminary elements are corrected until a satisfactory representation of all observations is obtained Before a definitive orbit can be obtained (i e, an orbit which will give accurate positions for a long period of time), the perturbations due to other objects must be computed (A W L, W K G)

ORBITAL MOTION. Two Body Problem.

ORCHID FAMILY. Orchidaceae The Orchids, which form the second largest family of plants, are the highest development of the **Monocotyledons,** just as the **Composite Family** marks the highest point of evo-

lution reached by the **Dicotyledons.** But between the two families a most striking contrast exists The Composites are most beautifully formed to enjoy a more abundant life, the numerous small flowers are massed in compact heads, so pollination is almost certain of accomplishment The reduction of the fruit to a single ovule and the presence of various barbs or scales or bristles, called the pappus, greatly favor the probability of successful continuance of the species In the 9000-10,000 species of Orchids, the individual flowers are usually very conspicuous objects often of bizarre form and rare beauty But they depend entirely on insects for **pollination** and often exhibit elaborate modifications to insure successful insect pollination The seeds are minute and borne in tremendous numbers, few of which germinate and grow to maturity As a result, orchid plants are relatively rare, a fact which has contributed not a little to the zeal with which collectors have sought these plants

Originally orchids were known only from the reports brought back by travelers from the tropics who spoke of the brilliant colors, the curious forms and the delightful fragrance and also of the mystery and folk-lore which often attached to orchids Later botanists gained a wider knowledge of the family from dried specimens, in which color, fragrance, and, to a considerable extent, form, were lacking In time, however, living plants were obtained by collectors and carried to western lands There they were grown, usually without much success, since it was assumed that they could grow only in a very hot humid atmosphere Only the most tolerant species stood this, and they only partially Gradually, however, better understanding of the plants' requirements was obtained, and successful culture followed, so that during the first third of the nineteenth century orchids became popular Necessarily they are expensive to collect, they are not easy to transport, and they can be grown only in glass houses under fairly uniform conditions of temperature and humidity

Orchids are primarily plants of the tropical rain forests, where they grow in greatest abundance In these forests they are found mostly as **epiphytes,** plants growing on other plants Such plants grow attached to the branches of large trees, or massed in a crotch of the tree, or even attached to the trunk Often they occur high up on the topmost branches of lofty trees, where they are inaccessible except when the supporting tree falls, bringing all its attached plants to earth Other species of orchids, including nearly all those found in extra-tropical regions, are terrestrial All orchids, wherever they grow, are herbaceous perennials A few species are **saprophytes,** lacking **chlorophyll** entirely, and obtaining their energy by absorption from the soil of complex organic substances

In terrestrial orchids the roots are rather coarse and sparsely branching In many species one of these roots becomes greatly swollen with food, as the growing season advances, forming a tuberous body which will be used to promote rapid growth in the following season In epiphytic orchids two kinds of roots are found One of these grows tightly appressed to the supporting plant, is not affected by gravity but is vegetatively **phototropic,** growing into crevices in the supporting plant The other roots are the aerial roots, coarse branching objects which hang down, often in conspicuous masses, from the base of the plant The epidermis and the outer portion of the **cortex,** which is called the velamen, are composed of dead cells with perforated walls which readily absorb any water which may come to them and retain it tenaciously The inner tissues of the cortex are green and capable of carrying on **photosynthesis.** In some orchids slender absorbing branches grow out from the base of the other roots and penetrate the mass of debris which frequently collects at the base of the plant

The stems of terrestrial orchids are erect and leafy, and terminated by the **inflorescence.** In many epiphytic forms the leaves are dropped at the end of the growing season, the bare stem remaining The internodes of such stems are often conspicuously swollen, forming pseudobulbs in which are stored water and food reserves In other epiphytic species the leaves are fleshy and serve for storage

The most characteristic and in many species the most conspicuous part of the plant is the flower In all orchids the flowers are irregular but formed on a very uniform pattern In all there is a six-parted **perianth** composed of two groups of three members each One of the inner three differs from all the others and is designated the lip or labellum This becomes variously fringed in some orchids, broadly expanded in others, and even saccate (slipper-like), as in the Lady's Slipper It is commonly much more brilliantly colored than the other five parts and gives to the flower its showiness It serves as a landing place for insects, and is often a definite factor in bringing about pollination Often various outgrowths such as spurs add further complexity to the flower The essential organs of the flower, the **stamens** and **pistil** are united into a single body, the column, which is a characteristic feature of the orchid flower Its structure varies somewhat in the different groups of the family In orchids there are only one or in some species, two, **anthers** present The greater number of species have a single anther, which has two lobes, each filled with a mass of pollen grains held together by fine elastic threads Such a mass is called a pollinium The threads all unite to form a slender stalk which ends in a sticky mass resulting from the breaking down of certain cells in the rostellum The latter is a special organ which represents one of the **stigmas** of the flower

An insect comes to the orchid flower seeking the nectar which it contains In getting this nectar the insect comes in contact with the sticky mass of cells which become firmly cemented to some part of the body, often the eyes, or the **antennae** When the insect leaves the flower, it drags the pollinium out The latter may be in a position so that when the insect enters the next flower, the pollen comes directly in contact with the stigma and pollination is accomplished In many cases, however, a striking change occurs The stalk of the pollinium, due to changes in its water content, bends through an angle of 90°, and so brings the pollen mass into a position which will insure its reaching the surface of the stigma of the next flower visited by the insect There are many, often complex, variations in this process of pollination in Orchids, all on this general method In the second group of orchids the pollen is not combined into masses

The **ovary** of the orchid flower is inferior, that is, all the floral organs are borne at the apex of the ovary, which contains an immense number of ovules attached to its walls After fertilization, the ovules develop into very minute, light seeds, which are easily blown about by air currents

Raising of orchids from seed is a very difficult problem, in which the ordinary grower is seldom successful Development from seeds is very slow, several years being required to bring the plants to maturity Propagation is usually by means of cuttings Orchids are commonly grown for the beauty of the flowers, or for the weird shapes and striking colors which the latter often show Only one of them, **Vanilla,** is of any great importance commercially In times past many orchids were reputed to have medicinal value

Common orchids found in the United States are the *Cypripediums* or Lady's Slippers, the *Habenarias* or Fringed Orchids, *Spiranthes* or Lady's Tresses, *Epipactis,* the Rattlesnake Plantain, and *Pogonia,* the Grass Pink (R M W)

ORCHITIS Inflammation of the **testicle. This may** occur in **mumps, gonorrhea, syphilis** or **tuberculosis**

or it may result from injury The disease is marked by pain, sense of weight or fullness and swelling (R S M)

ORDER. A taxonomic division of the class See **Classification** In this work the orders of the animal kingdom are listed with brief notes or for reference to the larger groups under which they are discussed

Orders are characterized by important details of structural development and are the least of the major taxonomic divisions The families into which they are divided are in many cases determined by minor evolutionary trends (A W L)

ORDINARY DIFFERENTIAL EQUATIONS An **equation** which connects a **function** y of a single **independent variable** x with its **derivatives** of the first n orders, of the form

$$F\left(x, y, \frac{dy}{dx}, \frac{d^2y}{dx^2}, \cdots, \frac{d^ny}{dx^n}\right) = 0,$$

where F is a polynomial function, is called an ordinary differential equation and its order is defined to be n

If several functions y, z, are connected with one another and their derivatives by as many equations as there are functions, we have a system of ordinary differential equations, as for example,

$$\frac{dy}{dx} = f(x, y, z) \quad \text{and} \quad \frac{dz}{dx} = \phi(x, y, z)$$

By a solution or a primitive or an integral of an ordinary differential equation in x and y is meant a function $y = f(x)$ which satisfies the equation

The most general function which satisfies a differential equation of order n contains n arbitrary constants A solution containing n arbitrary constants is called the general solution If special values of the constants are used in the general solution, we obtain particular solutions An equation may sometimes have a singular solution, which is a solution of the equation which cannot be obtained from the general solution for any particular values of the constants, a singular solution contains no arbitrary constant

In applied problems, we are in most cases concerned with particular solutions The determination of the general solution is usually a necessary preliminary step, after which the required particular solution is found by determining the arbitrary constants by using given initial conditions

The order of a differential equation is the order of the highest derivative that occurs in it

When an ordinary differential equation is rational and integral with respect to all the derivatives that occur in it, its degree with respect to the derivative of highest order is called the degree of the equation

The geometric interpretation of an ordinary differential equation of the first order is as follows Any differential equation $F(x,y,y') = 0$, of the first order and n^{th} degree, represents an infinite set of curves, n of which (real or imaginary) will pass through any assigned point (x_1,y_1), and will there have the n slopes obtained by solving the differential equation algebraically for y' (L L S)

ORDINARY DIFFERENTIAL EQUATIONS OF FIRST ORDER AND FIRST DEGREE. A differential equation of the first order and degree $\frac{dy}{dx} = f(x, y)$ may be written in the differential form $M\,dx + N\,dy = 0$, where M and N are functions of x and y

The simplest type of equation here is the separable case If it is possible to separate the variables and write the equation in the form $f(x)\,dx = g(y)\,dy$, it may be integrated at once

If in the differential equation $M\,dx + N\,dy = 0$, the functions M and N are **homogeneous functions** of x and y, the equation may be solved by making the substitution $y = vx$, for the resulting equation in v and x is then separable

To solve an equation of the form

$$(ax + by + c)dx + (\alpha x + \beta y + \gamma)dy = 0,$$

make the substitution $x = x' + h$, $y = y' + k$, choose h and k so that $ah + bk + c = 0$, $\alpha h + \beta k + \gamma = 0$, then the equation becomes homogeneous, unless $a/b = \alpha/\beta$, in which case the substitution $z = ax + by$, or $z = \alpha x + \beta y$ will give rise to an equation in which the variables are separable

A linear differential equation of the first order is an equation of the form

$$\frac{dy}{dx} + Py = Q,$$

where P and Q are functions of x (but not of y) Such an equation may be integrated by multiplying through by $e^{\int P dx}$ (an integrating factor) The solution may be written

$$ye^{\int P dx} = \int Qe^{\int P dx}\,dx + c$$

The equation $\frac{dy}{dx} + Py = Qy^n$ may be reduced to a linear equation by the substitution $z = y^{1-n}$, it becomes

$$\frac{dz}{dx} - (n-1)Pz = -(n-1)Q$$

A differential equation $M\,dx + N\,dy = 0$ is called an exact differential equation if the left member is an exact differential of some function of x and y

The necessary and sufficient condition that $M\,dx + N\,dy = 0$ be exact is that $\frac{\partial M}{\partial y} = \frac{\partial N}{\partial x}$

If the differential equation is not exact, it may be possible to find a function, in general involving x and y, such that when both sides are multiplied by it, the equation becomes exact, such a factor is called an integrating factor (L L S)

ORDINARY DIFFERENTIAL EQUATIONS OF FIRST ORDER AND HIGHER DEGREE THAN THE FIRST In dealing with these equations, it is customary to abbreviate the derivative by the letter p

We may denote the given equation, of the first order, by $F(x, y, p) = 0$

There are three cases that may be considered separately, depending on whether the equation $F(x, y, p) = 0$ can be solved algebraically for p in terms of x and y, or for y in terms of x and p, or for x in terms of y and p

If $F(x,y,p) = 0$ can be solved for p in terms of x and y, we obtain thus several **differential equations of the first order and first degree,** which may each be solved for y in terms of x If these solutions are $f_1(x,y,C) = 0$, $f_2(x,y,C) = 0$, , the general solution of $F(x,y,p) = 0$ may be written

$$f_1(x,y,C)\ f_2(x,y,C) \qquad = 0$$

If $F(x,y,p) = 0$ can be solved for y in terms of x and p, we obtain one or more equations of the type $y = \psi(x,p)$ If we differentiate each such equation

$y = \psi(x,p)$ with respect to x, we obtain a differential equation of the first order in p which does not involve y, and may be solved for p in terms of x, say $\phi(x,p)=C$. For any particular value of C, the equations $y = \psi(x,p)$ and $\phi(x,p) = C$ may be interpreted as **parametric equations** of a curve in terms of the parameter p, the set of all such curves represents the solution of the equation $y = \psi(x,p)$

In a similar manner we may treat the case when $F(x,y,p) = 0$ can be solved for x in terms of y and p Having found x in terms of y and p, we differentiate with respect to y and replace $\frac{dx}{dy}$ by $1/p$ We may then proceed as before

In differential equations of the first order and higher degree than the first, singular solutions may occur Let $F(x,y,p) = 0$ be such an equation, and let $f(x,y,C) = 0$ denote its general solution The equation $f(x,y,C) = 0$ represents a family of curves, which may have an **envelope**, i e, a curve $\phi(x,y) = 0$ which is touched at each of its points by one of the curves of the preceding family Then $\phi(x,y) = 0$ will be a solution of the differential equation, but it will not generally be included among the particular solutions obtained by assigning particular values to C in the general solution $f(x,y,C) = 0$ Such a solution $\phi(x,y) = 0$ is called a singular solution of the given differential equation

A differential equation of the form $y = px + f(p)$ is called a Clairaut equation Its general solution is $y = Cx + f(C)$ Another solution is $x = -f'(t)$, $y = tx + f(t)$, which is a singular solution (L L S)

ORDINARY DIFFERENTIAL EQUATIONS OF THE SECOND ORDER. An ordinary differential equation of the second order may in general be written in the form

$$\frac{d^2y}{dx^2} = F\left(x, y, \frac{dy}{dx}\right).$$

We shall here consider only very briefly several important special types, in which one of the variables is absent from the equation

If the function y is lacking in the differential equation, put $\frac{dy}{dx} = p$, then $\frac{d^2y}{dx^2} = \frac{dp}{dx}$, and the differential equation takes the form $\frac{dp}{dx} = \phi(x, p)$, which is an **ordinary differential equation of the first order** in p as a function of x After finding p as a function of x, we may replace p by $\frac{dy}{dx}$, and again solve a first order differential equation to express y as a function of x

If the independent variable x is lacking in the differential equation but y is present, put $\frac{dy}{dx} = p$, so that $F\left(x, y, \frac{dy}{dx}\right)$ becomes a function $\psi(y, p)$, then since $\frac{d^2y}{dx^2} = \frac{dp}{dx} = \frac{dp}{dy}\frac{dy}{dx} = p\frac{dp}{dy}$, the given differential equation becomes $p\frac{dp}{dy} = \psi(y, p)$, which is a first order equation with p a function of y After finding p as a function of y, we replace p by $\frac{dy}{dx}$ and solve another first order differential equation for y as a function of x

A special device for differential equations of the type $\frac{d^2y}{dx^2} = f(y)$ is the following Put $\frac{dy}{dx} = p$, then the equation becomes

$$\frac{dp}{dx} = f(y)$$

Multiply both sides by $2p$, then since $2p\frac{dp}{dx} = \frac{d}{dx}(p^2)$ and $2pf(y) = 2f(y)\frac{dy}{dx}$, we have $\frac{d}{dx}(p^2) = 2f(y)\frac{dy}{dx}$.

Integrating, we get $p^2 = 2\int f(y)dy + c = \phi(y)$, say

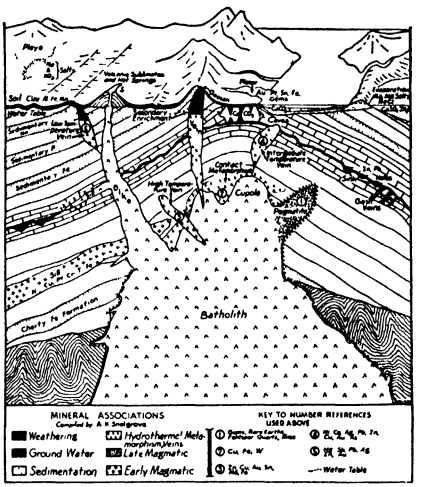
Extract the square root, replace p by $\frac{dy}{dx}$, and integrate again by separation of variables, obtaining finally y as a function of x (L L S)

ORDINATE OF A POINT. Rectangular Coordinates in a Plane.

ORDOVICIAN A period of the **Paleozoic Era**. Type locality, border of Wales and Shropshire, England

The formations of this system were first studied and described by Charles Lapworth in 1879 The Ordovician period began 440 million years ago and lasted for 60 million years In 1874 J D Dana had already proposed a post-**Cambrian** system, the **Canadian**. This system has only been recently recognized in Britain (Northwest Highlands of Scotland) where it is still considered as upper Cambrian by some British geologists (1937) In 1911, E O Ulrich proposed a new system (period) called the Ozarkian, to include some of the upper Cambrian and some of the lower Canadian There is still considerable doubt as to the systemic importance of the Ozarkian, especially as it appears to be absent in Great Britain Ordovician formations are well exposed in North America due to the fact that a large part of the continent was submerged during this period The marine sediments are of two principal types, **limestones** and **shales**, the former contain "shelly **fossils**" and the latter, principally **graptolites**. Thus the American Ordovician covers an enormous area and has an endless variety of local developments, for during the vast lapse of time which is included in the period, the shallow **epeiric seas** were continually shifting their positions, outlines and depths The United States Ordovician contains no **igneous rocks** with the exception of volcanic ashes, called bentonites The formations of this system are well exposed in Portugal, Switzerland, Bohemia, Austria, Hungary, Ireland, eastern Asia, China, Manchuria, Siberia, Himalayas, Burma, Morocco, Australia, New Zealand, northern Argentina, Bolivia and eastern Peru The maximum thickness of Ordovician strata, 40,000 feet, occurs in Australia All classes of marine invertebrates occur as fossils, a number of which classes are now extinct The principal types are **graptolites, corals, echinoderms, bryozoans, pelecypods, nautiloids, trilolites** and **ostracods** (See also **Invertebrate Paleontology**) The strata of eastern North America are an important source of petroleum Because of the wide surficial distribution of the Ordovician limestones they are much quarried for foundation structures, road metal, flux for the reduction of iron ores, and especially for the lime used in mortar, whitewash, fertilizers and Portland cement In Vermont and Tennessee occur valuable deposits of **marble**. Lead and zinc ores in rocks of Ordovician age are mined in Iowa, southern Wisconsin and northern Illinois Phosphates of the same age are mined in central Tennessee In eastern North America the Ordovician closed with a period of mountain building named the **Taconic Revolution** by J D Dana, in 1895 (R M F)

ORE. A mineral aggregate in which the valuable metalliferous minerals are sufficiently abundant to make the aggregate worth mining Types and origins of ore deposits are illustrated on the following page (R M F)



Diagrammatic illustration of the origin of the ore deposits (Field, *Outline of Geology*, Princeton University Press)

ORFE, GOLDEN ORFE Pisces, Teleostei A domesticated variety of the ide, a European fish of the **carp** family This form is golden yellow Introduced into England during the nineteenth century (A W L)

ORGAN A multicellular structure made up of various **tissues** for the performance of some complex function The stomach, for example, contains in its walls tissues of all of the five principal divisions Its function is the digestion of food and this end is gained by the cooperative exercise of the simpler functions of all of the tissues composing it (A W L)

ORGANELLE. A specialized structure of the single **cell** composing the body of the **protozoans** Organelles are comparable with the **organs** of multicellular animals in their relation to individual life but differ in their simplicity of structure Also called cell organs (A W L)

ORGANIC CHEMISTRY. Chemistry.

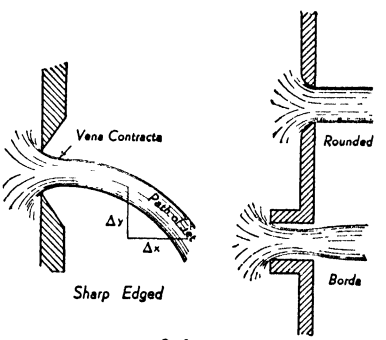
ORGANIC DISEASE A disease in which definite structural changes take place in the course of disease These changes may be temporary or permanent in character (R S M)

ORGANIZATION. The association of specialized parts in the body of an organism for the coordinated performance of various functions for the welfare of the entire individual All living things, no matter how simple, show some degree of organization, hence it is regarded as a distinctive property of living matter Some of the details of animal organization are taken up under **anatomy** and others under the various organ systems (A W L)

ORGANOGENY, The formation of **organs** in the **embryo.** After the formation of the **germ layers** and their initial stages of differentiation, each layer or its subordinate parts gives rise to certain of the organs characteristic of the adult by processes described under **embryology.** (A W L)

ORIBI. Mammalia, Artiodactyla *Ourebia.* South African **antelopes** of dainty build They are less than two feet high, with sharply pointed horns four or five inches in length The color is tawny above and white below (A W L)

ORIFICE. An orifice is an opening having a closed perimeter through which a fluid may discharge The orifice may be open to the atmosphere, which is the case of free discharge, or it may be partially or entirely submerged in the discharged fluid The standard orifice is the sharp edged orifice shown in the illustration but other types, such as the well rounded orifice, the partially rounded orifice, the Borda mouthpiece, and the short tube orifice, have their special uses An orifice may be very small, as in the case of those used for leak ports or for calibration, or large, as illustrated by sluice gates in a dam The head of water on the orifice is measured from the water level surface to the center line of the orifice Should the head above the orifice be so small as to be less than approximately the vertical dimension of the orifice, the following remarks will not apply, as this would come under the special case of large orifices under low heads



Orifices

The streamlines in water approaching a sharp edged orifice converge on the orifice from all directions, and so continue to converge for approximately one-half of the orifice diameter downstream The jet contracts to a section somewhat smaller in diameter than the orifice, after which it increases in size The contracted section is known as the *vena contracta* The ratio of the cross-section of the jet at the vena contracta to the area of the orifice is known as the contraction coefficient Friction in the orifice slows the velocity to somewhat lower value than the ideal free spouting velocity which is $\sqrt{2gh}$ The ratio of actual to spouting velocity is the velocity coefficient Since the discharge is the product of velocity and area, the discharge coefficient is the product of velocity and contraction coefficients It has a numerical value of 61% for the average sharp edged orifice The discharge from an orifice of area a is

$$Q = 61a\sqrt{2gh}$$

The path taken by a jet discharging freely horizontally under head of h is parabolic in shape due to the pull of gravity acting on a particle having, originally, horizontal motion only The equation

$$x^2 = 4K_v^2hy$$

gives a curve of the center of the path of the jet K is the velocity coefficient which averages 98% for sharp edged orifices Suppression of the contraction of a jet increases the discharge from an orifice An orifice on the side wall of a tank near the bottom has a higher coefficient of contraction than one which is located farther away from the bottom Similarly an orifice with the upstream edges rounded has a higher coefficient of contraction than one with sharp edges. The discharge

may be as much as 30% greater for well rounded orifices Orifices which are submerged, orifices which are squared instead of circular, and orifices in which the water approaches with a high velocity, can not be treated by the equation given above without corrections being made for these special conditions

The above discussion relates to the flow of water through an orifice Orifices are much in use for measuring flows of vapors and gases The method employed is to place an orifice of some type in the pipe or duct carrying the fluid By means of a **manometer**, or pressure gage, the upstream and downstream pressures are measured, and the discharge can be determined from those readings coupled with the known area of the orifice The flow of a gas through an orifice depends on the area of the orifice, the upstream pressure, the temperature, and a factor which involves gas constants, such as the ratio of the specific heats at constant pressure and constant volume, and the ratio of the upstream and downstream pressures The formula for the weight of gas flowing is $\frac{C_1 C_2 a P}{\sqrt{T}}$ (pounds per second) C_1 is the constant just mentioned, C_2 the velocity of approach correction, P the upstream pressure, a the area of the orifice, and T the absolute temperature A great many steam meters are based on the principle of the orifice A sharp edged, or thin plate orifice, is clamped between the flanges at some joint of a flanged steam line Pressure leads are taken from upstream and downstream sections to an instrument which is a pressure measuring device, but which may be calibrated to read steam flow See **Flow Meter.** (F T M)

ORIOLE Aves, Passeriformes Brightly colored birds (**Aves**) of the family Oriolidae, found in all parts of the Old World The North American birds to which this name is applied belong to the family Icteridae and are more closely related to the blackbirds than to the true orioles The orchard oriole, *Icterus spurius,* and the Baltimore oriole, *I galbula,* are the most widely known species of the latter group (A W L)

ORION. (Map, page 306) This **constellation** is, on the whole, the richest and most impressive of all of the constellations The "belt and sword" of Orion are frequently referred to in both ancient and modern literature and even found recognition as the shoulder insignia of the 27th division of the United States Army during the world war, probably because of the fact that the division was commanded by General O'Ryan Despite the wide area covered, the physical characteristics of many of the stars are so similar that there is considerable evidence in support of the theory that they have a common origin

The star Betelgeuze must be considered as an exception to this class for it is quite different from the other bright members of the constellation Its color is a distinct yellow-orange as contrasted with the blue white tint of the typical "Orion star" It is a **giant star,** its diameter, as measured with the interferometer, being about 300 times that of the **sun.**

The middle "star" of the sword is not a star at all, but is a huge gaseous **nebula.** This is one of the very few nebulae that can be seen with any satisfaction in a small instrument Of course the larger the instrument the finer the view

Several of the bright stars in the constellation are multiple objects, and the possessor of a four-inch telescope will find the stars of Orion well worth more than a passing glance (W K G)

ORNITHOLOGY. The biological science which deals with facts relating to birds (**Aves**). The large number of species and the great range of habits of birds have furnished abundant material for purely scientific studies, and the beauty and general interest of the group have made bird study a hobby of many persons. Economically birds are important as destroyers of insect pests, as game, and less frequently as predators In these roles they have commanded the attention of the Biological Survey and of the many conservation boards and commissions of fish and game of the various states (A W L)

ORNITHOPTER. Ornithopters are the natural result of man's attempts to gratify his desire to fly An ornithopter is a flying machine which, like a bird, flies by flapping its wings It is quite logical that efforts should have been made to copy bird flight The first attempts to fly were with ornithopters One is recorded as having been built by Leonardo da Vinci in 1490, but, like the many ornithopters which have been built since that day, it was not a success The ornithopter is too complicated mechanically, and there is not a close enough resemblance between the flight of birds, and that with which man must be content, to permit much success in the field of the flapping wing machine (F T M)

ORNITHORYNCHUS Fossil **mammals.**

OROGENY. Epeirogeny.

ORPIMENT. This mineral, like realgar its frequent associate, is an **arsenic** sulfide Orpiment, however, is the trisulfide corresponding to the formula As_2S_3 It is **monoclinic** with a resinous to somewhat pearly luster, color, various shades of lemon yellow, translucent to nearly opaque Orpiment is found in association with **realgar,** although a somewhat rarer mineral It is believed to be formed from the alteration of other arsenic bearing minerals It occurs in Czechoslovakia, Rumania, Macedonia, Japan, and in the United States in Utah, Nevada and Wyoming The name orpiment is derived from a corruption of the Latin *auripigmentum* meaning golden paint, because of its color as well as the belief that it contained gold It was formerly much used as a dye, but its place has been largely taken by an artificial product of similar composition (E S C.S)

ORRIS ROOT. Volatile oils

ORSAT ANALYSIS Flue Gas Analysis.

ORTHITE. Allanite.

ORTHOCLASE. Feldspar.

ORTHOGENESIS. A theory of organic **evolution** which assumes the occurrence of progressive change in living things along definite lines of development

In **fossil** series it is always possible to see orderly progression or retrogression from form to form According to some evolutionists this type of development has taken place under the impulse of unknown controlling factors as a directive tendency Others point out that one result of evolution is certain to be an ancestrial series which, if isolated, appears to be orthogenetic

Since every heritage must have certain potentialities, the evolution of any group must proceed along the lines made possible by these potentialities To this extent orthogenesis is an established principle No comprehensive theory of evolution, however, fails to admit the existence of other factors, at least in a directive capacity, and so orthogenesis is not to be regarded as an explanation of organic evolution. (A W L)

ORTHOGNEISS. Gneiss.

ORTHOGONAL CIRCLES. Circles.

ORTHOPEDICS. A special department of general surgery having to do with the diagnosis and treatment of the deformities and chronic diseases of the bones and joints. (R S M)

ORTHOPTERA. Insects of many forms with many common names, constituting one of the larger orders The principal members of the group are the **grasshoppers, crickets, mantises, stick insects,** and **cockroaches.** Locusts are grasshoppers Some authorities place these major forms in separate orders, but the general tendency is to group them together

The order is characterized by biting mouth parts and gradual metamorphosis (**Paurometabola**) When wings are present there are two pairs, the front wings somewhat thickened as tegmina and the hind pair broad and membranous, folding beneath the tegmina when at rest

These insects have a wide range of habits and occupy many terrestrial habitats The locusts are important crop pests in some areas and cockroaches are common household pests (A W L)

ORTHORHOMBIC SYSTEM. Crystallography.

ORTHOSILICATE. Silicon; also Garnet.

ORTHOSITE. The term proposed by Turner, in 1900, for a rock of granitic texture but composed almost entirely of the feldspar, **orthoclase.** (R M F)

ORTOLAN. Aves Passeriformes A European bird, *Emberiza hortulana,* whose flesh is regarded as an unusual delicacy Many of the birds are caught in nets and fattened for the market One of the **buntings.** (A W L)

ORYX. Mammalia, Artiodactyla A genus of **antelopes** found in the desert regions of Africa and thence to Syria The name is also anglicized as a common name of some species All species have very long horns, straight or slightly recurved The **gemsbok, beisa,** leucoryx and beatrix antelope are oryxes (A W L)

OSAZONES. Hydrazines, Hydrazones and Osazones

OSCILLATION. An oscillation is to and fro, or vibratory motion, of an object, a wave, electrons, etc Mechanical oscillation is exemplified in the **pendulum,** by its regular swing back and forth The center of oscillation of a pendulum is one of its conjugate points See **Kinetics.** Electrical oscillation occurs in a circuit in which electricity surges back and forth Electromagnetic waves are oscillatory in nature, and can be produced by **oscillators.** The number of oscillations per second is known as the **frequency** of oscillation, and its reciprocal is the period (F T M)

OSCILLATOR. The electric oscillator is composed of circuits and equipment which will produce electromagnetic waves of a given frequency Electric oscillation is created by forcing **electrons** to one side of an open circuit by a voltage The removal of this voltage brings the electrons rapidly to and past their normal position, after which they again return in a series of oscillations, which, unless aided by further applications of voltage, die away The simple Hertz oscillator for the production of Hertzian rays (in radio) consists of two metal plates for radiating the waves into a space Each plate is connected to one of two spheres, forming an air gap The plates are charged through **inductances** which choke back the high frequency oscillations when a spark is discharged across the gap, so that the discharge is oscillatory between the plates Very high frequencies are produced by this type of oscillator The oscillators of modern radio stations are **vacuum tube** types Due the fact that an amplifier circuit involving a thermionic tube will produce many times the amount of power put in, the reintroduction into the input circuit of a certain fraction of the output will cause the circuit to oscillate The frequency of this oscillatory circuit can be controlled by the tuning of **inductance and capacitance** connected to the grid circuit. (F.T.M.)

OSCILLOGRAPH. This name applies to a variety of instruments, including certain vibration **galvanometers,** which automatically trace, or at least render visible, curves representing variable currents, electromotive forces, or other electrical quantities For example, the electric oscillations in a circuit may cause the **electromagnetic** vibration of a filament bearing a small mirror which, reflecting a beam of light, leaves a trace on a moving photographic film, or a diaphragm may be vibrated through electrostatic forces controlled by varying potential The most generally adaptable forms are of the **cathode-ray** type, originated by Braun. In these, a slender stream of cathode particles, **usually** from a hot-filament cathode, issues from a small anode opening (like negative **canal rays**), and is deflected by means of a rapidly varying magnetic or electric field or both, so that its far end oscillates in faithful reproduction of the currents or voltages responsible for the fields The stream may fall on a fluorescent screen where its vibrations become visible, or may leave its trace on a photographic plate or moving film In one form, the motion along the time axis called the "sweep," is secured by causing the stream to deflect under the influence of an increasing electric field controlled by a slowly charging **condenser.** (L D W)

OSCULATING ORBITS. Orbit.

OSCULUM The opening of the central cavity (paragaster, gastral or paragastric cavity) of **sponges.** Water passes into this cavity through the small pores in the body wall and flows out of it by the osculum (A W L)

OSE. Esker

OSMETERIUM A scent gland found in some insects. A common example is the forked eversible organ just behind the head of the caterpillars of swallowtail butterflies This organ is thrust out when the insect is alarmed It is brightly colored and gives off a powerful odor, usually reminiscent of the animal's food plant but too strong to be agreeable to the human nose (A W L.)

OSMIUM. Symbol: Os. Atomic number: 76. Atomic weight. 190 2 Density. 22 40 Hardness 7 Melting point 2700° C (Isotopes, page 239)

Compact osmium is a bluish-white metal, and is not attacked by acids Discovered by Tennant in 1804

Finely divided osmium is a **catalyzer** for the reactions (1) **hydrogen** plus **oxygen** at 50° C forming water, (2) hydrogen plus **nitrogen** at 185 atmospheres and 900° C forming **ammonia.**

Osmium occurs native with **platinum,** and with **iridium** (osmiridium, 20%–40% Os) By boiling finely divided osmium-containing material with **aqua regia,** volatile, poisonous osmium tetroxide distils over, and is absorbed in **sodium** hydroxide solution. The resultant red solution, containing sodium osmate (Na_2OsO_4), is later acidified, and reduced to osmium metal by zinc metal

Osmium tetroxide is used in preparing microscopic slides, where it stains selective portions of tissues black

Chlorides Osmium dichloride ($OsCl_2$), osmium trichloride ($OsCl_3$), osmium tetrachloride ($OsCl_4$)

Hydroxide: Osmium hydroxide ($Os(OH)_4$), brown precipitate, by solutions of hydroxides, e g, **sodium** hydroxide

Oxides. Osmium monoxide (OsO), osmium sesquioxide (Os_2O_3); osmium dioxide (OsO_2), osmium tetroxide, or osmic acid (OsO_4) The last compound has melting point 40° C, boiling point 100° C.

Sulfides· Osmium disulfide (OsS_2), brown precipitate, in acid solution by **hydrogen sulfide;** osmium tetrasulfide (OsS_4), in neutral solution.

Osmium tetroxide is reduced by **ferrous** sulfate solution to osmium dioxide. Osmium compounds are reduced to osmium metal by ignition in hydrogen. (R K S.)

OSMOSIS. The passage of liquids or gases from solution through membranes When solutions of different degrees of concentration are separated by a membrane (a common form of membrane for experiment is a very thin sheet of collodion) substances diffuse through from the solution in which they are more concentrated to that in which they are less so, provided that the membrane is permeable to them By this process materials pass both into and out of the cells of the living bodies. (See **Diffusion of Fluids.**) (A W L)

OSPHRADIUM. A branching sensory organ of **molluska,** supposed to be olfactory in function It sometimes resembles a **ctenidium.** (A.W L)

OSPREY. Aves, Falconiformes A large bird of prey of almost worldwide distribution. It is a skillful fisher and is known in North America as the fish hawk, *Pandion haliaetus* (A W L)

OSSICLE. 1 The calcareous plates in the body wall of **echinoderms.** In some species, notably the sea urchins, they are connected to form a shell and in others, especially the sea cucumbers, they are small and scattered 2. A small bone, such as the chain of three auditory ossicles (hammer, anvil and stirrup) in the middle **ear** of mammals (A W L)

OSSIFICATION. The formation of bone or the conversion of tissue into bone or a bone-like substance. (R S M.)

OSTEITIS. A low grade inflammation of bone marked by tenderness, pain and enlargement of the bone (R S M)

OSTEITIS FIBROSA CYSTICA. Parathyroid Gland. (R S M)

OSTEO-ARTHRITIS. Arthritis. (R S M.)

OSTEOLEPIS. Fossil Fishes.

OSTEOLOGY. A division of vertebrate anatomy which deals with the **skeletal system.** The study of bones. Comparative osteology is the study and comparison of the bones of different races and different species of organisms. (A W L, R S M)

OSTEOMA. A growth composed of bone which may develop on the surface of a bone or, at times, in other soft structures of the body. (R S M)

OSTEOMYELITIS. Infection of bone substance The infection may be acute or chronic The treatment is surgical and is apt to be prolonged and stubborn due to the slow reparative processes of the bone Many organisms can cause osteomyelitis but the common microorganisms are various strains of the *Staphylococcus and Streptococcus* groups

The infection follows injury to bone or is carried directly to bone by the blood stream

The symptoms of an acute osteomyelitis are high fever, marked local pain over bone involved with swelling, redness and local heat of the surrounding soft tissues and marked constitutional symptoms The mortality in acute osteomyelitis is fairly high (R S M)

OSTEOPATHY. A system of treatment in which diseases are treated by manipulations of bones and joints with intent to restore to normal the disturbed mechanism of the body The official definition of osteopathy adapted by the American Osteopathic Association is "That system of the healing art which places the chief emphasis on the structural integrity of the body mechanism as being the most important single factor to maintain the well-being of the organism in health or disease." (R.S M)

OSTIUM. The terminal opening or mouth of a duct and other openings of hollow organs The slits in the wall of the tubular heart of **insects,** the opening of a radial canal into the central cavity of **sponges,** and the opening of the **vertebrate** oviduct into the abdominal cavity are specific examples (A.W L)

OSTRACODA. Crustacea.

OSTRACODERMS. Fossil Fishes.

OSTRICH. Aves, Struthioniformes *Struthio* An African bird (**Aves**) of one or possibly two or three closely related species. These large birds are widely known because they have long been kept in captivity for their plumes and are readily maintained in zoos They attain a height of eight feet and a weight of three hundred pounds The neck and legs are long, the feet bear a single large toe and one much smaller, and the wings are very small

Ostriches are at home in hot and country They run very rapidly and when cornered defend themselves chiefly by powerful kicks The nests are mere hollows in the ground and in warmer regions the eggs are not incubated during the day

Ostriches have been kept in large numbers in Africa and in the warmer parts of North America When their plumes were in great demand the industry is said to have attained a value of about $10,000,000 annually

The **rheas** are called American ostriches (A W L)

OTITIS MEDIA. Infection of the middle ear This condition is very common, and is most frequently seen in children It often leads to **mastoiditis** The infection reaches the middle ear through the **Eustachian canal** from the **pharynx.** It usually occurs secondary to an acute upper respiratory infection such as **coryza, pharyngitis,** or acute **tonsillitis.** Children with adenoids and large tonsils are more subject to ear infections Coughing, hard blowing of the nose, and the use of nasal douches or sprays often spread the infection from the throat to the ear As soon as there is sufficient pus in the cavity of the middle ear to cause pressure, the pain becomes excruciating Rise in temperature and loss of hearing in the affected ear are present Very early cases are the only ones that can be treated conservatively Those that show pressure on the ear drum, and severe pain require incision of the drum membrane before rupture of the drum takes place Most cases recover shortly and heal within two weeks with little or no impairment of hearing after two months When the symptoms and discharge continue for a longer period, mastoid involvement is usually present. (R S M)

OTOCYST. Lithocyst.

OTOPORPA A protuberance extending upward from the base of a **lithocyst** in some of the jellyfishes (A W L)

OTTER. Mammalia, Carnivora Elongate animals with short legs, broad head, and webbed toes They are excellent swimmers, even catching fish apparently for the pleasure of the pursuit.

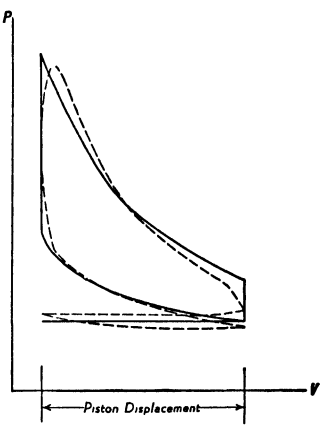
Otters are found on every continent except Australia Different species vary from two to three feet in length exclusive of the long tail, but there is relatively little difference in their general appearance. *Lutra canadensis* is found in North America

Otter fur is thick, soft and glossy, and is among the most valuable commercially The fur of the sea otter, *Latax lutris,* one of the largest species, is regarded as the most valuable of all furs The species inhabits the northern Pacific, in both Asiatic and American waters, where it feeds on marine invertebrates It was once abundant but through indiscriminate trapping it has become very rare (A W L)

OTTO CYCLE. The possibilities of an **internal combustion engine** which would operate on the **four-stroke cycle** were analyzed in the nineteenth century by de Rochas The action of an engine, which was at that time described only, is in all fundamental respects the same as that used today Shortly after this internal combustion engine analysis was made, the German Otto built an engine which operated on the four-stroke cycle, and which has come, since, to be called the Otto cycle. The Otto cycle is carried out by a series of operations, namely, and in order

1 Suction during outward stroke of the piston
2 Compression during inward stroke of the piston.
3 Expansion during outward stroke of the piston following ignition at inward dead center
4 Exhaust during inward stroke of the piston.

Although the first engines built by the Otto works were four-stroke cycle engines, the Otto engine can be adapted to a two-stroke cycle An engine which operates on the Otto cycle has considerable clearance volume (when the piston is on dead center) into which the air and fuel drawn in on the suction stroke are compressed As the piston pauses instantaneously on dead center position, the charge is **ignited** and **combustion** of the charge occurs at constant volume The heat added by this combustion greatly increases the pressure During the expansion stroke, this pressure is lowered, and a considerable amount of the heat is taken from the gas to be converted into work At the end of expansion, the pressure is dropped to the exhaust point, and the exhaust gases are pushed out of the cylinder, which is thus cleared for the next suction stroke. In the figure which



Otto cycle diagram

illustrates the Otto cycle in theory and in practice, the cycle is shown on the pressure-volume plane The ideal cycle is shown solid, and departures from it, made by actual cycles, are shown dotted The ideal four-stroke cycle is made up of two isovolumetric changes, one representing the combustion of fuel at constant volume, the other the rejection of heat to the exhaust at constant volume There are two **adiabatic** changes, one representing the compression of the charge, the other the power stroke Finally, there are two coincident constant pressure changes, representing the ideal exhaust and suction strokes. An actual working cycle will not have quite the same processes Combustion of a fuel is not instantaneous in nature. That occurring in the gasoline engine occupies an appreciable length of time compared to piston motion, so that isovolumetric pressure rise is not possible The point of ignition must be advanced before inward dead center, or there will be considerable loss of work by delayed combustion. An exchange of heat between cylinder cooling water jackets and cylinder contents tends to destroy the adiabatic relationship assumed for the ideal cycle The exhaust can not be at constant pressure because of the inertia of gases leaving the cylinder and the definite rate of valve action of mechanically driven values Furthermore, the exhaust and suction lines can not be coincident, since exhaust must be above atmospheric pressure by the amount of friction losses through the ports and manifolds, while suction must be below atmospheric pressure for the same reason The cylinder horsepower of an engine operating on this cycle is $\frac{PLAN}{33{,}000}$, wherein P is the mean effective pressure, and N is the sum of power strokes per minute The N of a four-stroke cycle, single-acting engine is one-half the number of revolutions per minute L and A are the stroke and piston area

The ideal efficiency of this cycle is expressed by the equation

$$E = 1 - \frac{1}{r^{k-1}}$$

r is the ratio of expansion, and k the ratio of the specific heats at constant pressure and constant volume This air standard efficiency is higher than the actual efficiency because it neglects cooling losses and friction losses The actual efficiency of the Otto cycle is usually between 20 and 25% The ratios of expansion employed have been steadily raised by manufacturers in order to increase the efficiency of their product, for, as is seen in the above equation, an increase of r will increase the efficiency of the Otto engine Modern motor cars are built having r as large as 7, but only by the use of aluminum cylinder heads, which conduct the heat from the cylinder more rapidly. An average value of r for the Otto cycle would be 5 (P T M)

OTTO ENGINE The Otto cycle is described in another section The **internal combustion engine,** which operates on that cycle, is of considerable importance because of its widespread use for both stationary and motive service The advantages which have established the Otto engine as an important prime mover are its high average effective pressure, its high rotative speed, its ease of starting, and its adaptability to production methods of manufacture The Otto engine, acting as a heat engine, is supplied with a gaseous or liquid fuel which is burned explosively in its cylinder with a liberation of heat, some 25% of which will eventually find its way into useful horsepower output The principal parts of the Otto cycle machine are as follows

1. **Cylinder.** That part in which the combustion is made to occur, and in which the heated gases expand
2. The mechanical linkage of members, by means of which a gas pressure is converted to a useful torque on a shaft. These parts consist, ordinarily, of a **piston, connecting rod,** and **crankshaft.**
3. **Ignition system.**
4. **Carburetion** and fuel system.
5. **Lubrication.**
6. **Manifolds.**
7. **Valves** and **valve gear.**
8. Frame and bedplate

The piston, cylinder, connecting rod, and crankshaft form the principal parts These are integrated and aligned by being fastened to a frame or bedplate, which is often of the fully enclosed type, so that spray lubrication may be used. Valves operated by the valve gear provide the function of admitting and releasing the working medium to and from the cylinder, while manifolds distribute or collect the gases in the multi-cylindered engines The two auxiliary systems of carburetion

and ignition are essential in the gasoline engine, the carburetion to prepare the fuel, and ignition to ignite it An average heat balance for this type engine would be as follows.

Output	25%
Cooling	36%
Exhaust	34%
Friction.	5%
Total	100%

A typical multi-cylindered engine is arranged with cylinders in line or in banks, or radially The cylinders are aligned so that the connecting rods may bear on the same crankshaft This crankshaft drives the necessary auxiliaries, and delivers the remaining power as useful output at a coupling, pulley, or clutch Each cylinder has at least one inlet and one exhaust valve mechanically operated and synchronized with the cycle The ignition apparatus is located in the combustion chamber either as an igniter head or a spark plug The openings to the cylinder, which are opened and closed by the valves, lead to ports, to which manifolds are connected Auxiliaries which must be driven by the engine, and which consume part of its gross output, are the aforementioned valves, the lubricating oil pumps, cooling water circulating pumps, the **generator** for current to the ignition system, the igniters or timers of the ignition system, and sometimes an air fan The cylinders are mounted on a crankcase, which provides alignment, and also supports the crankshaft bearings

The operation of an Otto engine, may be described beginning with the suction stroke At the beginning of the suction stroke, the inlet valve will be open, and will remain so until the outward stroke is completed, drawing in through the carburetor and manifolds a mixture of gasoline and air in explosive proportions The quantity drawn in per stroke depends on the **volumetric efficiency** created by the induction system On the succeeding inward stroke of the piston the inlet valve remains open for possibly 10 to 15 degrees of crankshaft travel because there is a certain inertia of the gas column moving in the manifolds and ports, and the flow will not immediately reverse upon reversal of the piston travel The inlet ports should remain open as long as any gas will flow into the cylinder, so that the volumetric efficiency will be maximum After closure of the inlet valve, the gas is compressed into the clearance space at the extremity of the cylinder This clearance space is the combustion space, and its shape has been given a great deal of study in connection with **detonation.** In this space is located the sparking plug which receives the high voltage impulse from the ignition system when the crank pin is still 10 to 15 degrees (sometimes even more) before dead center The advance of this spark before dead center is variable, so that it may be advanced more at high rotative speeds, thus aiding completion of the explosion before expansion begins On the outward stroke, which is the power stroke, both valves remain closed until the crank is about 30° before outward dead center, when the exhaust valve begins to open The valve is given this lead on the piston position in order that it may be fully open at the dead center position, so that on the inward exhaust stroke a complete scavenging of burned gases from the cylinder can be a possibility In fact, the exhaust valve remains open until after the piston is slightly past inward dead center position

Power is a maximum at rated speed The number of power strokes per minute in a four-stroke cycle engine of a single-acting type is one-half the number of revolutions per minute times the number of cylinders In a two-stroke single-acting engine it is the number of revolutions per minute times the number of cylinders In the double-acting engine, it is always twice that of the corresponding single-acting engine Thus a two-cycle, double-acting engine would have four times as many power strokes for the same rotative speed as a four-cycle single-acting engine The amount of power developed by the Otto engine may be varied in several ways, among which are the following.

Quantity governing In quantity governing, the amount of air mixed with a unit of fuel is kept the same, but the quantity fed per cycle is decreased for decreased power, and vice versa This system is the type ordinarily employed on the automobile engine, where the quantity is governed by interposing an artificial resistance between the carburetor and the cylinder in the form of a valve, which may be opened or closed by the driver The disadvantage of quantity governing is that it reduces the efficiency because the full compression pressure is not reached when the engine is operating throttled

Quality governing With this the full compression pressure is reached at the end of the compression stroke because the amount of air charged per cycle remains constant Power is varied by altering the mixture of fuel and air This system of governing is faulty in that unexplosive mixtures are produced at very light loads, causing a hit and miss type governing It is suitable to gas, but not gasoline, engines

Hit and miss governing An inexpensive simple form of constant speed governing used on light portable and stationary engines, is known as hit and miss governing It is governing by means of varying the number of power strokes per minute by causing some normal power strokes to be missed This can be done by one of three ways —by opening the switch in the ignition circuit, causing failure to ignite, by holding the exhaust valve open during the suction stroke, and by leaving the inlet valve closed during the suction stroke

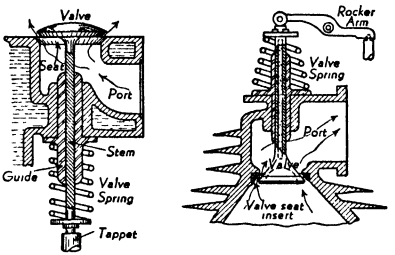
The combustion of gasoline in the Otto engine is given as follows (**Gasoline** is a mixture of many hydrocarbons, for which the formula C_8H_{18} is taken as a fair average composition)

$$C_8H_{18} + 12\,5O_2 = 8CO_2 + 9H_2O$$

Calculations based on this equation show that 15 2 pounds of air are required for the complete combustion of each pound of gasoline A deficiency of air results in the formation of **carbon monoxide** and **hydrogen,** but if there is only a small deficiency, the hydrogen may be assumed as being completely burned Theoretically, **oxygen** and carbon monoxide should not be present in the combustion of a perfect mixture, but actually oxygen will be found in the combustion of lean mixtures, and carbon monoxide will persist in the products of combustion of rich mixtures The limits of explosive mixtures of gasoline and air are between 12 and 19 pounds of air per pound of gasoline Maximum power is derived at about 13 pounds of air, the ideal conditions call for 15 2 pounds, and maximum economy is obtained with even leaner mixtures

There is no more critical part of the Otto cycle than the valves, for these are required to remain pressure-tight under the severe condition of high operating temperature The exhaust valves of heavily loaded engines operate continuously in an atmosphere of flame, and become red hot The valves, especially the exhaust valve, which has not the benefit of the cooling derived from an incoming charge, are sources of trouble in the Otto engine By the use of special cooling and of alloy steels, these failures have been greatly reduced in number The poppet valve is used on nearly all Otto engines The only other type to be employed at all is the sleeve valve, in which a sleeve is placed between the piston and the cylinder The piston slides smoothly in the sleeve, which has some slight motion relative to the cylinder walls The sleeve is driven by eccentrics or cams, so that a slot in it registers with a fixed port on the cylinder wall when the cylinder is to be opened to the manifolds Two concentric sleeves are used in the Knight sleeve valve design. Of much more importance from the standpoint of usage, is the poppet valve This valve has a disk-like head attached to a stem The stem reciprocates

in a valve guide under the action of a cam which bears against the end of the stem, or which operates a tappet which, in turn, bears against the valve stem The head has a face which is a portion of a cone, and which sets in a conical seat in the cylinder, or combustion chamber. There is no sliding action between the valve and its seat. Mushroom and tulip type poppet valves are shown in the accompanying diagram The mushroom type is the simplest, and is suitable for ordinary work When valves run continuously at very high temperatures, and are made fairly large, the mushroom head has a tendency to break or warp, because its strength is derived by cantilever action, and there is a point of weakness at the



Mushroom type inlet valve — water cooled cylinder

Tulip type exhaust valve — air cooled cylinder

Figure 1 Poppet valves

attachment of the stem The tulip valve is in tension instead of bending It is less liable to leak and gives a better streamlining in the port This type of valve, when constructed with a hollow stem, partially filled with metallic sodium, which assists in the transfer of heat from the head to the rest of the stem, has been able to perform satisfactorily in the high output aeronautical type engines The materials which are used must be alloy steel to withstand the corrosion, abrasion, scaling, burning, and high stress met in service While carbon steel may be used for inlet valves, chrome nickel or chrome silicon exhaust valves are required The valve seats are often cut and reamed into the cast iron which comprises the cylinder block of small and medium duty engines Large valved engines, and engines having aluminum cylinder heads, require inserts of aluminum bronze, stellite, or special alloys, to form the valve seats

Valves (Figure 1) are actuated by an operating gear deriving its motion ultimately from the crankshaft Since the motion of a poppet valve is a reciprocation of short throw, the cam is the most practical intermediary between the rotative motion of the crankshaft and the reciprocating motion of the valve Due to the fact that the valve needs to reciprocate only once during the two revolutions of a four-stroke cycle, the cam shaft must be a half-speed shaft driven from the crankshaft by gears or chain The cam bears against a follower, which

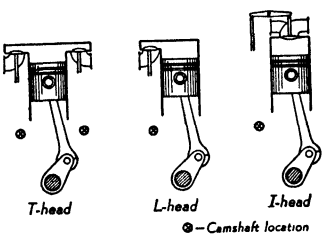


Figure 2 Common cylinder shapes as governed by valve position

may be of roller type, or flat face This follower may be the end of the valve stem, or it may be a tappet, push rod, or rocker arm between cam and valve stem, depending on the relative location of the cam shaft and valves Any discussion of valve operating gear would necessarily be based on some knowledge of common cylinder head arrangements (Figure 2) These might be classified as T, L, I, and F arrangements, these letters being symbolic of the shape of the cylinder head In the T head, the combustion chamber has pockets on either side, in one of which is located the exhaust valve, in the other the inlet valve Earlier engines were so built, but the construction has been abandoned because two cam shafts were necessary The L head arrangement is the most common today The valves are both located in the same pocket on the same side of the cylinder Inline multi-cylinder engines, then, have all the valves in a single line, so that they may be driven by cams, all of which are machined on a common cam shaft When the valves are located overhead in the top of the cylinder instead of in a special valve pocket, the arrangement is known as the I head The valves open downward into the cylinder in the I head, whereas in the T and L they open upward I head arrangement has advantages of more direct gas flow to the cylinder, thus promoting higher volumetric efficiency, but has the disadvantage of a more complicated valve gear In the F head, which has been but little used, the exhaust and inlet valves are mounted one over the other in a valve pocket, one being similar to an L head valve, the other to an I head valve

Valves in L head engines are set directly in line with the cam shaft, so that the cam either bears directly on the end of the valve stem, or indirectly, through a relatively short follower As the cam provides positive motion in one direction only, the valve is opened against a spring pressure The valve spring holds the cam follower against the cam On I head engines, the cam shaft must either be placed above the cylinder, a somewhat awkward position, or motion must be transmitted from its crankcase location to the valve by push rod and rocker arm.

The high cylinder temperatures of internal combustion engines would quickly destroy any lubricating film if positive cooling of some sort were not adopted By positively abstracting about one-third of the heat of combustion to a cooling system, a temperature gradient is maintained through the cylinder wall, and the moving parts can be adequately lubricated The heat so abstracted is loaded on either air or water, though in a great many cases air is the final cooling medium for the water The water is circulated through a radiator, where it is cooled by a current of air drawn through the radiator Direct air cooling requires extending the outer surface of the cylinder, because computations show that a plain cylinder would have a temperature exceeding 1800° F Cylinders are finned and flanged so that the external surface will be sufficient to dissipate the required amount of heat to a stream of air A positive circulation of air over the fins is also necessary This is accomplished by fans and by baffles which direct the air over the finned surface Air cooling is most successful where the cylinders are individual, whereas liquid cooling is better suited to en bloc construction The liquid is contained in a thin layer held around the cylinder head, or completely around the cylinder by the cooling jacket This may be a metallic cover welded or otherwise fastened around the cylinder, leaving a water space between it and the cylinder, or the water space may be an opening in the casting made by cores Most liquid cooling is with water, but special liquids, such as alcohol, glycerine, ethylene glycol, are added for several reasons, among which are to be noted low freezing temperatures, anti-rusting properties, and better heat transfer The water used in a cooling system must be clean and relatively pure, so that scale will not accumulate inside the jackets It can be used in a once-through system, or it

can be recirculated The heat may be absorbed as heat of the liquid, obtained by an increase of water temperature to a maximum of around 200° F, or it may be absorbed as latent heat in evaporating the water in the jacket Usually the water-cooling system is of the recirculation type, the heat being ultimately given to the air by means of radiator, cooling tower, or spray pond.

The lubrication of this type of engine is of the utmost importance because of high speed, temperature, and pressure, coupled with the interdependence of all parts upon the proper functioning of the remainder. Parts needing lubrication are the piston and cylinder, the valve gear, the connecting rod bearings, the crankshaft, and camshaft bearings

Auxiliaries such as fans, generators, starters, also have their points of lubrication Three systems of lubrication most used are the splash, the semi-force feed, and the force feed, all of these relating to the enclosed crankcase type engine. In the splash system oil is pumped into troughs located so that the ends of the connecting rods dip into a pool of oil and splash it about inside the crankcase. The semi-force feed system has lubrication of the crankshaft bearings and the camshaft bearings by oil which is conveyed to them under pressure through tubes. The connecting rod bearings and cylinders are lubricated by splash There is neither trough nor splash in the full force feed Oil from the pump is carried to the crankshaft bearings through tubes, and to the connecting rod bearings through drilled passages in the webs of the crank Centrifugal force throws it out of the connecting rod bearing as the latter revolves, so that the crankcase is filled with an oil mist which lubricates the piston and wrist pin Occasionally one will find the connecting rod drilled in its entire length so that the piston end of the connecting rod also receives oil under pressure The oil so delivered to the bearings drains into the crankcase, from which it is either taken as needed by the oil pump, or is immediately removed and placed in an external tank by a scavenging oil pump These two systems are known as the dry and the wet sump systems.

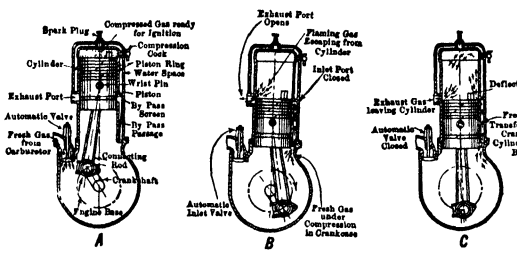


Figure 3 Two port two cycle engine

During the operation of the engine there is a steady loss of oil Some is burned in the combustion chamber, some leaks through gaskets and around shafts, and some is blown out of the crankcase breather as a mist That which is burned in the combustion chamber accounts largely for the accumulation of carbon so often found there The incomplete combustion of fuel, and dust and dirt from the air, contribute somewhat to combustion chamber deposits, but to a much lesser degree than does oil Some oil in the combustion chamber is necessary if the piston is to be properly lubricated, but wear or sticking of the piston rings may cause the piston to assume some pumping action, and deliver to the combustion chamber a great deal more oil than would be necessary for cylinder lubrication, certainly more than is desirable from the standpoint of the condition of the combustion chamber In addition to creating a carbon deposit, an excessive amount of oil may foul the sparking plug points, and cause sticking of the valves. Carbon in the cylinder head provides a black surface which initially aids heat transfer, but, as it thickens, greatly retards heat transfer, due to the low heat transfer coefficient of carbon Then hot spots remain in the cylinder and pre-ignition and detonation are liable to occur. The thicker the accumulation of carbon, the hotter the combustion chamber becomes, and carbon reaches a maximum thickness beyond which accumulations are burned off as rapidly as they are formed.

The foregoing remarks apply, in the main, to the four-stroke cycle engine In many respects they would apply equally to the two-stroke, but there are some essential points of difference. The two-cycle engine is characterized by the absence of valve gear, since the piston moves to uncover ports in such a way that the events of admission and exhaust are accomplished without the use of valves Figure 3A represents the two-cycle engine nearing the inward dead center, with the compressed gas ready for ignition Ignition occurs, and the resulting combustion raises the pressure and drives the piston outward on a power stroke Near the end of this outward stroke the piston uncovers an exhaust port in the lower part of the cylinder wall, and the residual pressure drives the exhaust gas quickly out through this port (Fig 3B) Further outward motion to the dead center position then uncovers a port leading from the crankcase to the cylinder The crankcase is filled with a slightly compressed mixture of gasoline and air, which is rapidly passed through this port (Fig 3C) Entering the cylinder, being deflected upwards, it tends to drive the remaining burned gas out through the exhaust port, which is still open As the piston moves on its inward stroke, it closes these ports and compresses the gas into the clearance space The same motion tends to create a vacuum in the air-tight crankcase, with the result that a fresh charge is introduced into the crankcase to be compressed on the down stroke The comparatively shorter length of time available in this engine for charging and scavenging the cylinder makes it impossible to attain volumetric efficiencies comparable with the four-stroke cycle, except for relatively small, slow-moving engines, like boat engines (F T M)

OTTRELITE. Chlortoid.

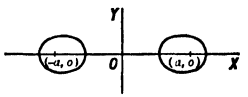
OUNCE. Mammalia, Carnivora. The snow leopard of Asia, *Felis uncia*, a moderately large cat found at high altitudes in the central part of the continent. The fur is long and thick, grayish or slightly tawny above with darker black-ringed spots. (A W L.)

OUTCROP Everywhere beneath the soil at greater or less depths there exists the solid continuous masses of rock which make up the earth's crust. Wherever rock appears protruding through the soil cover it is spoken of as an outcrop. (E S C.S.)

OUZEL. Aves, Passeriformes. 1 The ring ouzel, *Turdus torguatus*, a mountain bird (Aves) of central and northern Europe A thrush. 2 The **blackbird** of Europe and eastern Asia, also a **thrush.** 3 The water ouzel, or dipper The name water ouzel applies to several species of the northern hemisphere which haunt rapid streams Although not a swimming bird it wades into deep water, where it is said to make its way by using both feet and wings The North American species, *Cinclus mexicanus*, is characteristically a western mountain bird Its dull gray color is more than offset by its interesting habits and by a glorious song, heard all too rarely

Sometimes spelled ousel. (A.W.L)

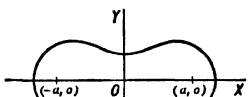
OVALS OF CASSINI. This is the name given to the plane curve defined as the locus of a point that moves so that the product of its distances from two fixed points $(-a, o)$ and (a, o) is equal to a constant k^2 (Figures 1 and 2.) Its equation in polar coordinates is



$k < a$

Figure 1.

$$(r^2 + a^2)^2 = 4a^2r^2\cos^2\theta + k^4.$$



$k > a$

Figure 2
Ovals of Cassini

If $k = a$, we get the **lemniscate** (L L S)

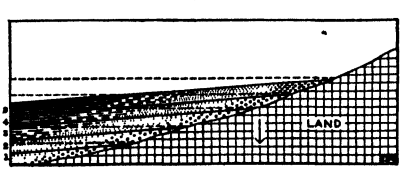
OVARIOLE. One of the tubular components of the insect ovary. It consists of regions in which the egg cells are formed and in which they grow and mature. (A W L)

OVARY. For the use of this term in botany, see **Flower.** For its general use in zoology, see **Gonad.** In human anatomy, the ovary is one of the two female sexual glands in which **ova** are found Each gland is elongated, almond-shaped, and found close to the side wall of the pelvis. With the onset of puberty cyclical changes take place in the ovary After the **menopause** the ovary diminishes in size and activity

The ovary forms both an internal and external secretion The external secretions are the ova The internal secretions cause the changes characteristic of the menstrual cycle, the changes that follow impregnation which are necessary for development of the fertilized ovum, and the changes in the **mammary glands** occurring during pregnancy Further, the ovary produces **hormones** that cause development of the female genital organs and the secondary sex characteristics The ovary is directly stimulated or inhibited by hormones from other endocrine glands, notably the **pituitary** and in a lesser degree by the **thyroid** and **adrenal glands.** (R S M)

OVEN-BIRD. Aves, Passeriformes 1 The European willow **wren,** *Phylloscopus trochilus,* and other birds which build domed nests 2 A North American Warbler, *Seiurus aurocapillus,* also called the golden-crowned thrush. 3 South American birds of several species which build mud nests resembling old-fashioned ovens Genus *Furnarius* (A W L)

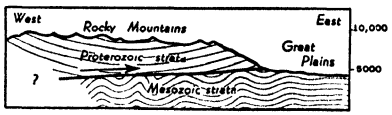
OVERLAP. This term refers to the gradual burial of the land mass or mountain slopes from which the **sediments** were derived. (R M F)



This diagrammatic section shows the principle of overlap Horizontal broken lines represent different stages of sea level relative to the land As the sea encroached toward the right upon the subsiding land, deposition of the sediments 1, 2, 3, 4, 5, extended farther and farther to the right, later formed beds thus overlapping earlier formed beds.

OVERSATURATED. As used by **petrologists,** this term, proposed by Shand in 1915, signifies **igneous** rocks containing free **silica** of **magmatic** origin, and in the form of **quarts** or **tridymite.** (R M F)

OVERTHRUST. A low angle **fault** of the thrust or compressional type frequently resulting in the translocation of a mass of rocks several miles Because of the low angle of the thrust as well as the possible inversion of great piles of formations this type of fault-



Diagrammatic structure section showing how the great body of Proterozoic strata has been thrust-faulted from the west for miles over upon Late Mesozoic strata in Glacier National Park, Montana The Mesozoic beds were folded by action of the over-riding block Length of section, about 25 miles Vertical scale, much exaggerated

ing or failure of the **lithosphere** has led, and still leads, to considerable technical difficulties in determining the **stratigraphic** history in regions where low angle faulting predominates (R M F)

OVERTONES. Vibrations and Waves; Musical Sounds.

OVICELL. Oecium.

OVIPOSITOR. An organ used by some of the **arthropods** to deposit their eggs. It consists of a maximum of three pairs of appendages formed to transmit the egg, to prepare a place for it, and to place it properly In some of the insects the organ is used merely to attach the egg to some surface, but in many parasitic species (**Hymenoptera**) it is a piercing organ as well It is used by the **grasshoppers** to force a burrow in the earth to receive the eggs and by **cicadas** to pierce the wood of twigs for a similar purpose Both long-horned grasshoppers and sawflies cut the tissues of plants by means of the ovipositor. None of these examples is quite as remarkable as the **ichneumon flies** (parasitic Hymenoptera) which have a slender ovipositor several inches long, used to drill into the wood of tree trunks These species are parasitic in the larval stage on the larvae of wood-boring insects, hence the egg must be deposited in the burrow of the host

The sting of **wasps** and **bees** is also an ovipositor, in this case highly modified and associated with poison glands (A W L)

OVO-TESTIS. Gonad.

OVULE. Flower.

OVUM. Gamete.

OWL. Aves, Strigiformes Nocturnal birds (**Aves**) of prey with hooked beaks and strong curved talons They differ from the other birds of prey in having the eyes directed forward and surrounded by a more or less evident disk of small radiating feathers Owls have soft thick plumage and are characteristically silent in flight as a result.

The North American species range in size from the six-inch Acadian owl to the two-foot great horned owl, *Bubo virginianus,* and a similar range of size is noted in the rest of the world from the pigmy owls of the Old World to the great hawk-owl of Australia. The group is represented on all continents

Although owls are characteristically predacious they do not disdain insects as food. The smaller species catch mice and other small animals and larger owls

prey upon animals as large as rabbits. The great horned owl is said to be an undesirable marauder in poultry yards at times. Certainly it catches birds, but owls in general probably do more good than harm in their destruction of small rodents. (A.W.L.)

OWLET MOTH. Insecta, Lepidoptera. A common name for the **moths** of the great family Noctuidae. Used chiefly in Europe. (A.W.L.)

OX, OXEN. Mammalia, Artiodactyla. Hoofed animals with two functional toes on each foot, with hollow horns in both sexes, and with a long tail, usually tufted at the end. The horns are never spiral as in sheep, goats, and some antelopes, but are usually curved. They are mostly of massive build, with a short head, broad muzzle, and short thick neck.

Most of the species of this group are indigenous to the Old World. North America has the **musk ox** and the **bison,** and South America and Australia are entirely without representatives. A number of species have been domesticated and are used in all favorable parts of the world as a source of meat, milk, and hides, and to a lesser extent as draft animals. The common ox is *Bos taurus.*

The group includes the **aurochs,** humped cattle or **zebu,** the **gaur, gayal, banting, yak, bisons, buffalos** and the **musk ox,** which is related to the sheep. The European bison is also called the wisent or zubr, and the Indian buffalo is sometimes known as the arna. In the Philippines the tamarao and **carabao** are the buffalos used for draft purposes. The **anoa** is a small species related to the buffalos and antelopes; it is found in Celebes. (A.W.L.)

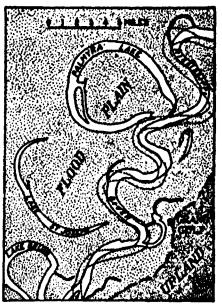
OXALIC ACID AND OXALATES. Oxalic acid ($H_2 \cdot C_2O_4 \cdot 2H_2O$ or $COOH \cdot COOH \cdot 2H_2O$) is a white solid, melting point of crystals 101° C. (of anhydrous 180° C.), sublimes at 150° C., soluble in water, alcohol, or ether. **Calcium** oxalate, on account of its solubility characteristics, is of importance in the separation and recovery of oxalic acid. Calcium oxalate plus dilute **sulfuric acid** yields oxalic acid plus calcium sulfate, and the latter may be separated by filtration. Oxalic acid may be obtained by evaporation of the filtrate. With concentrated **sulfuric acid** heated, calcium oxalate, or other oxalate or oxalic acid, yields equal volumes of **carbon dioxide** and **carbon monoxide** gases. Oxalic acid (or oxalates), after being dissolved in dilute sulfuric acid, is readily oxidized to carbon dioxide by **permanganate.**

Representative esters of oxalic acid are: Methyl oxalic acid ($COOH \cdot COOCH_3$), melting point 37° C., boiling point 108° C. at 12 mm. pressure; Dimethyl oxalate ($(COOCH_3)_2$), melting point 54° C., boiling point 163° C.; Diethyl oxalate ($(COOC_2H_5)_2$), melting point —41° C., boiling point 186° C.

Oxalic acid may be obtained (1) from some natural products, e.g., wood sorrel, and other members of the oxalis family, as **potassium** hydrogen oxalate, the bark of certain species of **eucalyptus** (sometimes containing 20% calcium oxalate in the cells and cell-walls), (2) by reaction of acid with an oxalate, e.g., calcium oxalate plus sulfuric acid as above. Sodium oxalate is made (1) by heating **sodium** formate at 300° C. in vacuum, with the evolution of **hydrogen** gas, (2) by reaction of **carbon dioxide** plus metallic **sodium** at 360° C., (3) by heating wood powder ("sawdust"), particularly of **coniferous** woods, with **sodium** hydroxide (addition of potassium hydroxide enables one to use a moderate temperature, say 220° C.), (4) by oxidation of sucrose or starch with nitric acid. Oxalic acid is a dibasic acid, that is, two series of salts are known, a third series is also known, thus, sodium oxalate ($Na_2C_2O_4$), sodium binoxalate ($NaHC_2O_4$), sodium tetroxalate ($NaH_3(C_2O_4)_2$).

Oxalic acid is used (1) in the preparation of oxalates, e.g., **titanium** potassium oxalate, and esters, (2) in the purification of certain chemicals, e.g., **glycerol,** stearates, (3) in bleaching straw, (4) as in ink and rust remover, (5) in the leather and textile industries, (6) in the manufacture of dyes, (7) in the preparation of glyoxalic and glycollic acids by regulated reduction.

A common test for oxalic acid is as follows: Heat solution with resorcinol (See **Phenol**) in a test tube and on cooling add carefully a layer of sulfuric acid. A blue ring at the junction of the two layers indicates oxalic acid. (R.K.S.)



Meanders and oxbow lakes of part of Mississippi River flood plain in 1883 (heavy lines) and 1896 (dotted lines). (By William Davis, based upon Government Surveys.)

OXAZOLE. Pyrrole and Related Compounds.

OX BOW LAKE. The type of lake developed on the flood plains, especially in the delta regions, of large rivers. Ox Bow Lakes represent the detached or truncated former meanders of the main stream which, from time to time, straightens its course by forming cut-offs or short cuts. (R.M.F.)

OXIDATION. Reactions Involving Oxidation-Reduction.

OXIDES. See **Oxygen;** and individual elements.

OXIMES. Hydroxylamines and Oximes.

OX-PECKER. Aves, Passeriformes. African birds, (**Aves**) of a group related to the starlings. The common name refers to their habit of climbing about the bodies of domestic cattle in search of ticks and other external parasites. They also visit wild animals for the same purpose. (A.W.L.)

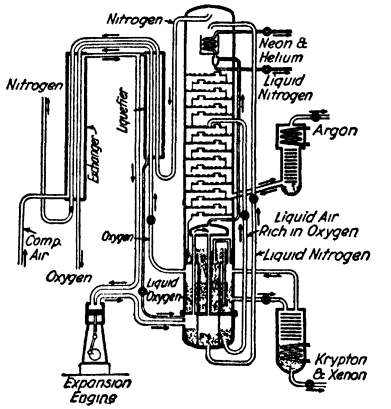
OXYACETYLENE WELDING. Welding.

OXYGEN. Symbol: O. Atomic number: 8. Atomic weight: 16.0000. Density: 1.42904 grams per liter, 0° C., 760 mm., or 1.105 when air equals 1.000. Formula of oxygen gas: O_2 (formula of ozone: O_3). Melting point of oxygen: —218.8° C. Boiling point: —183° C. Critical temperature: —118.8° C. Critical pressure: 49.7 atmospheres.

Oxygen is a colorless, odorless, tasteless, non-toxic gas, found free in the atmosphere (20.995% by weight of oxygen) mixed with **nitrogen, argon,** the rare gases, **carbon dioxide,** and water vapor. Liquid oxygen is strongly magnetic. Molten **silver** dissolves about ten volumes of oxygen, giving it up upon cooling, with an effect known as "spitting." Oxygen was discovered by Priestley in 1774 by heating **mercuric** oxide, and independently in the same year by Scheele. Isotopes: 16 (99.76%), 17 (0.04%), 18 (0.20%). Oxygen is necessary for the burning of substances. The temperature of ignition of each combustible substance is more or less characteristic, for example, **phosphorus** in air is ignited at 34° C., **ether** in air 340° C., **ethyl alcohol** in air 560° C., **kerosene** in air about 300° C., **hydrogen** in air about 600° C.

Oxygen occurs combined with **silicon, aluminum, iron** and other metals in all rocks (average of the solid crust of the earth 46.7% oxygen), as a constituent of practically all plant and animal substances, except **hydrocarbons,** as the most abundant element in the ocean (85.8% oxygen). The process of respiration of animals involves the reaction of free oxygen with the

animal organism at the temperature of its surroundings The burning of fuels when heated to the ignition temperature is a process of combination with free oxygen, as also the corrosion of iron, which is an important reaction at ordinary temperature

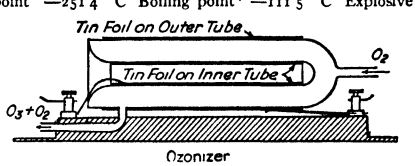


Diagrammatic representation of apparatus for rectification and fractionation of liquid air

Oxygen is prepared (1) by the fractional distillation of liquid air, (2) by the **electrolysis** of water containing an **electrolyte** such as **potassium** hydroxide, (3) by heating **potassium** perchlorate, which is preferable to potassium chlorate on account of the diminished hazard, and by heating **barium** peroxide or **lead** dioxide

When oxygen is subjected to the silent electric discharge, activated atomic oxygen is produced Atomic oxygen displays an afterglow upon cessation of the current, and the oxygen is notably active with **hydrogen bromide** forming water and **bromine**, with **hydrogen sulfide** forming **sulfur**, **sulfur dioxide**, **sulfur trioxide**, and **sulfuric acid**, with **carbon disulfide** forming **carbon monoxide**, **carbon dioxide**, and **sulfur dioxide** and, strangely, reduces **molybdenum** trioxide to a white oxide not reducible with **hydrogen** The concentration of atomic oxygen obtainable by the silent electric discharge through oxygen is estimated at 20%

Ozone (O_3) is a blue gas, of characteristic odor, formed when ordinary oxygen is subjected to electrostatic discharge Density 1 5 times that of oxygen gas Melting point —251 4° C Boiling point· —111 5° C Explosive



Ozonizer

by percussion, or under variations of pressure Ozone reacts (1) with **potassium** iodide, to liberate **iodine**, (2) with colored organic materials, e g , litmus, indigo, to destroy the color, (3) with **mercury**, to form a thin skin of mercurous oxide causing the mercury to cling to the containing vessel, (4) with **silver** film, to form silver peroxide (Ag_2O_2) black produced most readily at about 250° C , (5) with tetramethyldiaminodiphenylmethane $(CH_3)_2N\ C_6H_4\ CH_2\ C_6H_4\ N(CH_3)_2$ in alcohol solution with trace of **acetic acid** to form violet color (**hydrogen peroxide**, colorless, **chlorine** or **bromine**, blue, **nitrogen tetroxide**, yellow) In contrast to **hydrogen peroxide** ozone does not react with **dichromate**, **permanganate**, or **titanic** salt solutions Ozone reacts with olefin compounds to form ozonide addition compounds Ozonides are readily split at the olefin-ozone position upon warming alone, or upon warming their solutions in glacial acetic acid, with the formation of **aldehyde** and **acid** compounds which can be readily identified, thus serving to locate the olefin position in oleic acid ($C_{17}H_{33}$ COOH) as midway in the chain $CH_3(CH_2)_7CH$ $CH(CH_2)_7COOH$ Ozone is used (1) as a bleaching agent, e g , for fatty oils, (2) as a disinfectant for air and water, (3) as an oxidizing agent

Oxides are known of many elements Metallic oxides are (1) reactive with water, e g , **calcium**, **strontium**, **barium** oxides (CaO, SrO, BaO), (2) insoluble, e g , **ferric** oxide (Fe_2O_3), **ferrous** oxide (FeO), ferroferric oxide (Fe_3O_4), **cupric** oxide (CuO), **cuprous** oxide (Cu_2O), and may be otherwise subdivided, (a) reactive with **hydrochloric acid** to yield **chlorine**, e g , **lead** dioxide (PbO_2), plumboplumbic oxide (Pb_3O_4), **manganese** dioxide (MnO_2), (b) reactive with water or dilute acid to yield **hydrogen peroxide**, e g , **sodium** peroxide (Na_2O_2), **barium** peroxide (BaO_2). Non-metallic oxides are (1) reactive with water, e g , **carbon dioxide** (CO_2), **sulfur** dioxide (SO_2), **sulfur** trioxide (SO_3), **phosphorus** trioxide (P_2O_3), **phosphorus** pentoxide (P_2O_5), boron oxide (B_2O_3) forming the corresponding acids (H_2CO_3, H_2SO_3, H_2SO_4, HPO_3, H_3PO_4, H_3BO_3); reactive with water to form two acids, e g , nitrogen tetroxide (N_2O_4) yielding **nitrous** plus **nitric acids** (HNO_2 and HNO_3), **phosphorus** tetroxide (P_2O_4) yielding **phosphorus** plus **phosphoric acids** (H_3PO_3 and H_3PO_4), (2) insoluble or non-reactive with water, e g , **carbon monoxide** (CO), nitric oxide (NO), nitrous oxide (N_2O), **silicon** oxide (SiO_2) Amphoteric oxides are reactive both with acids and with bases to form salts, e g , **aluminum** oxide (Al_2O_3) with **sulfuric acid** yielding aluminum sulfate ($Al_2(SO_4)_3$), with **sodium** hydroxide yielding sodium aluminate ($NaAlO_2$), **lead** monoxide (PbO) with nitric **acid** yielding lead nitrate ($Pb(NO_3)_2$) and with sodium hydroxide yielding sodium plumbite (Na_2PbO_2)

Organic compounds of carbon, hydrogen, oxygen only are discussed as follows.

Acetals See **Aldehydes and Related Compounds**

Acids See **Acids, Carboxylic, and Related Compounds**

Acid anhydrides See **Acids, Carboxylic, and Related Compounds**

Alcohols

Aldehyde acids See **Acids, Carboxylic, and Related Compounds**

Aldehydes.

Anhydride, acid See **Acids, Carboxylic, and Related Compounds**

Anhydride, alcohol See **Alcohols and Related Compounds** (ethers)

Anthocyanins See **Glucosides**

Benzoin, Benzil, and Related Compounds.

Carbohydrates.

Cellulose See **Carbohydrates.**

Coumarone See **Furane and Related Compounds.**

Esters See also individual acids

Ethers See **Alcohols and Related Compounds.**

Fats See **Esters**, including Oils, Fats, and Waxes

Furane.

Glucosides.

Hydroxyacids See **Acids, Carboxylic, and Related Compounds.**

Hydroxyaldehydes. See **Aldehydes and Related Compounds.**

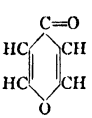
Hydroxyketones See **Aldehydes and Related Compounds.**

Ketenes See **Aldehydes and Related Compounds.**

Ketone acids See **Acids, Carboxylic, and Related Compounds.**

(*Continued on page 805*)

SCHEME SHOWING INTER-RELATIONSHIPS OF OXYGEN-FUNCTION NON-BENZENOID ORGANIC COMPOUNDS

$\left\{\begin{matrix}CH_4\\H\ CH_3\\CH_3\ CH_3\\(CH_3)_2CH_2\\(CH_3)_3CH\\(CH_3)_4C\end{matrix}\right.$	$\begin{matrix}CH_3OH\\H\ CH_2OH\\CH_3CH_2OH\\(CH_3)_2CHOH\\(CH_3)_3COH\end{matrix}$	$CH_2(OH)_2—H_2O$ $H\ CHO$ $CH_3\cdot CHO$ $(CH_3)_2CO$	$\left\{\begin{matrix}CH(OH)_3—H_2O\\H\ COOH\\CH_3\ COOH\end{matrix}\right.$	$\left\{\begin{matrix}C(OH)_4—H_2O\\HO\ COOH\\CO(OCH_3)_2\end{matrix}\right.$
$CH_3\ CH_3$ $\begin{matrix}CH_3\\\vert\\CH_3\end{matrix}$	$CH_3\ CH_2OH$ $CH_3CH_2\diagdown\!\!\diagup O$ $CH_3CH_2\diagup\!\!\diagdown$ $\begin{matrix}CH_2\\\Vert\\CH_2\end{matrix}$	$CH_3\cdot CHO$ $\begin{matrix}CH\\\Vert\\CH\end{matrix}$ $CH_3CO\ OCH_3$ $CH_3CH(OC_2H_5)_2$ | $CH_3CH(OC\cdot CH_3)_2$	$CH_3\ COOH$ $CH_3CO\diagdown\!\!\diagup O$ $CH_3CO\diagup\!\!\diagdown$ $\begin{matrix}CH_2\\\Vert\\CO\end{matrix}$	
  	$\begin{matrix}CH_2OH\\\vert\\CH_2OH\\CH_2OH\\\vert\\CHO\\CH_2OC_2H_5\\\vert\\CH_2OH\end{matrix}$ 	$\begin{matrix}CHO\\\vert\\CHO\end{matrix}$ $\begin{matrix}CH_2OH & CHO\\\vert & \vert\\COOH & COOH\end{matrix}$	$\begin{matrix}COOH\\\vert\\COOH\end{matrix}$	

SUPERIMPOSABLE KEY TO NAMES OF ABOVE COMPOUNDS

Methane Methane Ethane Propane Trimethylmethane Tetramethylmethane	Monohydroxymethane Methyl alcohol Ethyl alcohol Isopropyl alcohol Trimethylcarbinol	Dihydroxymethane (hypothetical) Formaldehyde Acetaldehyde Acetone (ketone)	Trihydroxymethane (hypothetical) Formic acid Acetic acid	Tetrahydroxymethane (hypothetical) Carbonic acid Dimethylcarbonate (ester)
Ethane Ethane	Ethyl alcohol Ethoxy ethane (ether) Ethylene Diethoxy	Acetaldehyde Acetylene Methyl acetate (ester) acetal Diacetyl	Acetic acid Acetic anhydride (acid anhydride) Ketene acetal	
    Furane Pyrone	Ethylene glycol Glycollic aldehyde Ethoxyethyl alcohol (ether) Ethylene oxide	Glyoxal Glyoxyllic acid Glyoxalic acid	Oxalic acid	

SUPPLEMENTARY SCHEME FOR OXYGEN-FUNCTION BENZENOID COMPOUNDS

C_6H_6 $C_6H_5 \cdot CH_3$ $(C_6H_5)_2CH_2$ $(C_6H_5)_3CH$ $(C_6H_5)_4C$ $C_6H_5 \cdot H$	$C_6H_5CH_2OH$ $(C_6H_5)_2CHOH$ $(C_6H_5)_3COH$ $C_6H_5 \cdot OH$ (1) HOC_6H_4OH (4)	C_6H_5CHO $(C_6H_5)_2CO$ (1) $O{=}C_6H_4{=}O$ (4)	C_6H_5COOH

SUPERIMPOSABLE KEY TO NAMES OF ABOVE COMPOUNDS

Benzene Toluene Diphenylmethane Triphenylmethane Tetraphenylmethane Benzene	Benzyl alcohol Diphenylcarbinol Triphenylcarbinol Phenol 1,4-dihydroxyphenol (hydroquinone)	Benzaldehyde Benzophenone (ketone) 1,4-benzoquinone (quinone)	Benzoic acid

(R.K.S.)

Ketones See **Aldehydes and Related Compounds.**

Lactones. See **Acids, Carboxylic, and Related Compounds.**

Lactides See **Acids, Carboxylic, and Related Compounds.**

Oils, fatty See **Esters,** including Oils, Fats, and Waxes

Oxides See **Alcohols and Related Compounds. Phenols.**

Phthaleins See **Phthalic Acid, Phthalates, and Phthaleins.**

Pyrones See **Furane and Related Compounds.**

Quinones See **Phenols and Quinones.**

Saccharides See **Carbohydrates.**

Starch See **Carbohydrates.**

Sterols See **Alcohols and Related Compounds.**

Sugars See **Carbohydrates.**

Tannins.

Waxes See **Esters,** including Oils, Fats, and Waxes

OXYPYROLINE. Amino-acids, Polypeptides, and Proteins.

OYSTER. Mollusca, Lamellibranchiata Bivalve **mollusks** of the family Ostreidae Pearl oysters are species of different families found only in warmer oceans, while the edible oysters include a European species (*Ostrea edulis*), a species of the Atlantic coast of North America (*O virginica*), and the Pacific coast oyster (*O lurida*) The common oyster of commerce has been transplanted successfully to the Pacific coast All are marine

Oysters are the most important of the edible invertebrates They have been cultivated since the days of the Roman Empire and are now gathered from the oyster beds of the United States alone at an estimated rate of 25,000,000 bushels per year. Fortunately they are extremely prolific, a single oyster of the common American species producing as many as twenty to sixty millions of eggs in a breeding season. The young oysters develop in the gills of the parent into ciliated (cilia) **larvae** called spat which swim freely for a few days and then settle to the bottom and become attached From that time they are permanently fixed In cultivated beds they may be moved to favorable places after once attaching themselves, and after three to five years they attain market size The beds require protection against starfishes and other natural enemies, and for the consumer's sake they must be guarded against pollution by human wastes Oysters that have lain near sewage outlets are dangerous as possible carriers of typhoid germs, although when they are cooked before eating they are likely to be sterilized (A.W.L.)

OYSTER-CATCHER. Aves, Charadriiformes Birds (**Aves**) of few species but worldwide distribution They are related to the avocets, from which they differ in being more stoutly built They frequent the coasts and eat bivalve mollusks, among a much greater variety of food The American species is *Haematopus palliatus* (A.W.L.)

OYSTER PLANT, SALSIFY. *Tragopogon porrifolius* **Compositae Family**

OZARKIAN. Ordovician.

OZOKERITE. A mineral wax which occurs as a natural, solid **hydrocarbon,** yellowish brown to green in color and usually translucent with a waxy luster (E.S.C.S.)

OZONE. Oxygen.

OZONIDES. Oxygen.

P

P SERIES. X-Ray Spectra.

PACA. Mammalia, Rodentia A stoutly built **rodent**, *Agouti paca*, about two feet long, marked with rows of light spots on a fawn to blackish ground color It occurs through most of South America east of the Andes Related to the agoutis (A W L)

PACHYDERMATA. An obsolete name for a group of mammals, including the **elephants** It is reflected in the name pachyderm sometimes applied to these animals The word means thick skinned (A W L)

PACIFIC SUITE. A term proposed by A Harker, in 1896, for the chemically, structurally, and geographically related **igneous rocks** of the Pacific coast line Chemically the rocks of this suite are described as calc-alkali, and are represented by such types as **andesites, granodiorites** and their relatives, as compared with the alkali igneous rocks of the **Atlantic Suite** (R M P)

PADDLE FISH. Pisces, Chondrostei Large fishes (**Pisces**) related to the sturgeons The snout is prolonged into a spatulate protuberance Only two species are known, one in the large rivers of China and the other in the Mississippi and its larger tributaries The latter, *Polyodon spathula*, is also called the spoon-bill, spoon-beaked sturgeon, and spoon-billed catfish (A W L)

PADDY BIRD Aves, Passeriformes The Java sparrow, *Ardeola grayii*, a **munia** (A W L)

PAEDOGAMY. Autogamy.

PAEDOGENESIS. The attainment of sexual maturity by animals during an immature stage of development Closely related to **neoteny.** (A W L)

PAGET'S DISEASE *Osteitis deformans* A chronic disorder of the bones of unknown origin characterized by enlargement and deformity of the skull, spine and long bones

The disease develops after sixty, the first sign being an increase in the diameter of the head and a bowing of the legs causing shortness of height. Some cases are marked by severe pain over the involved bones

Treatment is unsatisfactory **Calcium, vitamin D, ultraviolet** light, and **X-ray** are used (R S M)

PAHOEHOE An Hawaiian term introduced to geological nomenclature by C E Dutton, in 1883, and signifying a lava flow with a smooth, ropy surface Contrast with **aa** (R M P)

PAINT. Resins and **Paints.**

PAINTER, Puma.

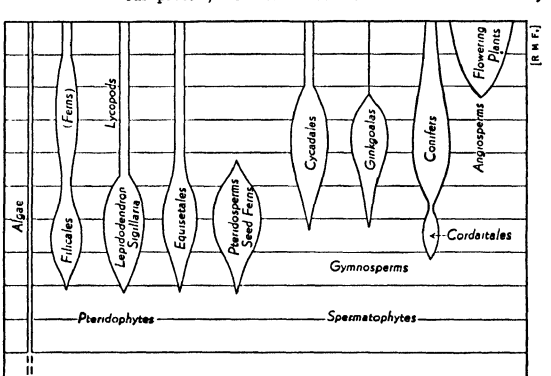
PALA. Impala.

PALATE. The partition between the oral cavity and the nasal passages The anterior portion contains flat bones and is called the hard palate, while the posterior soft palate is made up entirely of soft tissues (A W L)

PALEA A small, usually thin **bract** or scale borne on the **axis** of a grass flower, just above the **lemma** (R M W)

PALEOBOTANY. This is the study of ancient plants which are known today only through **fossil** remains These are of two general types One is in the form of impressions, imprints which are left when the original material was surrounded by such material as mud, sand or volcanic ash, and gradually destroyed, leaving a sharp outline but no particular details as to structure In the other type of fossil much of the original structure is revealed The original material was surrounded by foreign material as in the first case The substance of the plant was replaced by minerals so gradually, in many cases, that the most minute details of the plant structure are preserved in the fossil Not only are the cell walls preserved, but in some cases even the **nucleus** remains recognizable On woody plants recognizable **fungi** have been found growing, all completely fossilized Fossils of this type are called petrifactions

Originally the study of fossil material was a laborious process, for sections of the material were necessary



Geologic range of plants (Field, *Geology Manual*, Part II, Princeton University Press)

and sections of such fossils were not easily made At first these sections were obtained by cutting the fossil in two, grinding the cut surface smooth and examining it, or fastening it firmly to a glass slide and making a second cut close to the slide, thus getting a thin section which was then ground as thin as possible Naturally the preparation of fossil material was not only a tedious process, but also one that wasted much of the material,

In recent years an entirely different and much more satisfactory method has been developed One surface of the fossil is first ground flat This flat surface is then etched with **hydrochloric acid** or **hydrofluoric acid** according to the material composing the fossil When the acid has etched deeply enough, it is washed off with water and the surface dried The dried surface is flooded with a celloidin solution and the latter allowed to dry The dried celloidin film is then carefully peeled from the surface of the fossil, removing with it a thin film of fossil material The peeled surface is reground and the process repeated as long as desired, or until the fossil is completely "sectioned" The thin peels may be either mounted on glass slides, like sections of living material, or they may be dried under pressure, so that they remain flat The advantages of fossil peels for scientific investigations are many They are so thin that they can easily be examined with high magnifications, they can be rapidly made, they permit serial sections of the material In this process little of the material is wasted Finally, fossil peels permit examination of material which can be sectioned only with the greatest difficulty by any other method This method of preparation has greatly advanced the study of fossil life

Paleobotany yields much interesting information about the plants of prehistoric times, notably of the **Carboniferous** and **Devonian** periods Probably the best known fossil plants are those which grew during the Carboniferous period of the **Palaeozoic** Era Coal itself, the carbonized remains of plant life, has been much studied The nature of the processes by which coal has been formed is such that coal is often not the best material to study to get a picture of the fossil plants composing it But found associated with the coal are mineral masses called coal balls Within these, plant remains are often preserved with beautiful detail The coal balls are readily sectioned by peels which yield much information as to the nature of the plants growing at that time

Plants growing in the Carboniferous period differed strikingly from those of today Many were trees of large size but rather weird in appearance, today their relatives are small and inconspicuous, if indeed they have not entirely disappeared *Lepidodendron* was then a common genus with many species These plants had radiating roots which forked **dichotomously** and spread out near the surface of the ground, the stem was columnar and covered with a rough bark which in the younger parts was composed of spirally arranged cushions of various shapes Compared with the large size of these stems the **vascular** tissues were very small, giving little support to the stem Stems having a diameter of 10 inches or more would have a stele less than 3 inches across Characteristically branching was dichotomous, forming an open crown of branches covered with needle-shaped leaves, and bearing cones having an outward appearance somewhat like those of several living **conifers**, but structurally quite different Another genus whose members often attained large size was *Sigillaria*, which became increasingly common as the Carboniferous period continued These plants also had tall thick stems each bearing at its top a crown of branches covered with needle-like leaves Giant **horse-tails**, known as *Calamites*, were also abundant

All these plants and many others have a structure which suggests that they grew in a very uniform climate In the Carboniferous period many other lower forms of life undoubtedly existed The nature of these plants was such that preservation would not occur In older periods all plants are of lower form

Until the **Devonian** period fossils suggest that only algal (See **Algae**) forms existed, living in water and usually not well preserved unless they are calcareous (e g containing **calcium**) forms In the Devonian undoubtedly land plants first appear. Mostly these were rather small plants of simple habit, probably they grew in marshy places. The plants were without roots or leaves, but had a prostrate **rhizome** from which arose erect sparingly branched stems, many of which bore **sporangia** at their tips These stems had a well developed vascular system Other Devonian plants were larger, some being 10 to 12 feet high, and much branched As the Devonian period continued, the plants became larger and more complex, acquiring an aspect more like that of present-day plants The Devonian period saw the appearance of plants on land and the establishment of a definite and varied land flora The Carboniferous period was one in which land vegetation became well established and luxuriant Only at the close of this period did plants appear which could be considered as definite types of the modern vegetation

The following brief classification of plants includes the principle types of fossil plants from the **pre-Cambrian** to the **Pleistocene**, together with the paleontological record of their **evolution**

I **Thallophytes** Lowest and simplest plants They range from microscopic bacteria to enormous sea-weeds They reproduce by simple cell division and are found from pre-Cambrian to the present

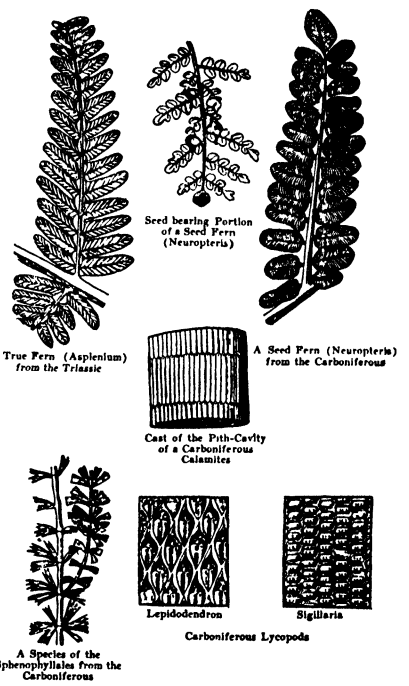


Figure 1

(Field, *Laboratory Manual*, Princeton University Press)

(I-a) **Algae** (marine sea weeds and fresh-water plants) Some of the algae secrete calcium carbonate These calcareous algae are quite an abundant constituent of modern coral reefs Algal (**cryptozoan**) reefs occur as early as the late **Proterozoic**

(I-b) **Fungi**. These plants depend upon other living plants or organic debris for food Include familiar

forms such as mildew, yeast, wheat rust, and mushrooms Not important as fossils

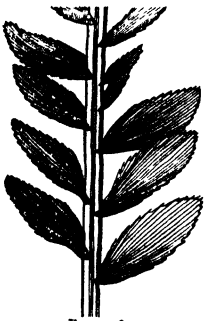


Figure 2
A Cycad (*Plagiozamites*) from the Carboniferous (Field, *Laboratory Manual*, Princeton University Press)

II **Bryophytes** (moss plants) These plants possess stems and leaves, though no true roots or woody tissue Small and delicate forms, living only in moist habits Reproduce by simple **spores** Occur from **Carboniferous** to present Not important as fossils

III **Pteridophytes** (fern plants These plants have acquired roots and woody tissue in stems, and larger and more complex plant body **Devonian** to present They reproduce by spores developed on leaves or **catkins**, and they are dependent upon moisture for fertilization

(III-a) **Filicales** (true **ferns**) A dominant Carboniferous type, illustrated on page 807 4000 living species, ranging from small temperate ferns to large tropical tree-ferns

(III-b) **Lycopodiales** (club mosses) Large tree forms in Carboniferous 500 living species, all small and herbaceous *Lepidodendron* and *Sigillaria* are best known Paleozoic types, illustrated on page 807

(III-c) Equisetales (**Horsetails**) Tall tree types (*Calamites*) in Carboniferous 25 species now living, all small and herbaceous, illustrated on page 807

(III-d) Sphenophyllales Small, thin-stemmed plants (illustrated on page 807) of late Paleozoic Now extinct Closely related to Equisetales

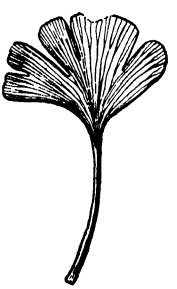


Figure 3.
A Jurassic Ginkgo (Field, *Laboratory Manual*, Princeton University Press)

IV **Spermatophytes** (seed plants) Dominant terrestrial forms of modern flora Most highly evolved plants Reproduction by male and female spores, producing real seed on mother plant Not dependent upon moisture for fertilization Three important groups

Figure 4.
A Common Tertiary Conifer (*Sequoia*) (Field, *Laboratory Manual*, Princeton University Press)

(IV-a) Cycadofilicales or Pteridosperms (seed-ferns) Important Paleozoic group, now extinct, illustrated on page 807 Possessed fernlike foliage but also true, though simple seeds Perhaps represent transitional form between ferns and modern seed-plants An important fossil genus is *Glossopteris* which is found in the **Permian** formations of both South America and Africa

(IV-b) **Gymnosperms** (naked seeds) Seeds not protected by a covering, but borne on scales, usually in cones Trees mainly evergreen, with scales or needle-shaped foliage Five groups

(IV-b-1) Cycadales Tropical **cycads** or sago-palms Dominant in **Mesozoic** in 3 families, only one of which has survived (Figure 2 above)

(IV-b-2) Cordaitales Tall Paleozoic tree form Now extinct Supposed ancestor of modern conifers

(IV-b-3 Ginkgoales (Figure 3 above) Peculiar tree, dominant in Mesozoic Only 1 species in Western China now living

(IV-b-4) Coniferales Modern evergreen **conifers.** Mesozoic to present (Figure 4) 350 species now living, mostly temperate forms, such as the pines, spruces, hemlocks and cedars

(IV-b-5) Gnetales Desert type Peculiar and unimportant group

(IV-c) **Angiosperms** (enclosed seed) Seed protected by a hard capsule Only group which produces real "flowers" Leaves usually broad and **deciduous** Represent highest type and most numerous of modern plants Upper **Cretaceous** to present Two groups

Figure 5
A Tertiary Willow (*Salix*) A common Dicotyledon (Field, *Laboratory Manual*, Princeton University Press)

(IV-c-1) **Monocotyledons** Plant begins growth with single leaflet or **cotyledon** Leaves parallel-veined No growth rings in the stem Parts of the flowers arranged in threes or multiples of three Mostly herbaceous Supposedly derived from dicotyledons 30,000 species now living, grasses, sedges, etc

(IV-c-2) **Dicotyledons.** Plant begins growth with two cotyledons Leaves net-veined Annual growth rings present in the stem Floral parts arranged in multiples of four or five 100,000 species now living, oaks, willows, maples, chestnuts (Figure 5) (R M F, R M W)

PALEOCENE. The earliest period in the **Cenozoic** Era of the geologic time-scale (See **Historical Geology.**) It is also spoken of as basal **Tertiary** The term was first proposed by Schimper in 1874 The greatest thickness of the formations of this system occur in Wyoming The Paleocene began approximately 60 million years ago and lasted for about 10 million years In the United States the sediments are mainly of terrestrial origin, occurring as intermontane deposits of sands, gravels, and clays The Paleocene is chiefly remarkable in that the **dinosaurs** have been replaced by the archaic or earliest types of mammals, including survivors of the **Mesozoic** Multituberculates Principal types are creodonts (archaic flesh-eaters), amblypods and **condylarths** (primitive hoofed animals) Also several species of primitive **insectivores,** lemuroids (ancestral monkeys) and **carnivores** (R M F)

PALEOCHRONOLOGY. The table of geological periods correlated with the succession of animal forms that have existed in the past, as determined by the study of fossil remains (**Palaeontology**) **Evolution** (A W L)

PALEOCLIMATOLOGY. The study of ancient climates which obtained during the previous periods of the earth's history, as determined by the criteria derived from **sedimentary rocks** and the included **fossils** Certain types of fossils such as **corals** are assumed to have lived in tropical seas **Limestones** are assumed to have been formed only in warm seas **Aeolian** sandstones, red sediments, **playa** deposits, salt, **gypsum,** and desiccation products in general, are usually evidence of aridity **Tillites** are evidence of glacial climates Fossil plants are particularly good evidence as to the climatic conditions under which they lived (See **Paleobotany**) (R M F)

PALEOLITHIC. Paleontology of Man.

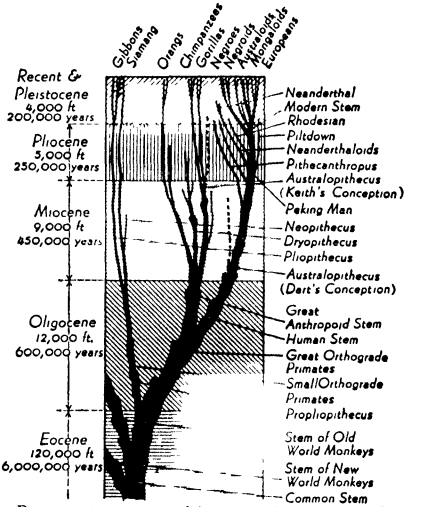
PALEOMASTODON. Fossil Mammals.

PALEONEMERTEA Nemertea.

PALEONTOLOGY. The study of fossils A fossil is the evidence of the former existence of an organism, either animal or plant Fossils may be classified according to their method of fossilization as follows (1) Actual remains, sharks teeth, ear bones of whales, chitin, etc (2) Petrifactions Minute replacements in which the original organic matter has been completely or partially replaced by mineral matter The principal replacing minerals are calcite, quartz, chert and pyrite (3) Molds and casts of interiors and exteriors (4) Prints of leaves, jelly-fish, etc, sometimes showing carbonized traces of organic matter, as in the case of some fossil plants (5) Coprolites, fossil excrement (6) Tracks, trails and burrows The geologist is principally interested in fossils, not from the point of view of paleobiology, but rather as valuable aids to **stratigraphy** in helping to determine the relative ages of the **sedimentary rocks** in which the fossils occur Unfortunately the fossil record is so incomplete that the general principle of evolution is of little or no value for determining the age of the smaller divisions of the geological time scale Because of the complexity of the fossil record and the host of fossil types, including whole classes of organisms, which are now extinct, Paleontology has been subdivided into the following natural divisions (1) Micropaleontology, or the study of microscopic fossils, especially the **foraminifera;** (2) Invertebrate Paleontology, (3) Vertebrate Paleontology, (4) Paleobotany, (5) Stratigraphic Paleontology (R M F)

PALEONTOLOGY OF MAN Since the time of Charles Darwin's publication "On the Origin of Species" (1859), certain formations from the **Pleistocene** have been found to contain fossil remains which are anatomically different from any existing race of men, but which are also more "human" than any other existing type of anthropoid Within the last few years the study of fossil man, including the study of his increasing mentality, as disclosed by his creative art (artifacts), has led to a special branch of geological history called the Paleontology of Man The accompanying diagrammatic presentation of the fossil and stratigraphic record of man is in the form of a family tree, buried in the stratigraphic record of successive **sedimentary** formations containing numerous fossil animals and plants, which help to date, or correlate, the ancestral stock and divergent branches of *Homo Sapiens* The generic and specific names represent specific types, certain of which are supposed to be "milestones" in man's total evolutionary journey from a lower form of anthropoid to his present state The geological proofs of the evolution of man depend upon the following studies, both in the field and in the laboratory

1 Paleontology The comparative anatomy of the fossil bones, principally the bones of the skull, teeth, and to a certain extent the limbs The comparison of analogous bones of different fossil types The comparison of the analogous bones of fossil types with those of living anthropoids, including man
2 Artifacts Comparative studies of the cultures of extinct races of men, including instruments, sculpture, and painting
3 Archeology Including both the vertical (stratigraphic) and lateral (paleogeographic) distribution of anthropoid bones and artifacts The correlation (relative age) of each "find" which may have a bearing on the evolution of man may not be determined primarily by the apparent evolutionary stage of the object because (1) The known total vertical (stratigraphic) range of a fossil species or artifact may be increased by further discoveries (2) Concepts as to the evolutionary stage of a fossil species may be still further strengthened or radically changed by new discoveries of fossil bones and artifacts which either do or do not fit into the previously postulated evolutionary series



Diagrammatic synopsis of human evolution (Keith)
(Field, *Outline*, Barnes & Noble)

The accompanying chart illustrates, in stratigraphic sequence, the cultural history of prehistoric man from some 350,000 years ago to the present day A few of the most significant progenitors, or prehistoric relatives of the genus *Homo* are

1 Peking Man (*Sinanthropus*) This type, and *Pithecanthropus*, are the oldest known primitive progenitors of man While *Sinanthropus* may occur stratigraphically lower than *Pithecanthropus*, it appears to be fairly closely related to *Pithecanthropus*, and possibly a slightly higher type (see chart of cultural ages) The bone beds in which the Peking Man was discovered are dated as early Pleistocene, and it is estimated that he lived some 250,000 years ago The discoveries were made in a limestone cave near Peking The undisturbed cave deposits contain 110 feet of richly fossiliferous deposits which date the "human" remains
2 Java Man (*Pithecanthropus*) Has been thought, and still may be, the nearest known approach to the "missing link" Total evidence intimates an animal having a brain of 900 94 cc, or approximately that of the lowest limit amongst the primitive living races of mankind (aboriginal Australian woman) The discovery was made in the same stratigraphic horizon as a number of **fossil mammals** of **Pliocene** age, near Trinil, Java, in 1891 The restoration of the type depends upon a skull cap, some teeth and a femur which may or may not have belonged to the same individual, or to the same species
3 Piltdown Man (*Eoanthropus*) The most ancient fossil man so far discovered in England Cranial capacity some 300-400 cc greater than that of the Peking Man While not in the direct evolutionary line of the existing races of man, it probably represents a higher western race which was probably contemporaneous with a lower eastern type The skull was found at Piltdown, Sussex, England, in river gravels The associated artifacts

have been determined as probably Pre-Chellean in age, and may be older than the skull. The exact age of the formation is still under dispute, but it appears to be Pliocene or early **Pleistocene**

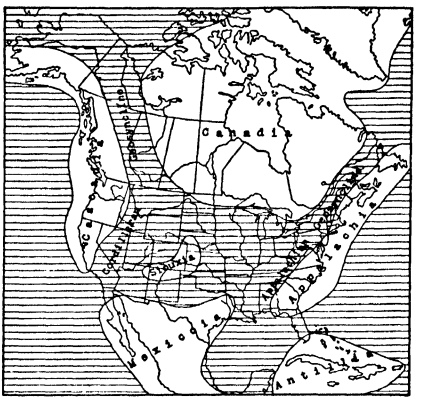
4 Neanderthal (*Homo neanderthalensis*) A well established race with progenitors probably well down in the Pliocene, and probably contemporaneous with the earlier races previously cited Cranial capacity on the order of 1600 cubic centimeters, or possibly somewhat larger than that of modern man This race appears to have died out during the late Pleistocene and is not directly ancestral to the living races of man The Neanderthal race had a wide geographic distribution, including eastern and western Europe and Africa The first discovery was the Gibraltar skull in 1848, but the type locality is a cave in the Neanderthal gorge of the valley of the Dussel, a German tributary of the Rhine Numerous, complete skeletons are known The jaw, flatness of the cranium, pronounced eyebrow (supra-orbital) ridges and thickness of bone in the skull are decidedly simian The development of retouch, and the flake for special types of flint instruments have tended to supersede the more primitive general utility tool called a hand stone or coup de poing of the earlier Chellean and Acheulian cultures

5 Crô-Magnon (*Homo Sapiens*) The highest type of the extinct races of men, both anatomically and mentally Not directly ancestral to the modern races of men, because of distinct differences in the skull Abundant fossil skeletons have been found, including children and adults of both sexes Skull large, and brain size exceeding that of the average modern man On the other hand the skull retains primitive characters It is long and narrow (dolichocephalic) with relatively broad face, large eye sockets and pronounced supraorbital ridges Complete skeletons show that the males were broad-chested and fairly erect, with an average stature of 6 feet 1½ inches The culture ranges from Aurignacian to the close of the Paleolithic (Azilian) The Aurignacian culture includes flint, bone and horn instruments, including the burin, or engraving tool Also the first evidence of prehistoric art in the form of sculptures, tinted engravings on the walls of limestone caverns, and art mobiler, or figurines During the Solutrian occurred the culmination of the retouch in the making of flint instruments, as exemplified in the pointes en feuille de laurier, or laurel-leaf points The following Magdalenian period represents the culmination of the Paleolithic or prehistoric culture With the decadence of flint, and the increasing use of bone instruments also occurs the climax of Paleolithic art, including engraving, sculpture and painting The Azilian shows a complete revolution in culture with a degeneration of the retouch in making flint instruments and the foreshadowing of the polished stone instruments of the Neolithic (R M F)

Sketches of stone implements of various cultural ages used by Paleolithic man Upper left, Chellean, upper right, Mousterian, and lower, Solutrian (*The Nature of the World and Man*, University of Chicago Press)

PALEOSTRACA. Xiphosura.

PALEOZOIC. The **Era** of "ancient" life or the age of invertebrates Subdivided from the base up, into the following **Periods: Cambrian, Ozarkian, Canadian, Ordovician,** (lower Paleozoic) **Silurian, Devonian** (middle Paleozoic) **Mississippian, Pennsylvanian, Permian,** (upper Paleozoic) The lower Paleozoic was characterized by the first known marine faunas, dominance of **trilobites**, rise of animals with hard shells (Cambrian), rise of **nautiloids,** armored **fishes** and **corals,** also first evidence of colonial life (Ordovician) The middle Paleozoic was characterized by: the rise of **lung-fishes** and **scorpions** (Silurian), first known land floras (Devonian) not very different from those of the Pennsylvanian, earliest evidence of a terrestrial vertebrate in the form of a single foot print from the Devonian of Pennsylvania The upper Paleozoic was characterized by ancient sharks, and **echinoderms,** (Mississippian), primitive reptiles and insects, (Pennsylvanian), periodic glaciation and extinction of many Paleozoic groups during and after the Permian Rise of modern insects, land vertebrates and **ammonites** (Permian) The Paleozoic Era began 500 million years ago and lasted for 300 million years (R M F)



A highly generalized map of North America showing a rather typical arrangement of the principal Paleozoic positive and negative areas, and also the Appalachian and Cordilleran geosynclines, from Middle Cambrian to Middle Pennsylvanian time

PALINGENESIS A term proposed by Sederholm in 1907 for the reversal of **petrological** processes, such as the melting of **batholithic** and **metamorphic rocks** *in situ* Theoretically the completion of a cycle of rock genesis (R M F)

PALISADES DISTURBANCE. Triassic.

PALLADIUM Symbol Pd Atomic number 46. Atomic weight 106 7 Density 12 16 Hardness 4 8 Melting point 1553° C

Compact palladium is a white metal, and due to its property of softening at temperatures below the melting point can be easily welded Heated in air to redness palladium becomes coated with oxide The molten metal absorbs **oxygen,** and on cooling "spits" like **silver** Finely divided palladium adsorbs 1000 to 3000 times its volume of hydrogen gas, and retains most of this gas when heated to 100° C **Acetylene** is adsorbed similarly Palladium is slowly dissolved by boiling **hydrochloric** or **sulfuric acid** and by cold **nitric acid,** is readily dissolved by **aqua regia,** upon heating reacts with **chlorine** and with **sulfur,** upon fusion with **potassium** hydrogen sulfate forms palladous sulfate, soluble in water, reacts with fused **sodium** hydroxide Discovered by Wollaston in 1803

Palladium metal is used in dentistry, in non-magnetic springs for watches and clocks, as a permanent mirror when deposited on glass in jewelry as white gold

when alloyed with **gold**, being superior in whitening power to **platinum** in this respect

Palladium occurs native in platinum ores, sometimes to the extent of 2%, and in sufficient amount in the nickel ores of Canada to be recovered in the process of their manufacture When **osmium** and **ruthenium** are present, they are removed as volatile oxides, when platinum and **iridium**, by precipitation of the **ammonium** chloro-compounds, insoluble in alcohol, upon addition of **ammonium** chloride, and precipitation of palladium as the ammonium chloro-compound with ammonium chloride and **chlorine** leaves rhodium in the solution The ammonium chloropalladate is ignited and reduced by heating with hydrogen to yield palladium metal.

Chlorides· Palladous chloride ($PdCl_2$), absorbs **carbon monoxide** gas, a reaction which is used for estimating this gas in mixtures, palladium tetrachloride ($PdCl_4$), more commonly as chloropalladic acid (H_2PdCl_6).

Chloropalladate· Ammonium chloropalladate ($(NH_4)_2PdCl_6$), slightly soluble in water, and insoluble in alcohol

Oxides Palladium monoxide (PdO), black, palladium dioxide (PdO_2), black (R K S)

PALLET, PALETTE A structure formed of horny and calcareous materials, associated with the siphons of **shipworms** A pair of pallets lie near the end of the siphons and serve as a plug for the burrow in which the worm lives (A W L)

PALLIAL GILL. Folds of the **mantle** in some of the bivalve **mollusks** which serve as respiratory organs. (A W L)

PALLIAL LINE. The scar on the inner surface of the shell of a bivalve **mollusk** which marks the marginal attachment of the **mantle** folds (A W L)

PALLIUM. A mantle-like structure 1 The cortex of the cerebrum (**brain**) with its underlying white substance 2 The **mantle** of mollusks (A W L)

PALMATE. Leaf.

PALM FAMILY. Palmaceae This family of plants contains some 1100 species, most of which are tropical Many are of large size A tall woody stem bearing at its top a crown of large compound leaves characterizes most of them, although some are short and bushy, while a few are vine-like Only rarely does branching occur, although many do develop numerous basal offshoots The leaves are either **pinnately** or **palmately** compound The **inflorescence** is either a simple or a compound **spike**, surrounded by a **spathe** which may become extremely large The flowers are regular, with their parts in threes or multiples of three Wind **pollination** generally occurs in palms The **fruit** is a berry or a drupe, which in many species has a fibrous pericarp.

Many species of palms are planted extensively, because of their ornamental habit, in tropical and subtropical countries Large numbers are also grown as greenhouse or conservatory plants A few species are of great economic value Chief among these is the **Coconut** palm Somewhat less valuable than the Coconut is the Date Palm This plant, *Phoenix dactylifera*, is a tree whose mature trunk often attains a height of 75-100 feet. From the base of this trunk numerous **adventitious roots** extend into the soil to a depth of 20 feet or more From the base of the stem many **basal offshoots** develop The pinnate leaves are from ten to twenty feet long, with the individual pinnae sharp-pointed, linear and from one to three feet long. These leaves remain attached for an indefinite time to the trunk, giving it a very ragged appearance. In cultivation the old leaves are removed The inflorescence is a large branched spike enclosed in a large tough spathe. In a mature tree a single flower cluster may be composed of several thousands of flowers The flowers are of two different sexes, borne on different plants, and are small, wax-white and of firm texture The pistillate (See **Pistil**) flowers have three **carpels**, each with a short curved **stigma** The carpels are almost surrounded by the **perianth**, composed of three united **sepals** and three **petals**. The staminate (See **Stamen**) flowers, bearing six stamens, are of larger size than the pistillate and more showy The fruit is a one-seeded **berry** After fertilization only one of the three carpels develops, the other two being suppressed At first the carpel is wax-white, but some time after fertilization it becomes green and remains so during growth. As the berry becomes mature, the color changes to yellow or red or a blending of these colors, according to the variety of date When ripe the color of the berry varies from pale straw color through deep amber to a deep purple The seed of the date contains an abundance of **endosperm** and a rather small **embryo.**

Many varieties of dates are grown in cultivation Since cross-pollination is usually necessary to produce seeds, propagation by seeds cannot be used to increase the number of plants For such plants would not remain true to the seed-bearing parent in type but would be affected by the pollen from the staminate plant, such crossing would cause the formation of new varieties with the possibility that less desirable forms might arise Furthermore, about half the seedlings would be staminate, producing no fruit To perpetuate desirable varieties propagation is largely by means of the basal offshoots These shoots are cut from the parent and planted, ensuring new plants identical with the parent

Cultivation of the date has been carried on in Arabia and adjoining countries since prehistoric times It is probable that the plant is native to this region, even though it is unknown in the wild state Today the date palm is grown widely in regions having a sufficently hot climate The Mesopotamian valley is the chief producing region of the world In the United States the date can be grown successfully only in a very limited region in the southern parts of California, Nevada and Arizona

The principal product of the plant is the edible fruit. In the Orient the fruit is often fermented, yielding a very potent alcoholic drink, and also vinegar Various materials used in building houses, and making baskets, ropes, and household articles are also obtained from the tree in regions where other sources of such materials may be lacking

Another useful palm is the Oil Palm, *Elaeis guineensis*, a native plant occurring in large numbers in the forests of the west coast of Africa The plant is also extensively cultivated elsewhere in Africa and in the East Indies, particularly in Sumatra From the fruit of this palm two valuable oils are obtained The orange-yellow **pericarp** yields palm oil, much used in the making of soaps The **endosperm** yields a white pleasantly flavored oil known as palm-kernel oil, also used in making soaps. In Africa the fruits are eaten by the natives

In India, *Phoenix sylvestris* is widely cultivated as a plant from which sugar is obtained Many other palms are used as sources for sugar in regions where they grow (R.M W)

PALMITIC ACID AND PALMITATES. Palmitic acid ($H\ C_{16}H_{31}O_2$ or $C_{15}H_{31}\ COOH$ or $CH_3(CH_2)_{14}\cdot COOH$) is a white solid, melting point 64° C, boiling point 272° C at 100 mm pressure, insoluble in water, moderately soluble in alcohol, soluble in ether Palmitic acid is present as cetyl ester in spermaceti from which, by **hydrolysis**, the acid may be obtained; it is present in bee's wax as the melissic ester; and in most vege-

table and animal oils and fats, in greater or less amounts, as glyceryl tripalmitate or as mixed **esters**, along with **stearic** and **oleic acids**. Palmitic acid is separated from stearic and oleic acids by fractional vacuum **distillation**, and by fractional **crystallization** With **sodium** hydroxide, palmitic acid forms sodium palmitate, a soap Most soaps are mixtures of sodium stearate, palmitate and oleate

Representative esters of palmitic acid are methyl palmitate ($C_{15}H_{31}COOCH_3$) melting point 30° C, boiling point 195° C at 15 mm pressure, ethyl palmitate ($C_{15}H_{31}COOC_2H_5$), melting point 24° C, boiling point 185° C at 10 mm pressure, cetyl palmitate ($C_{15}H_{31}COOC_{16}H_{33}$), melting point 54° C, glyceryl tripalmitate (tripalmitin) ($C_3H_5(COOC_{15}H_{31})_3$), melting point 65° C, boiling point 310° C, approximately

As the glyceryl ester, palmitic acid is one of the constituents of many vegetable and animal oils and fats. See **Esters.** (R K S)

PALOLO WORM. Annelida, Polychaeta Marine worms of the genus *Leodice* which live in burrows in coral rock They have two body regions In the posterior part the reproductive organs develop, and when they are mature this part breaks away from the anterior region and swims to the surface of the sea The attainment of sexual maturity occurs at a specific time, and during this period the water swarms with the reproductive portions of the worms The anterior part remains in the burrow and during the succeeding year produces another reproductive region One species lives in the southern Pacific Ocean and another in the West Indies (A W L)

PALPIFER. Maxilla.

PALPIGER. Labium.

PALPITATION. The consciousness of temporarily abnormal action of the **heart**, characterized by increased force, rate or irregularity of the beat Palpitation is a symptom present in many conditions, it is not a disease in itself It is commonly seen in emotional, nervous or excitable subjects, as an accompaniment of some stomach disorders, acute fevers, following the drinking of tea, coffee or alcohol in certain individuals, and often as a symptom of organic heart disease (R S M)

PALP, PALPUS. An appendage of sensory functions 1 In some of the segmented worms thick fleshy protuberances on the head are called palpi 2 **Bivalve mollusks** bear two pairs of flaplike appendages near the anterior end of the body which are called palps 3 The **maxillae** and **labium** of insects each bear a pair of segmented appendages called palpi. (A W L)

PAMPEAN FAUNA. Pleistocene.

PANAMA HAT PALM. *Carludovica palmata.* Cyclanthaceae This plant is very abundant in tropical forests of America, where it forms large clumps of long-petioled leaves In contrast to true palms, the Panama hat palm is stemless It is frequently planted as an ornamental plant For making Panama hats, the young leaves are gathered, cut into narrow strips, bleached, and woven into the hats These hats are actually manufactured only in a section of Equador, and not in Panama (R M W)

PANCREAS. A large digestive gland whose duct empties into the alimentary tract **(Digestive System)** The name is sometimes applied to a mass of tissue surrounding the duct of the principal digestive gland of the **squid** but it belongs characteristically to the **vertebrates.** The vertebrate pancreas develops as a group of outgrowths from the embryonic **(embryo)** gut just behind the stomach. In the higher vertebrates one outgrowth is dorsal and one or two ventral, but all normally unite to form one mass which usually discharges by one of the original ducts, although in some species both persist The ventral duct often joins the duct of the liver In man this duct becomes the pancreatic duct, joining the hepatic duct to discharge into the intestine by the common bile duct. The pancreas is a compound acinous gland The human pancreas is a large, elongated gland situated on the posterial abdominal wall behind the stomach above the level of the navel, lying between the spleen on the left and the duodenum on the right The pancreas has both an external and an internal secretion

The external secretion of the pancreas empties into the duodenum This digestive fluid contains at least three important **enzymes** (1) Trypsin, which interacts with an enzyme secreted by certain cells of the small intestine. It causes **protein** food substances to be broken down into simpler forms so that they may be absorbed and utilized by the body, (2) Amylase, which assists in the digestion of **starch**, and (3) Lipase, which breaks down **fatty** foods into glycerine and fatty acids

The internal secretion of the pancreas is formed by small cell groups scattered throughout the gland substance They are called Islands of Langerhans and their function is to secrete **insulin** into the blood stream Insulin is necessary for the oxidation of **sugar** by the body When insufficient insulin is manufactured by the gland diabetes occurs When too much insulin is discharged into the blood stream hyperinsulinism develops and is characterized by a low blood sugar accompanied by weakness and fainting spells

The pancreas is stimulated and pours out its secretion due to the action of secretin, a **hormone** originating in the walls of the duodenum This hormone is activated by the passage of acid food from the stomach into the duodenum The hormone is then absorbed in the blood stream where it acts upon the pancreas

The pancreas is subject to acute and chronic **infections** and **tumor** and cyst formation (A W L, R S M)

PANDA. Mammalia, Carnivora A peculiar animal, *Aelurus fulgens,* of the southeastern Himalayas Its body is about two feet long, exclusive of the long furry tail, and the legs are strong and only moderately long The head is shaped much like that of the raccoons, which seem to be fairly closely related Also called the red cat-bear from its slight resemblance to both forms (A W L)

PANGOLIN. Mammalia, Edentata. The scaly anteaters, a group of peculiar Old World animals which are covered with overlapping horny scales of large size They are slender animals with a long tail and short legs bearing powerful claws Like other anteaters they have a sharp snout and long sticky tongue and live chiefly on termites

The several species are confined to Africa and the southeastern part of Asia, where the most common one is *Manis pentadactyla* (A W L)

PANICLE. Flower.

PAN-IDIOMORPHIC. A term proposed by Rosenbusch signifying an **igneous rock** whose texture is **idiomorphic** (R.M F.)

PANTHER. Puma.

PANTOGRAPH. Parallel Mechanism.

PANTOPODA. Synonym of **Pycnogonida.**

PANTOSTOMATIDA. **Mastigophora.**

PAPAL MITRE Mollusca, Gasteropoda A marine shell of the Indian Ocean It is white with red spots The name is a translation of the scientific name *Mitra papalis* (A W L)

PAPAVERINE **Alkaloids.**

PAPAYA Papaw *Carica papaya* Caricaceae This is a tropical American tree with a straight rarely branching trunk from 6 to 25 feet tall On the upper portion of the stem is borne a crown of large compound, long-petioled leaves The pale yellow, fragrant flowers are of two kinds, pistillate (See **Pistil**) and staminate (See **Stamen**), borne on different plants Papayas are therefore **dioecious plants.** The smooth-skinned fruits vary considerably in shape and size, those of wild plants being not much larger than eggs, while cultivated fruits are much larger The orange-colored flesh is sweet and juicy, and surrounds a central cavity which contains the numerous seeds Usually the fruit is eaten raw, but may be used in salads or cooked It is not a good shipping fruit, so rarely appears in United States markets

From the fruit and sap of the plant is obtained an **enzyme,** papain, which is used as a digestive aid, its action being much like that of pepsin The leaves, cooked with meat, are said to tenderize meat

The plant is widely introduced in many tropical lands It is extensively grown in the Hawaiian Islands and to some extent in Florida and California Propagation is mainly by seed

The name papaw, sometimes given to this fruit, is also applied to a North American tree, *Asimina triloba,* with which it should not be confused (R M W)

PAPER One of the most important factors in the progress of civilization has been paper, a thin flat tissue composed of closely matted fibers obtained almost entirely from plant sources In modern life paper finds a variety of uses, for writing, for containers, wrappers, wall covering, and—perhaps most important—in all the forms of printing newspapers, magazines, books

The art of making paper seems to have been discovered first by the Chinese, who were making paper as early as the beginning of the Christian era From China the process was carried to Arabia and thence to Europe Paper was not an important article at first and, since it is not a very durable substance under ordinary conditions, could not compete with parchment or vellum as a medium for the written word In the fifteenth century writing became more general and the demand for a cheaper material increased Paper became an important product At this time paper was made largely from vegetable fibers reclaimed from cloth (especially linen), as had been done since the invention of paper in China This paper was made entirely by hand, as is done even today in the manufacture of certain expensive types of paper In making hand-made paper, a pulp is formed by soaking the vegetable fibers in water in a vat From this vat the pulp is dipped out in a mold, the bottom of which is a fine screen By a deft motion of this mold the soft pulp is spread over the screen in a thin layer of matted fibers The water in the pulp drains off, leaving a rather firm mass which is turned out on a piece of felt More pieces of half-dried pulp spread on felt are added The whole pile is then pressed to squeeze out more of the water, press the fibers closer together and form a firm sheet These are then removed from between the felts, pressed again, and dried During the final treatment surface sizing is added to render a surface more suitable to receive ink Sheets of hand-made paper are naturally of limited size and expensive

To meet the great demand for paper, machine methods were developed. This increased demand for paper also led to the utilization of material which could be obtained in quantities much greater than rags Out of this developed the vast pulp industry which today converts vegetable material, mostly soft woods such as spruce and fir, as well as poplar, into a white felt-like mass of fibrous substance, known as pulp Several methods are in use to obtain the fibers from the wood. In one, the logs are barked and then ground by pushing against large grindstones By this process the separate fibers of the wood are dissociated, their ends being more or less frayed in the process Water flowing over the grinding surfaces keeps the temperature resulting from friction from rising unduly, and also removes the fibers These are then washed and drained, undesirable substances such as bits of bark and other materials removed, and then pressed into sheets These sheets of pulp are folded into bundles, which are then shipped to the paper mills Pulp mills are commonly located near the source of wood supplies Ground pulp is largely made from spruce wood and is principally used in making newsprint paper Usually it is mixed with some chemically prepared pulp so that the paper may have greater strength to resist tearing in handling

Chemical pulp is prepared by several processes In these the wood is first barked, and then further cleaned by hand or other mechanical equipment to remove bark, pitch, and other foreign material as completely as possible It is then cut up into chips which are screened to remove the fine sawdust and dirt The chips are cooked or digested in very large vertical tanks or digesters Digestion is accomplished by means of various chemicals In the sulfite process, **sulfur dioxide** dissolved in **calcium** bisulfite or **magnesium** bisulfite is used In the soda pulp process, a solution of **sodium** hydroxide in water is used In the sulfate process, sodium sulfate is added to the sodium hydroxide solution Digesting is done under pressure and at high temperatures The sulfite process is used with coniferous woods such as spruce, fir and hemlock, the soda process with poplar and other deciduous woods, and the sulfate process for coniferous woods After digesting, the fiber mass is washed to free it of chemicals and pressed into sheets of pulp

To convert the pulp into paper by machines, it is first put into large tub-like containers with water There it is thoroughly beaten by constantly passing between a roll and stationary plate, the surfaces of both being made up of narrow, closely spaced steel bars. During the beating a certain amount of blue dye is added to neutralize the yellow tint otherwise present. Later alum, sizing and bleaching materials are also added In the case of rag pulps the bleaching is done in the washer beaters, but in the case of wood pulps it constitutes the principal problem as far as bleaching is concerned The bleaching is carried out in large tanks designed specifically for the purpose The chief bleaching agents are chlorine and calcium hypochlorite When the mass is thoroughly beaten and mixed, it is run onto a very fine copper screen which is in the form of an endless belt several feet wide Vibration of the screen spreads the material in a thin uniform layer As it is carried along much water in the soft mass drains out To prevent the material from running over the edge thick rubber belts are placed on either side Mechanical suction removes much of the water left after draining, after which the felted mat passes between rollers on a thick woolen felt which is carried between a series of heavy rollers Passing between these the paper is pressed into a firm thin sheet, which then has sufficient strength to pass without support of screen or felt through a long series of heated rolls From these it may go directly to the calender machines, stacks of heavy rolls which give to it a smooth firm surface. If a better surface is required, paper then goes to the coating machines, where it receives a coating of a clay or other mineral pigments and casein, which imparts a very smooth glossy sur-

face suitable for fine reproduction of photographs Many variations are found in the details of the various processes leading to the production of finished paper

The principal woods used in the making of paper are spruce, hemlock, southern pine, poplar and fir, with smaller quantities of several other woods Attempts have been made at various times to use other plant materials, such as cotton and corn stalks, and various straws So far these have given only slight promise because of the difficulty and expense of obtaining the fibers. Large quantities of cereal straw, namely, oat, wheat, rye, and barley are used in making brown, coarse straw pulp which is principally used for making paper boards for corrugated paper From waste paper, pasteboard and cheap grades of paper are made Large quantities of the better quality waste paper if unsoiled or deinked are used in the various grades of printing paper Unbleached waste papers and lower grade waste which may be badly soiled are disintegrated without deinking and used for the manufacture of container board, boxboard, and some of the low quality grades of paper (See **Carbohydrates.**) (R M W)

PAPER WASP. Insecta, Hymenoptera The hornets and yellow-jackets **Wasps** which build their nests of coarse paper made by chewing fragments from weathered or partially decayed wood Some build subterranean nests and others suspend the nest from the eaves of buildings or from the boughs of trees (A W L)

PAPPUS. Composite Family.

PAPPUS' THEOREMS These are two mathematical results obtained by Pappus (c 300 A D) concerning areas and volumes of solids generated by rotation of a plane figure about an axis

If an arc of a curve in a plane is rotated about an axis not cutting it, the area generated by the arc equals the length of the arc times the perimeter of the circle described by its **centroid.**

If a closed region in a plane is rotated about an axis not cutting it, the volume generated by the region equals the area of the region times the perimeter of the circle described by the centroid of the region (L L S)

PAPULA. Thin-walled projections from the surface of starfishes They increase the surface available for respiratory and excretory interchange (A W L)

PAPYRUS. *Cyperus Papyrus* Cyperaceae In early times writing was done on sheets of material known as papyri These were prepared from the stems of a huge species of reed growing on river banks and in marshes in Egypt and other eastern countries This plant, *Cyperus Papyrus*, has a thick **rhizome** which often grows several feet in length The pith of the rhizome is edible, and frequently is used as food in eastern countries From the rhizomes arise the erect stems of the plant, which are from three to twelve feet tall and bear at the top a radiating mass of flower spikes In making papyri, the stems were first cut into thin strips These were placed side by side until the desired width, varying from four to twelve inches, or more, was obtained Across this layer another was placed, with the strips at right angles to the first It is possible that the strips were interwoven This material so arranged was then immersed in water and left to soak for some time After soaking the layer was beaten flat and into a coherent sheet which was then dried in the sun Separate sheets of papyrus were pasted together so that rolls of considerable length were obtained So prepared, papyrus forms a thin flexible sheet of great durability, though some of the larger sheets tended to tear and break apart with use Papyrus making was principally carried on in Egypt, but the plant was introduced into other eastern countries in early times, and attempts at papyrus making undertaken The **product** was often inferior to the Egyptian papyri (**R.M.W.**)

PARABASAL BODY. A structure associated with the **nucleus** of some of the flagellate protozoans (**Mastigophora**) Its functions are unknown (A W L)

PARABOLA. The parabola is one of the conic sections, and may be obtained by cutting a right circular cone by a plane which is parallel to an element of the cone

A parabola is the **locus** of a point which moves so that its distances from a fixed line and a fixed point are equal (Figure 1) The fixed line is called the directrix, and the fixed point the focus The line through the focus perpendicular to the directrix is called the axis of the parabola, it is an axis of symmetry of the curve The point midway between the focus and the directrix, which is the intersection of the curve and the axis, is called the vertex of the curve The chord of the curve through the focus and perpendicular to the axis is called the latus rectum (or focal width) of the parabola The line joining any point of the curve to the focus is called a focal radius

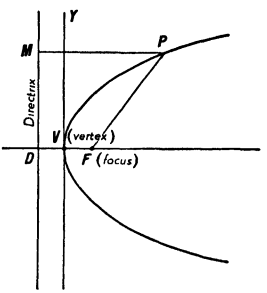
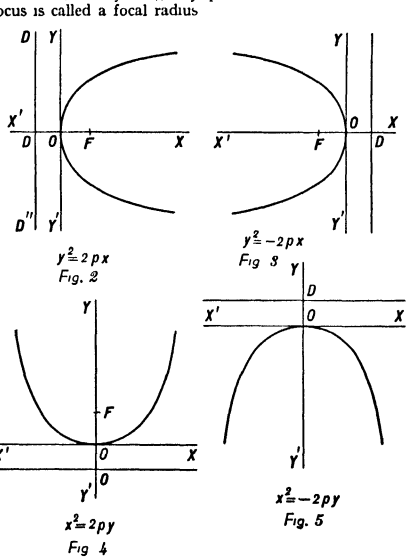


Figure 1 Parabola



Parabola

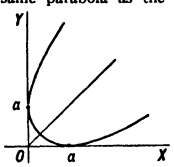
If the origin is taken at the vertex and the X-axis along the axis of the parabola, and if p is the distance of the focus from the directrix, then the equation of the parabola is

$$y^2 = 2px, \text{ (Figure 2)},$$

if **rectangular coordinates** are used, and if the curve is open to the right The focus is at $(\frac{1}{2}p, 0)$ and the equation of the directrix is $x = -\frac{1}{2}p$

The length of the latus rectum is $2p$

The equation $y^2 = -2px$ $(p > 0)$ represents the same parabola as the preceding, but open to the left, with focus at $(-\frac{1}{2}p, 0)$ and directrix $x = \frac{1}{2}p$ (Figure 3)



Parabola $x^2 + y^2 = a^2$
Figure 6

The equation $x^2 = 2py$ $(p > 0)$ represents a parabola with vertex at the origin and axis on the Y-axis, open above, with focus at $(0, \frac{1}{2}p)$ and directrix $y = -\frac{1}{2}p$ (Figure 4)

The equation $x^2 = -2py$ $(p > 0)$ represents the same parabola open below (Figure 5)

The equation $(y-k)^2 = 2p(x-h)$ represents a parabola with vertex at (h,k) and $y = k$ as axis of symmetry

The equation $(x-h)^2 = 2p(y-k)$ represents a parabola with vertex at (h,k) and $x = h$ as axis of symmetry

The equation $x^2 + y^2 = a^2$ represents a parabola tangent to the coordinate axes and having its principal axis bisecting the first (and third) quadrants (Figure 6)

The parabola may be constructed geometrically in several different ways

Given the focus and directrix of a parabola, it may be constructed point by point as follows (Figure 7) Draw the axis MX, construct the vertex V as the midpoint of MF Through any point A on the axis to the right of V draw a line AB parallel to the directrix From F as center with radius MA strike arcs to intersect AB at P and Q Then P and Q are points on the curve By changing the position of A we may construct as many points on the curve as desired

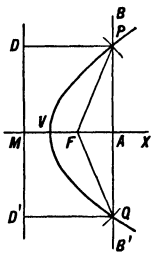


Figure 7 Construction of parabola

A construction by continuous motion is the following (Figure 8) An arc of a parabola can readily be drawn in the following way At the vertex A of a draughtsman's triangle fasten one end of a string of length AB Fasten the other end at the focus F of the required parabola and place the other leg BC of the triangle along the directrix Hold the string taut by pressing it against the side of the triangle with the point of a pencil at P If the side BC of the triangle is now made to slide along the directrix, the point P will describe an arc of a parabola

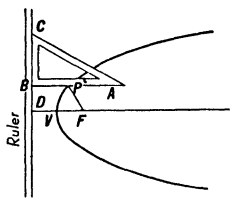


Figure 8 Construction of parabola

When the span AB and height OH of a parabolic arch are given, points on the arch may be constructed as follows (Figure 9) Draw the rectangle $ABCD$ Divide AH and AC into the same number of equal parts Starting from A, let the successive points of division be on AH: a, b, c and on AC: l, m, n Draw aa' perpendicular to AB and draw Ol, mark point of intersection of aa' and Ol, and do likewise for the points b and m, and c and n. The points of intersection are points on the parabola required

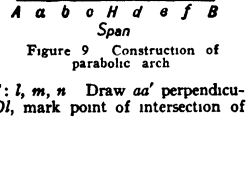


Figure 9 Construction of parabolic arch

The equation of the tangent to the parabola $y^2 = 2px$ at the point (x_1, y_1) is $y_1 y = p(x + x_1)$

The equation of the tangent with slope m to the parabola $y^2 = 2px$ is $y = mx + \frac{p}{2m}$.

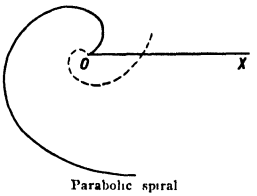
Some applications of the parabola are

The path of a projectile near the surface of the earth (air resistance being neglected) is a parabola

A cable of a suspension bridge, if the load is uniformly distributed along the bridge, assumes a parabolic form

A parabolic mirror is one whose reflecting surface may be generated by revolving a parabola about its axis (Searchlights, locomotive headlight, reflecting telescope)

If a pan of water is rotated about a vertical axis, the surface of the water assumes a parabolic shape. (L L S)



Parabolic spiral

PARABOLIC SPIRAL. The parabolic spiral is a geometric curve of spiral form It is the graph of the equation in polar coordinates $r^2 = a^2\theta$ (L L S)

PARABOLOID OF REVOLUTION. Paraboloids.

PARABOLOIDS The paraboloids are geometrical surfaces belonging to the class known as **quadric surfaces** The **surface** represented in **rectangular coordinates** by the equation

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 2cz$$

is called an elliptic paraboloid, since its sections parallel to the coordinate planes are one **elliptic** set and two **parabolic** sets (Figure 1)

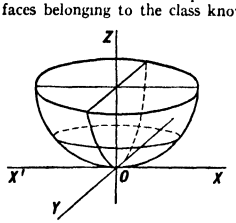


Figure 1 Elliptic paraboloid

If $a = b$, the elliptic set of sections becomes circular, and the equation represents a paraboloid of revolution, which may be obtained by revolving a **parabola** about its axis of symmetry

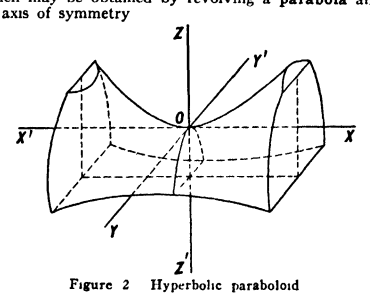


Figure 2 Hyperbolic paraboloid

The surface represented in rectangular coordinates by the equation

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 2cz$$

is called a hyperbolic paraboloid (Figure 2) since its sections parallel to the coordinate planes are: one set of **hyperbolas** and two sets of parabolas (L L S)

PARACHUTE. The parachute is an aerial life-saving device, and is worn by pilots and passengers of aircraft as a safety measure The safety parachute is not used except in emergencies, when its wearer is faced with the necessity of quitting the aircraft in midair This discussion omits consideration of the parachute combination employed in exhibition jumps The parachute is made up of a circular silk (pongee in cheaper grades) canopy about 24 feet in diameter At intervals around the edge of this canopy are attached shroud lines which lead to risers These are members of webbing joining the ring, to which are gathered the shroud lines, with the harness, which is worn by the user, and in which he is suspended when the parachute is in use At the center of the canopy is a circular vent edged with rubber bands which tend to keep the vent closed, but which will stretch and allow it to expand to ease the shock when the canopy is opened The parachute is worn as a back pack, a seat pack, or lap pack The seat pack is the most convenient type for the average person since the back may rest comfortably against the seat and the pack will act as a cushion to sit on The lap pack is used chiefly for exhibition jumps A parachute is packed into a canvas cover, shroud lines and all The pack is held closed by a flexible wire which passes through eyelets in the pack cover Two things cause the mainsail to be thrown out of the pack when the flexible wire, which is called the rip cord, is pulled to release the parachute Rubber bands attached to the canvas cover pull it away from the parachute itself and spring ribs throw a small pilot parachute into the airstream, where it forms an anchor which drags the mainsail

The recommended practice when leaving an airplane is to dive headlong, pulling the rip cord when clear of the aircraft, so that there may be no danger of the aircraft fouling some part of the chute About three-fifths of a second after the rip cord is pulled, the mainsail is inflated, and the velocity of descent is checked While there are records of successful parachute landings from jumps made below 500 feet, any parachute jump from below that altitude may be considered extremely hazardous The standard rate of descent of a 24 foot parachute is 17 feet per second, which is said to be equivalent to a jump from a 10 foot wall A saving of over 1500 lives has been accorded the free type of parachute since its development by the United States Army Air Corps in the years following the World War.

In addition to the parachuting of humans, the parachute has been used to drop circulars, food, supplies, and consigned cargo to points inaccessible to any other transportation, and to points not possessing a landing field So important is the requirement of correct and careful packing of the parachute that the United States Department of Commerce undertakes to license parachute packing ability A parachute which has been correctly packed within three months of the time of use and which is in good physical condition, is certain to open when released (F T M)

PARACONIINE. Alkaloids.

PARADOXURE. Mammalia, Carnivora An anglicized form of the generic name *Paradoxurus*, applying to the civets. (A W L)

PARAFFIN Petroleum.

PARAFORMALDEHYDE. Formaldehyde.

PARAGASTER. The large central cavity of **sponges**, also called the gastral, paragastral, or paragastric cavity It is superficially like the enteric cavity of the gastrula of higher animals but it is formed by an involution of the layer of cells which cover the external surface of the **larval** sponge Water passes into it through the canal system of the body wall and flows out through the **osculum.** It is not a digestive cavity. (A W L)

PARAGASTRIC CAVITY. Paragaster.

PARAGENESIS The term applied by **petrographers** to the succession, or order of development, of the minerals in an **igneous** or **metamorphic** rock More particularly applied to the order of crystallization of related minerals in a vein or ore-body, including processes of alteration (R M F)

PARAGLOSSA. Paragnatha.

PARAGNATHA. 1 The lobes into which the lower lip or metastoma of the **crustacean** mouth is sometimes divided 2 Lobes or appendages borne by the **hypopharynx** of the insect mouth They lie between the mandibles and **maxillae** and have also been called paraglossae, superlinguae and maxillulae They are homologous with the paragnatha of crustaceans (A W L)

PARAGNEISS. Gneiss.

PARAGUAY TEA. Maté.

PARALDEHYDE. A powerful sleep-producing drug which may be given by mouth, by vein and by rectum It is a volatile liquid with a penetrating burning taste It is rapidly absorbed and produces sleep very quickly After paraldehyde is given, the disagreeable odor of the drug is very noticeable as it is excreted in the breath (See **Acetaldehyde.**)

This drug is much used by alcoholics to quiet their nerves, and instances of paraldehyde habituation have been reported (R S M)

PARALLAX. As an observer moves about, the relative positions of distant objects seem to change This apparent change of position of distant objects, due to the actual change of position of the observer, is technically known as parallax, and the amount of apparent shift is known as the parallactic shift The amount of parallactic shift is inversely proportional to the distance of the object

In taking readings of instruments employing scales and pointers, care must be taken that the eye of the observer and the pointer are both in a line perpendicular to the plane of the scale To facilitate this, many instruments have a mirror in the plane of the scale so that the observer may eliminate parallax errors by bringing the reflected image of his eye coincident with the pointer and its reflected image

In astronomy parallax effects play a very important part In transferring from one system of coordinates to another parallax effects must always be applied when the location of the origin changes For example, observations are taken from the surface of the earth and **geocentric parallax** must be applied when transferring the observations to the center of the earth Distances of many celestial objects are expressed in terms of parallactic angles The angle subtended by an equatorial radius of the earth at the distance of the sun is known as **solar parallax,** while the angle subtended by the radius of the earth at the distance of any other member of the solar system is known as the horizontal parallax of that object. In measuring the distances of the stars the parallactic shift due to the revolution of the earth about the sun is employed, the angle subtended by one **astronomical unit** at the distance of the star being known as the **stellar parallax** of the object As the characteristics of **solar motion** become more completely known, parallactic shifts due to this motion will undoubtedly be used for the determination of distances. (W.K.G.)

PARALLEL MECHANISM. Parallel mechanisms are those in which the links which compose the mechanism are pinned together in a **parallelogram.** The parallel rulers (Figure 2) are simply two straight edges joined with pin joints by two connecting links having points of connection so spaced that the rulers and the connecting links form a parallelogram In this mechanism the straight edges are always parallel, but the perpendicular distance between them may be varied from zero up to the length of the connecting links An interesting application of the parallel linkage is shown in Figure 3 In this device the line *AB* is movable over the plane of the mechanism, within limits In all positions, however, the line will be parallel to the position shown in the illustration This linkage is the basis of the universal drafting machine, which is composed of two parallelograms connected through the intermediary of a rigid ring

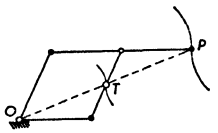


Figure 1 Pantograph

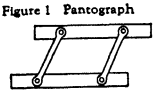


Figure 2 Parallel Rulers

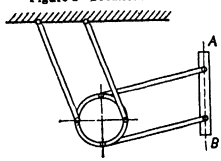


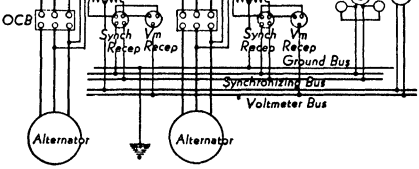
Figure 3 Drafting Machine

The pantograph has incorporated in it a parallel mechanism It increases or decreases the scale of the line which is being paralleled (Figure 1) The point *O* must be fixed, but the points *P* and *T* may be, interchangeably, the tracer point or pencil point, depending on whether the scale is to be reduced or increased It is necessary, however, for point *T* to be such that *O, T, P* are all on the same straight line The pantograph is used to copy drawings to the same or different scale, and to reduce or increase a motion in exact proportion to the original (F T M)

PARALLEL OPERATION. The parallel operation of equipment is taken in contrast to series or "booster" connections Parallel operation, of course, implies at least two units, although the individuals do not necessarily have to be of the same capacity Generally speaking, in the parallel operation the quantities of output of the units are additive, whereas in series operation certain characteristics, such as pressure, voltage, and the like are additive, and the quantity output is the same as for each machine Machines operated in parallel discharge to a common collective device such as a **header** or a **bus** or a **conveyor.** Among the more common instances of parallel operation are found the operation of two or more power plants feeding electrical energy into the same distribution network, the parallel operation of electric generating equipment within a plant, the parallel operation of prime movers such as **steam** or **hydroturbines,** and the parallel operation of **transformers.** Industry offers numerous examples of parallel operation of production machines, the output of which is collected by some mechanical conveyor system

On account of the interesting technical problems associated with the parallel operation of power equipment, particularly electric generating equipment, this field will be described in some detail Direct current **generators** can be parallel on a bus, and the load divided between them at will by adjustment of their shunt fields Shunt wound generators may be operated in parallel merely by being connected to the buses of the same polarity. In the case of compound wound generators, and most direct current machines are of this type, an equalizer bus must be connected between the series fields of the two **armatures.** Should the machines be paralleled without the equalizer, they might run satisfactorily until some slight unbalance caused one of them to supply a little more terminal voltage This would lead to a cumulative action due to the presence of series coils, and there would be a heavy surge of load to that machine, which would cause the other to operate as a motor accompanied by excessive circulation of current By using an equalizer bus, there is a stabilizing action due to the series field currents being determined by the total load current and the series field resistances of the different machines Any tendency to increase the armature current of one machine will have the effect of strengthening the field of the other, and increasing the load carried by the other As stated before, shifts of load between direct current generators in parallel are accomplished by altering the shunt field strength, and no manipulation need be given to the prime mover governors

When alternating current generators are connected in parallel, no such simple method of dividing load is possible, since variation of excitation only causes more wattless current to circulate between the machines A division of load in this field is accomplished by prime mover generator action, and the principles involved are explained under **governor.** As pointed out there, division of load is accomplished by adjustment of the prime mover governor Reverting to the alternating current generator itself, for parallel operation two alternators must have the same **phase** sequence and **frequency;** their voltages must be equal and in phase The phase sequence, once correctly established, need not be considered upon subsequent paralleling operations unless the generator or its leads has been altered in the meantime Visual indication that these electrical quantities are correct is obtained in routine operation by the voltmeter and synchroscope A diagram of typical synchronizing connections is shown herewith



Connection for synchronizing alternators

When transformers are to be connected in parallel, they should have the following similar characteristics (a) the same ratios of transformation, (b) the same terminal voltage ratios, (c) the same ratios of primary to secondary **impedance;** (d) the equivalent **resistances** and **reactances** should be in inverse ratio of the ratings (F T M)

PARALLEL SAILING. The term parallel sailing is frequently used to designate the problem of converting the distance traversed by a ship along a parallel of **latitude** into difference of **longitude.** This problem is solved under the subject of **departure** to which the reader is referred (W K G)

PARALYSIS. Loss of motor activity or sensation or both in part of the body Paralysis occurs when the nerve impulse has met with interference This may occur in the brain centers, the spinal cord centers or pathways, nerve trunks or individual nerves, or the nerve endings in the muscles. It may be temporary or permanent,

depending on the cause The cause may be due to a specific disease, to chemical or bacterial poisons, toxins or injury to nervous tissue (R S M)

PARALYSIS AGITANS (Shaking Palsy, Parkinson's disease) A chronic organic disorder of the central nervous system characterized by a spontaneous tremor, paralysis and rigidity of muscles

The cause is unknown Degenerative changes take place in cells and blood vessels in portions of the brain The symptoms of paralysis agitans occur fairly frequently after epidemic encephalitis

The onset of the disease is gradual and progresses but slowly The tremor is peculiar in that it finally is permanent and continues during rest Eventually weakness and rigidity appear Rigidity of the face muscles gives a mask-like appearance to the face which does not change with any emotion

Patients with this disorder may live for years Death is usually not due directly to the disease, but to complications or intercurrent infections developing in the patient whose vitality is impaired (R S M)

PARAMAGNETISM. **Magnetism.**

PARAMETRIC EQUATIONS. A plane curve is usually represented by a single equation in two **variables** representing **rectangular coordinates** or **polar coordinates.** Sometimes it is preferable to represent the curve by two equations expressing the coordinates separately in terms of a third variable called a parameter, these equations are then called parametric equations

We may also have parametric equations of surfaces and of curves in space (L L S)

PARAMORPHISM. A term used by mineralogists and petrologists to denote the passage of one mineral into another without any fundamental change of chemical elements A specific example is **uralite,** secondary **hornblende,** paramorphic after **augite.** Paramorphism has also been used to describe the process of **metamorphism** by which a rock is completely changed (R M F)

PARAOESOPHAGEAL OR PERIOESOPHAGEAL CONNECTIVES. The slender nerve cords that connect the dorsal brain of invertebrates with the ventral nerve cord (A W L)

PARAPODIUM A lobed appendage formed as a protuberance of the lateral body wall in some of the segmented worms (chiefly **Polychaeta**) The typical parapodium consists of two principal divisions, a dorsal notopodium and a ventral neuropodium Each may be divided into subordinate lobes A slender basal process, the dorsal cirrus, extends upward and outward from the edge of the notopodium and a similar ventral cirrus is borne by the lower edge of the neuropodium Each of these main divisions also bears a cluster of **setae** and contains a strong supporting rod, the **aciculum**

In various species of marine **annelids** the parapodia are modified in many ways to serve as respiratory organs, protective structures, and organs for the creation of water currents through the tubes occupied by the worms

It is possible that parapodia were the forerunners of the **biramous appendages** of **arthropods.** (A W L)

PARAQUE. Aves, Caprimulgiformes A large bird of Mexico and Texas which resembles the poor-will. One of the goatsuckers or **nightjars.** (A W L)

PARASITE DRAG. The **drag** of surfaces and objects immersed in a fluid stream is parasite drag if those surfaces create no useful force by their reaction with the fluid Parasite drag occurs on the hulls of water-craft, and on **aircraft.** In aircraft parlance, parasite drag is the **aerodynamic** drag of any part which does not create a useful lift In the average **airplane** the only element creating lift is the wing, consequently, all other drag is parasitic The parasite drag of an object in an airstream depends upon the square of the air velocity past it, on the streamlining, which is measured by the fineness ratio (dimension parallel to the wind/dimension across the wind), on surface smoothness, air density, and proximity to other objects (F T M)

PARASITIC ANIMALS. In general, parasitism is an association of living things in which one lives on or in the body of the other and consumes materials available in that body without rendering any service in return The organism which provides maintenance is the host and the one that lives at its expense is a parasite

Parasites are classified in various ways Those which remain on the surface of the body, such as **lice** and **ticks,** are called ectoparasites, and those which live in the alimentary tract or in tissues of the host are endoparasites One-celled animals, **flukes,** roundworms, the larvae of **bot flies,** and other forms belong to the latter category

Animals like **mosquitoes,** which visit others occasionally to secure food, are known as temporary parasites Species like some of the **leeches,** which may suck blood or catch invertebrates as prey, are facultative, and those which can live only in association with a host are obligate

Parasites which carry out their entire reproductive cycle in one host are known as autoxenous or autoecious, in contrast with those which must pass different stages in different hosts The latter are heteroecious or metoecious They include the malarial parasite which develops in man and the mosquito and the flukes, some of which develop in a snail and a vertebrate

None of these categories is rigidly distinct In each are included species which normally behave in one way but may adjust their mode of life to meet unusual circumstances, or species whose normal habits are not limited to one or the other type

No phylum of animals is made up entirely of parasitic species, but many members of the phyla **Protozoa, Platyhelminthes, Nemathelminthes,** and **Arthropoda** are parasites, and entire orders of these phyla are composed of parasitic species In many other groups a few parasitic species are known

The habit of depositing eggs in the nests of other animals, practiced by the European **cuckoo** and the **cowbird,** and by some of the **wasps** and **bees,** is also referred to as parasitism (A W L)

PARASITIC PLANTS. Parasitic plants obtain part or all of their food from other living organisms, called hosts Except for the lowest groups of plants, the host of a parasitic plant is another plant The greatest number of parasites are numbered among the **bacteria** and **fungi,** many of which cause diseases of great economic consequence

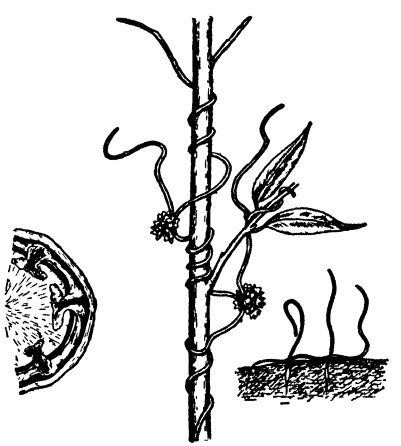
Among flowering plants there are relatively few parasites Of these there are two different types, differing very greatly in appearance One type contains those plants which are only partially parasitic, the other those which are total parasites, depending on the host entirely for their nourishment

In the first group the parasites are green and appear very much like ordinary plants. Indeed, some of them, such as the eyebright, a species of *Euphrasia* of the **Figwort Family,** can live independently, but usually attach their roots to those of other plants and obtain a part of their food requirements from the host Another member of the same family, the common cow wheat (*Melampyrum americanum*) of open woods is less independent Without a host, its growth is stunted To come to maturity and fruit it must find a host Since, like all the other members of this family, it grows where host plants (commonly grasses) are abundant, little difficulty in meeting a host occurs The roots of the parasite fasten to those of the host and send sucking organs, called haustoria, into the host roots From these the parasite draws the water and mineral salts it

needs. It seems to affect the host plant very little. Some members of this family do cause certain changes in the host plant, whose roots are stimulated by the parasite haustoria to become much enlarged, producing knob-like growths In this group of parasites, the principal difference from ordinary non-parasitic plants is a deficiency of roots

Another type of partial parasites, including the various mistletoes, do not grow on the ground, but attach themselves to the branches of trees In these parasites the seeds are usually very sticky and attractive to birds The latter carry them from one tree to another On germinating, the seed forms a structure called an adpressorium, which attaches itself firmly to the branch. Then a hard, penetrating, root-like growth pushes into the wood of the host until it reaches the water-conducting cells. There it may form numerous peg-like growths or branches, which greatly increase the absorbing surface Meanwhile the seed has sent out a normal stem which bears green leaves, and which branches abundantly This plant carries on **photosynthesis** normally, but gains all its water supply and mineral salts from a host plant Often such parasites are mistaken for branches of the host, and again for **epiphytes.** In these plants, no normal root system ever develops

Complete or total parasites are strikingly different They are usually entirely lacking in **chlorophyll,** and so cannot carry on photosynthesis They must obtain from the host plant their food supply, in the form of **carbohydrates** already synthesized by the host Since they do not carry on any photosynthesis, parasites of this group have the leaves reduced to minute scales or frequently entirely lacking Roots also are missing, being replaced by haustoria, the structures which enter the host and absorb nutrients from it.



Dodder, a parasite Middle, habit sketch, right, seedlings of dodder, left, section through stem of host and parasite showing haustoria of dodder reaching the fibro-vascular bundles of host (After Strasburger, Noll, Schenck and Schimper, *Lehrbuch der Botanik,* Gustav Fischer, Jena)

A common parasite, and one widely distributed and often very destructive, is the dodder (species of the genus *Cuscuta*), which parasitizes many crop plants, as well as wild hosts Dodders are twining vines in the same family as the morning glory, to which they are closely related The seed of the dodder germinates and forms a short root which attaches itself firmly to the soil, but does nothing more Then a long slender stem is formed. This swings about in a wide arc until it makes contact with some green plant. Around this the stem of the dodder winds tightly Soon that part between the host and the ground withers and dries, leaving the parasite to grow entirely at the expense of the host This it does very rapidly, pushing a series of haustoria into the stem of the host and absorbing from it all necessary food The mature dodder is a long, slender, much-branched vine The stem is regularly divided into nodes, at which are borne small scale leaves and, when mature, compact clusters of waxy white flowers. The entire plant is yellowish or pinkish and has very little chlorophyll Under favorable conditions a dodder plant will cover an area of many square feet with a tangle of slender branching stems which pass from one host plant to another Common species will attach to many different species of plants as hosts

The broomrapes (species of *Orobanche*) form another group of parasites These attach themselves to the roots of various host plants The parasite is a low-growing plant, lacking chlorophyll, with greatly reduced leaves and small but attractive flowers It is of little importance

In the tropics many species of parasitic flowering plants are found, some of them very striking. In many South American parasitic species the reduction of the plant body has continued until there remains but a short thick stem rising from the host plant's roots, and a mass of flowers, the latter often brilliantly colored. (See **Orchid Family**)

The extreme of reduction of parts occurs in certain parasites of the East Indies and Malayan jungles One species, *Rafflesia Arnoldii*, is worthy of note It grows attached to the spreading roots of species of *Cissus*, forming in them tumorous enlargements From these the flower of the parasite bursts out directly, there being practically no stem and no leaves Reduction of parts has left only the absorbing organs and the reproductive organ The flower is remarkable, being a dark mottled red structure nearly a yard across and possessing a powerful stench of carrion **Pollination** is accomplished by flies, which are attracted by this foul odor Other species of this genus are known, all conspicuous, if not as large, and all showing this same reduction of parts and the marked parasitic habit These parasites are not widely distributed, being necessarily confined to regions where the host plant grows The element of chance in pollination further restricts the range of the plants Parasites of this sort are extremely interesting to study, because of their unusual morphological features (R M W)

PARASPHENOID. A dermal bone supporting the roof of the mouth in fishes and amphibians Also found in the reptiles and birds, while in the mammals it is represented by the vomer (A W L)

PARASYMPATHETIC NERVOUS SYSTEM. Autonomic Nervous System.

PARATHYROID GLANDS. The parathyroid glands, usually four in number, are found on the posterior side of the lobes of the **thyroid gland,** two on a side Accessory glands may be found These glands were not discovered until 1880 by Sandstrom

These glands of internal secretion control the calcium **metabolism** of the body Complete removal results in death with painful spasms, twitching, and convulsions The symptoms are due to overexcitability of the nervous system due to the low concentration of **calcium** in the blood Without proper function of these glands calcium cannot be utilized by the body **Vitamin** D enters into this process acting in some manner with the **hormone** liberated by the parathyroid bodies Collip has described and prepared an extract of these glands which relieves symptoms from hypofunction of the glands

Overactivity of these glands causes a condition known as *Osteitis fibrosa cystica* (Von Recklinghausen's bone disease) In this condition the calcium is withdrawn from the bones into the blood stream. This produces

cystic areas in the bone Often **kidney** stones are formed from the excess of calcium secreted in the **urine** from the blood In this condition tumor formation is found in one of the parathyroid glands. Surgical removal of the involved gland results in clinical cure

Deficiency of the parathyroid hormone results in the condition known as tetany, characterized by spasm of the muscles with pain, due to deficiency of calcium in the blood. Continued deficiency results in defects of the teeth and in cataract formation (R S M)

PARATYPHOID FEVER. Paratyphoid and **typhoid** fevers are distinct and separate diseases Paratyphoid fever, however, is an acute general infection caused by the paratyphoid bacillus A or B having the same clinical signs and symptoms and pathological changes as are seen in typhoid fever The organism is in an intermediate position between *Bacillus typhosus* and *Bacillus Coli*

An attack of, or inoculation against, typhoid fever does not give immunity to paratyphoid fever. Until the World War, paratyphoid was considered a rare disease It was found at that time that not only did the inoculations against typhoid fail to give protection against paratyphoid, but that the disease was far more prevalent than previously believed At present inoculations are given using a triple vaccine which protects against typhoid and paratyphoid A and B.

The sources of infection are the same as of typhoid, as is the manner of contagion The incubation period varies from three to fifteen days Paratyphoid cannot be distinguished from typhoid by clinical signs or symptoms, but only by means of laboratory tests. It is a milder infection than typhoid as a rule, of shorter duration, and with a lower mortality

The complications of paratyphoid are similar to those of typhoid, and the chief causes of death are pneumonia, hemorrhage, and perforation of the intestines (ulcers) (R S M)

PARAZOA. A major division of the animal kingdom containing only the **sponges** (Porifera) In contrast with the one-celled Protozoa on the one hand and the many-celled Metazoa on the other, these animals are made up of many cells, but the cells are organized in tissues only to a limited extent and are not closely coordinated by a nervous system (A W I)

PARENCHYMA. In zoology, this term is commonly used in two ways 1 It designates the essential or functional elements of an organ in contrast to the connective elements or framework 2 Parenchyma also designates a loosely compacted tissue of **mesodermal** origin which fills the space between the viscera and the body wall in flatworms and some roundworms

In botany, parenchyma tissue is the fundamental tissue found in all parts of the plant From parenchyma cells all other kinds of cells are formed A typical parenchyma **cell** is thin-walled and more or less rounded in shape Mutual pressure of many parenchyma cells against one another causes them to become angular. They are generally isodiametric.

Parenchyma cells contain living **cytoplasm** and are potentially capable of dividing to form new cells at any time. In certain parts of the plant parenchyma cells have definite functions For instance, in the growing tips of both stems and roots there are groups of cells which divide rapidly, adding to the length of the stem or root These groups of actively dividing cells make up the meristematic region Many of the parenchyma cells, especially in the outer cortical tissues of stems and in leaves, contain **chloroplastids** and are green. Cells of this kind are called chlorenchyma cells In them **photosynthesis** is carried on In other parenchyma cells food reserves are stored **Carbohydrates** may move through the plant in the parenchyma cells Pith, **rays**, most of the cortex, and leaves (excepting the veins) are composed of parenchyma cells (A W L, R M W)

PARENTHESES. In **algebraic expressions** it is sometimes desirable to group several parts together to indicate that they are to form a single unit of investigation For this purpose, parentheses, ( ), brackets, [ ], braces, { }, and occasionally a vinculum, —, are used

Rules for the removal of parentheses in algebraic expressions are. If a parenthesis is preceded by a plus sign, the parentheses may be removed without any change in the terms within it, if a parenthesis is preceded by a minus sign, the parentheses may be removed if all the signs of the terms within it are changed.

By reversal of these rules, parentheses may be inserted in expressions (L L S)

PARESTHESIA. Any abnormal sensation of the surface of the body It may be described by the patient as burning, tickling, itching, pricking, etc, or he may find the sensation incapable of description The condition is usually a symptom of certain nerve disorders. (R S M.)

PARIETAL. One of the large bones of a pair which form the sides and roof of the human skull, and the smaller bones of similar relations in the skulls of other vertebrates The word is used in a similar descriptive sense to refer to the walls of various organs (A W L)

PARKINSON'S DISEASE. Paralysis agitans.

PARONYCHIA Infection of the tissues surrounding the finger nail The infection commonly follows injury, especially from a "hang nail" Treatment is surgical (R S M)

PAROTID GLAND. Salivary Glands.

PAROTITIS Infection of the **parotid glands** by any infective organisms It may occur as a complication of prolonged fevers, especially after operations or illnesses in the aged and debilitated **Mumps** is a form of parotitis caused by an unknown **virus** and is contagious (R S M)

PARRAQUET. Parrot. Also spelled parakeet, parrakeet, and in various other ways (A W L)

PARROT. Aves, Psittaciformes Birds (**Aves**) with a strong hooked beak and with two toes of the foot directed forward and two back They are represented on all continents except Europe but are confined chiefly to tropical and subtropical areas They eat nuts and other fruits and seeds, although the kea parrot, *Nestor notabilis*, of New Zealand is said to have acquired a taste for mutton

The brilliant colors of many parrots and their ready imitation of human speech have led to their being kept as cage birds for many centuries, hence they are familiar even beyond their natural range

There are many subsidiary forms of parrots. The nestor parrots of New Zealand and the neighboring islands are dark-colored birds, including the kea and the kaka The bad reputation of the former for destroying sheep has recently been denied, hence it is impossible to give accurate information on this point It is a mountain bird Cockatoos are crested species with the hook of the beak transversely ridged below, an Australian species is called the cockatiel. The lories and loriquets are small species of the Australian region Macaws are large brilliantly colored birds of the American tropics with a very large beak and long tail They are sometimes seen in captivity Conures are small species, including the only North American representative of the order, commonly called the Carolina paraquet, *Conuropsis carolinensis* The term paraquet, spelled in various ways, designates many small species of typical parrots of the Oriental and Australian regions Among them are the broadtail, turquoisine, and budgerigar, as well as other species with less striking names

They are closely related to the small parrots so often seen in cages under the name love-birds.

A curious member of the order is the owl-parrot or kakapo of New Zealand, which constitutes a distinct family It is a flightless bird of owl-like appearance, barring its more brilliant colors, and is largely nocturnal in habits (A W L)

PARROT-FISH, PARROT-WRASSE. Pisces, Teleostei Brightly colored marine fishes (**Pisces**) with a prominent beak formed by the partial coalescence of the teeth. They occur in tropical waters, chiefly about coral reefs. (A W L)

PARSEC. The parsec is a unit of distance used for expressing distances between stars and other members of the **sidereal universe** Technically an object is at a distance of one parsec when it has a **stellar parallax** of one inch (one second of arc) or, in other words, one **astronomical unit** would subtend an angle of one second at the distance of one parsec

Expressed in other units of distance·

1 parsec = 3 26 **light years**
= 206265 astronomical units
= $1\ 92 \times 10^{13}$ miles or about twenty millions of millions of miles
= $3\ 08 \times 10^{13}$ kilometers

Within recent years in the discussion of distances between **extra-galactic** objects the parsec is not large enough to be convenient and the terms kiloparsec (1000 parsecs) and even megaparsec (1,000,000 parsecs) have been proposed (W K G)

PARTHENOGENESIS. The development of eggs without **fertilization** In some groups of animals eggs normally develop in this way, either for a series of generations interrupted occasionally by a normal fertilization or as a special part of the reproductive process associated with the development of some young from fertilized eggs The **rotifers** are extensively parthenogenetic In some cases males are not known and it is possible that parthenogenesis has entirely superseded normal sexual reproduction Among the insects plant lice reproduce parthenogenetically for many generations, but in the temperate zones the onset of cold weather is accompanied by the appearance of a sexual generation The honey-bee and other related species carry on parthenogenesis to a limited extent Male or drone honeybees are produced from unfertilized eggs and females, both queens and workers, from eggs which have been fertilized

Artificial parthenogenesis has been induced experimentally by subjecting eggs to varied chemical and mechanical stimuli The eggs of marine invertebrates, such as sea urchins, have been especially favorable subjects, but Loeb, in one of the most famous experiments, produced several frogs from unfertilized eggs by the mechanical stimulus of pricking the egg with a needle (A W L)

PARTIAL DERIVATIVES. Let $u = f(x, y, z, \quad)$ be a **function** of two or more variables. If all the variables except one, say x, are held **constant** and x is given an increment Δx, and if Δu is the corresponding increment of u, and if we form the ratio $\Delta u/\Delta x$ and take the **limit** when $\Delta x \to 0$, then the limit $\lim_{\Delta x \to 0} \left(\frac{\Delta u}{\Delta x}\right)$ is called the partial derivative of u with respect to x, and is denoted by $\frac{\partial u}{\partial x}$ or u_x Similarly, we define the partial derivatives $\frac{\partial u}{\partial y}$, $\frac{\partial u}{\partial z}$, etc.

Partial derivatives of a function of two variables may be given a geometric interpretation as follows If $z = f(x, y)$ represents a **surface**, then $\frac{\partial z}{\partial x}$ represents the **slope** of the curve of intersection of the surface and a plane perpendicular to the Y-axis, and similarly for $\frac{\partial z}{\partial y}$

A change of variable in partial derivatives may be effected as follows Let u be a function of a first set of independent variables $x, y, z, \quad$, let us introduce a second set of variables $r, s, t, \cdots$, related to the first set of variables $x, y, z, \quad$ by explicit or implicit functional relations Then

$$\begin{cases} \frac{\partial u}{\partial r} = \frac{\partial u}{\partial x}\frac{\partial x}{\partial r} + \frac{\partial u}{\partial y}\frac{\partial y}{\partial r} + \frac{\partial u}{\partial z}\frac{\partial z}{\partial r} + \cdots, \\ \frac{\partial u}{\partial s} = \frac{\partial u}{\partial x}\frac{\partial x}{\partial s} + \frac{\partial u}{\partial y}\frac{\partial y}{\partial s} + \frac{\partial u}{\partial z}\frac{\partial z}{\partial s} + \cdots, \\ \frac{\partial u}{\partial t} = \frac{\partial u}{\partial x}\frac{\partial x}{\partial t} + \frac{\partial u}{\partial y}\frac{\partial y}{\partial t} + \frac{\partial u}{\partial t}\frac{\partial t}{\partial y} + \cdots, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \end{cases}$$

the number of equations being the same as the number of variables in the second set and the number of terms on the right in each equation being the same as the number of variables in the first set Also

$$\begin{cases} \frac{\partial u}{\partial x} = \frac{\partial u}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial u}{\partial s}\frac{\partial s}{\partial x} + \frac{\partial u}{\partial t}\frac{\partial t}{\partial x} + \cdots, \\ \frac{\partial u}{\partial y} = \frac{\partial u}{\partial r}\frac{\partial r}{\partial y} + \frac{\partial u}{\partial s}\frac{\partial s}{\partial y} + \frac{\partial u}{\partial t}\frac{\partial t}{\partial y} + \cdots, \\ \cdot \quad \cdot \quad \cdot \quad \cdot \quad \cdot \end{cases}$$

Let $u = f(x, y, z, \cdot \quad)$ be a function of two or more variables, and let $x, y, z, \quad$ be functions of a single independent variable t Then

$$\frac{du}{dt} = \frac{\partial u}{\partial x}\frac{dx}{dt} + \frac{\partial u}{\partial y}\frac{dy}{dt} + \frac{\partial u}{\partial z}\frac{dz}{dt} + \cdots$$

is called the total derivative of u with respect to t

Partial derivatives of higher order are defined thus In general, the partial derivatives $\frac{\partial u}{\partial x}$, $\frac{\partial u}{\partial y}$ of a function $u = f(x, y)$ are themselves functions either of x or of y or of both x and y They may then be differentiated partially with respect to x or y Thus, we get

$$\frac{\partial^2 u}{\partial x^2} = \frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}\right), \qquad \frac{\partial^2 u}{\partial y^2} = \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y}\right),$$
$$\frac{\partial^2 u}{\partial x \partial y} = \frac{\partial}{\partial x}\left(\frac{\partial u}{\partial y}\right), \qquad \frac{\partial^2 u}{\partial y \partial x} = \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial x}\right),$$
$$\frac{\partial^3 u}{\partial x^3} = \frac{\partial}{\partial x}\left(\frac{\partial^2 u}{\partial x^2}\right), \qquad \frac{\partial^3 u}{\partial x \partial y^2} = \frac{\partial}{\partial x}\left(\frac{\partial^2 u}{\partial y^2}\right), \text{ etc.}$$

Frequently the notation u_{xx} is used for $\frac{\partial^2 u}{\partial x^2}$, u_{xy} for $\frac{\partial^2 u}{\partial x \partial y}$, etc

For functions having continuous first partial derivatives,

$$\frac{\partial^2 u}{\partial x \partial y} = \frac{\partial^2 u}{\partial y \partial x} \quad \text{or} \quad u_{xy} = u_{yx} \qquad \text{(L L S)}$$

PARTIAL DIFFERENTIAL EQUATIONS. A partial differential equation is an **equation** which involves **partial derivatives**, it therefore involves an unknown function of two or more independent variables A solution of such an equation is a relation among the variables, dependent and independent, that satisfies the equation

In general the solution of a partial differential equation involves arbitrary functions, just as the solution of an ordinary differential equation involves arbitrary constants

The problem of solving partial differential equations is inherently more difficult than that of solving ordinary differential equations, so no further indication of methods of solution can be given here (L L S)

PARTIAL DIFFERENTIATION. Partial Derivatives.

PARTIAL FRACTIONS. When a given rational fraction is resolved into a sum of simpler fractions, usually with linear and quadratic denominators, the resulting fractions are often called partial fractions

The following fundamental theorem lies at the basis of the method of partial fractions·

Any rational proper fraction with real coefficients may be resolved into a set of partial fractions, of the following types

(1) To any linear factor, as $ax + b$, occurring once in the denominator of the given fraction, there corresponds a single partial fraction of the form $\frac{A}{ax + b}$, where A is a constant,

(2) To any linear factor, as $ax + b$, occurring r times in the denominator, there corresponds a set of r partial fractions of the form

$$\frac{A_1}{ax + b} + \frac{A_2}{(ax + b)^2} + \cdots + \frac{A_r}{(ax + b)^r},$$

where $A_1, \cdots, A_r$ are constants,

(3) To any quadratic factor, as $ax^2 + bx + c$, occurring once in the denominator, there corresponds a single partial fraction of the form $\frac{Ax + B}{ax^2 + bx + c}$, where A and B are constants,

(4) To any quadratic factor, as $ax^2 + bx + c$, occurring r times in the denominator, there corresponds a set of r partial fractions of the form

$$\frac{A_1x + B_1}{ax^2 + bx + c} + \frac{A_2x + B_2}{(ax^2 + bx + c)^2} + \cdots + \frac{A_rx + B_r}{(ax^2 + bx + c)^r},$$

where $A_1, B_1, \cdots, A_r, B_r$ are constants

The undetermined coefficients in these assumed forms of partial fractions may be found by clearing of fractions and equating coefficients of like powers of x on both sides of the equality, which is an **identity** in x, or by other special devices, such as substituting special values of x (L L S)

PARTICULAR SOLUTIONS OF A DIFFERENTIAL EQUATION. Ordinary Differential Equations.

PARTRIDGE. Aves, Galliformes Game birds (**Aves**) of numerous species, related to the pheasants and turkeys The francolins of Asia and Africa are included here True partridges are similar to the **quails** The latter, although more generally known in North America by the name quail, are members of the group They are found over Europe, Asia, Africa, and North America Aside from the common quail or bob-white of North America, the names quail and partridge are both applied to the several western species, and in the southern states even the bob-white becomes the partridge To confuse the term still further the ruffed **grouse** is often called a partridge in the northern states (A W L)

PARTURITION The process of **labor** or the act of giving birth to a child (R S M)

PASCAL'S LAW. Hydrostatics.

PASCAL'S TRIANGLE. Binomial Formula.

PASCHEN-BACK EFFECT. Zeeman Effect.

PASSERES, PASSERIFORMES. The largest order of birds, containing many families and several thousand species. All of the common songbirds belong here, including such familiar forms as **sparrows, warblers, wrens, thrushes,** and similar forms (A W L)

PASSION FLOWERS. *Passiflora* sp Passifloraceae The passion flowers are mostly tropical American plants which climb by means of axillary **tendrils** The leaves are of various shapes, sometimes varying greatly on a single plant. The flowers are borne singly or in small cymes in the **axils** of the leaves, and are of a variety of colors, some species having white flowers, others blue, and still others scarlet The five **sepals** are borne on the margin of a cup-like receptacle, as are the five **petals** and the corona, an outgrowth from the receptacle, which in many species is cut into numerous slender segments colored like petals Five **stamens** are borne at the base of the ovary, these bend outward over the corona The fruit is a **berry,** in which the seeds are surrounded by a fleshy **aril** Many species of passion flower are extensively grown for their curiously beautiful flowers In tropical America the edible fruits appear on the market (R M W)

PASSIVITY. When **iron** is immersed in **nitric acid** concentrated, there is no visible reaction (Keir, 1790), although nitric acid dilute results in a marked reaction with iron Upon removal of the iron from the nitric acid concentrated and immersion in **copper** sulfate solution, the iron is not plated by copper, although this occurs with ordinary iron Iron in such a condition is described as passive iron and the phenomenon is known as passivity

Passivity of iron is produced by other means than the use of nitric acid concentrated, for example, (1) by immersion in solutions of **chromic acid, iodic acid, arsenic acid, potassium** permanganate, potassium dichromate, **lead** nitrate, **hydrogen peroxide,** (2) by anodic oxidation in sulfuric acid **electrolyte** Other metals than iron are subject to passivity by anodic oxidation, e g, **cobalt, nickel, aluminum** In sulfuric acid dilute aluminum as **anode** withstands 25 volts, and in ammonium borate solution 500 volts Reversal of the current permits the current to pass, thus aluminum may serve as a rectifier of alternating current in a suitably constructed cell

Formation of a thin film of oxide on the surface of the metal was proposed as the explanation for the behavior (Schonbein, 1836) Passivity is readily removed by immersion in a non-oxidizing acid such as **hydrochloric acid,** or by heating in an atmosphere of **hydrogen** Passive iron shows the **photoelectric effect** less than ordinary iron (Allen, 1914), thus indicating a change of surface in the former (R K S)

PATCHOULI. Mint Family.

PATELLA. 1 A short segment of the jointed leg of **spiders** and related forms, between the **femur** and **tibia** 2 The kneecap of man and the corresponding bone of other vertebrates (A W L)

PATENT. A United States patent grant gives the inventor the right to exclude all others from making, using, or selling his invention for the term of 17 years, but it does not give the patentee the right to make, use, and sell his own invention if it is an improvement on some unexpired patent whose claims are infringed thereby The Patent Office in its investigation preceding the issue of a patent does not consider whether the invention infringes prior patents

A patent is granted only upon a regularly filed application, complete in all respects, upon payment of the fees, and only after a determination of utility and completeness of disclosure of the invention, and a search to determine its novelty

No patent is granted upon a mere idea or a suggestion.

There must be a complete description of the invention and it must be accompanied by drawings suitably illustrating the same, if it is of a machine or other device that can be illustrated If the device is not operative and not so clearly set forth as to make it capable of manufacture from the description, no patent can issue

An application for patent must be made by the inventor *only,* and no person who has not actually created a portion of the invention is entitled to be considered a joint inventor. A patent issued to more than one

inventor where only one has actually invented the device is invalid. A person who makes a financial contribution merely is not a joint inventor, but the invention may be assigned to him

Patents are not granted for useless devices, for printed matter, for methods of doing business, for improvements in devices which are the result of mere mechanical skill, nor for machines that will not operate, particularly for alleged perpetual motion machines.

A patent is not granted for a new composition of matter unless the component parts thereof, as well as the manner of making and using the same, are fully disclosed in the application when filed

No protection is afforded by the Patent Law prior to the actual issue of a patent The terms "Patent applied for" and "Patent pending" have no effect in law but give information that an application has been filed

Once a patent has been issued it is out of the jurisdiction of the Patent Office, and, therefore, the office is not concerned with questions of infringement, the scope of a patent, or any other questions that arise out of the grant These matters are within the jurisdiction of United States District Courts

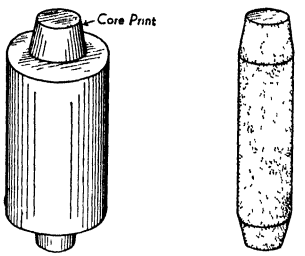
Protection of the Patent Law extends throughout continental United States, Alaska, Hawaii, and the Canal Zone, and, upon compliance with certain regulations, to Porto Rico, the Philippine Islands, the Virgin Isles, and Guam (F T M)

PATHOGENIC. That which causes disease or disorder of the body or its functions (R S M)

PATHOLOGY That branch of medicine which is concerned with the structural and functional changes caused by disease and abnormal functions of the body (R S M)

PATTERN. An object which serves as a guide or useful aid in the construction of some part is a pattern For example, patterns are used in the sheet metal trade from which to lay out shapes which will later be cut and fabricated A pattern could also be a **gage** or templet used to guide machine operations However, usually one thinks of patterns as associated with the foundry trade Here the word alludes to a full-scale model of the desired casting, which is constructed of wood because of the relative ease of working that material into the desired shape The pattern is placed in the "flask" and molding sand is rammed around it The flask is then separated along the parting line and the pattern withdrawn, leaving a hollow exactly the same shape as the pattern, the walls of which are of a material which will withstand the action of molten metal The molten metal is introduced into this hollow, and completely fills it Upon solidification there will be found a casting the shape of the pattern, but of metal Pattern making is wood working of a very specialized type, and the pattern maker must understand the operation of molding in all its various ramifications, else the molder would not be able successfully to mold his pattern The accuracy of the wood workmanship which goes into pattern making may have to be very great in some cases, while in other cases a great deal of tolerance may be permitted in the wood construction The difference between these two cases is explained by the fact that some casts are used as they come from the mold, while others are expected to be machined to a finished size The pattern must be larger than the finished casting by an amount equal to the shrinkage of the metal upon solidification Pattern makers take their dimensions from shrinkage rules, which automatically allow for this shrinkage by swelling the pattern For example, a 2-foot shrinkage rule for metal which has a shrinkage rate of ⅛ inch per foot, would actually be 24¼ inches long This rule must not be used for both iron and brass, as these metals shrink at different rates.

The pattern must have draft, that is, the sides which are parallel with the direction in which the pattern is withdrawn from the mold should be tapered slightly so that the initial movement will completely free the pattern from the sand Complicated castings often require that the pattern be made in several pieces, otherwise it might not be possible to withdraw the pattern from the sand If a casting is to have internal holes which will



Pattern and core for a hollow cylinder.

be difficult to build into the pattern, they may be made with a solid pattern by inserting in the mold, after the pattern is withdrawn, preformed baked sand cores The cores are supported in prints left in the sand by core prints which are part of the pattern, but which are not duplicated in the casting A pattern is finished with shellac or varnish to prevent its being swelled or warped by the moisture in the sand, and has screwed to it a draw plate The draw plate has a threaded hole in which the molder screws a draw screw which serves as a handle when lifting a flush pattern from the mold (F T M)

PAUROMETABOLA. A division of the insects characterized by gradual metamorphosis The insect hatches from the egg in a form resembling the adult and adapted for the same mode of life It is called a nymph As growth proceeds the nymphs of winged species acquire rudimentary wings in the form of small external flaps, which increase in size with each moult and become fully formed wings at the last transformation

The **cicadas** are in an order of this group but they differ from most of the other forms in having nymphs adapted for life under ground and consequently less like the adults than is usual

The group includes the orders **Orthoptera, Isoptera, Corrodentia, Dermaptera, Thysanoptera, Hemiptera,** and **Homoptera** (A W L)

PAUROPODA Minute animals related to the centipedes and millipedes Usually regarded as a distinct class of the phylum **Arthropoda** They resemble millipedes in having the segments of the body fused in pairs above but the legs are not grouped two pairs together They have a distinct head and body, branched antennae, and no eyes The body consists of twelve segments

Pauropods live in damp places under debris on the surface of the ground They have been recorded from Europe and the Americas (A W L)

PAVEMENT. **Highways.**

PAXILLA. A modified spine of starfishes A thick process bearing small spines at the end (A W L)

PEACH. **Rose Family.**

PEACH-TREE BORER. Insecta, Lepidoptera *Synanthedon* Any of three species of **moths** whose **larvae** burrow in the sapwood and inner bark of peach trees, sometimes killing younger trees The moths belong to the family Aegerudae, characterized by the long body and narrow wings, more or less free from scales All three species attack other fruits as well as peaches.

The larvae of all species are destroyed by digging them out of their burrows and by burning badly infested boughs or entire trees The common species is also treated by placing a ring of paradichlorobenzene (See under **Chlorine**) on the surface of the ground about two inches from the trunk and covering it with earth It should be left four to six weeks and should be applied on dates ranging from early September in New York to the middle of October in Georgia The treatment is not recommended for trees younger than three years, and for those up to six years not more than three-quarters of an ounce of the material should be used (A W L)

PEACH-TWIG BORER Insecta, Lepidoptera The **larva** of a small **moth**, *Anarsia lineatella*, which bores in the young twigs and fruit of peaches and other fruit trees It is an important pest, chiefly in the western states, where various spraying programs have been found effective in controlling it (A W L)

PEA FAMILY. Leguminosae The Pea Family is second only to the **Composite Family** among the **dicotyledons**, with respect to the number of species it includes Of its more than 10,000 species in nearly 500 genera, many are trees or shrubs, especially those in tropical regions Herbaceous species are numerous in temperate regions Many climbing plants, also, are found in the family Leguminous plants are found in all sorts of environments and climates

Nearly all the plants in this family have **pinnately** compound leaves The **stipules** present in the leaves are sometimes modified to persistent **spines** The flowers are either regular or irregular When regular, the flowers have five **sepals**, commonly more or less united, five **petals**, a varying number of **stamens** and a single **pistil** Irregular flowers are of the type known as papilionaceous, a name given because of the fancied resemblance of the flower to a butterfly In flowers of this type the **calyx** has five unequal, more or less united sepals, which frequently persist during development of the fruit, five separate petals, showing very constant difference in form The upper one, called the standard, is large and showy, the two lateral to this, called wings, are smaller in size, and the two lower ones are more or less united into one unit, called the keel or carina Within this keel are the ten **stamens**, which may be separate but in many genera are united in groups, the nine lower ones having their filaments more or less completely joined, while the tenth stamen remains free The pistil has a somewhat flattened **ovary**, a long **style**, and a terminal **stigma** The ovary contains several **ovules** The mature fruit is called a pod or legume, which when mature often splits open with sufficient force to eject the seeds to considerable distances The seeds in most cases have large food reserves stored in the thick cotyledons

There are three subfamilies in the Leguminoseae The Mimosoideae have regular flowers and valvate **corolla** The Caesalpinioideae have irregular (zygomorphic) flowers These two subfamilies are essentially tropical The Papilionatae have irregular (papilionaceous) flowers, and include most of the important cultivated forms

Many members of this family supply man with important foodstuffs, such as **beans**, peas, and **peanuts**, while others are important forage crops for domestic animals. The high **protein** content of the plant is the principal reason for its importance as a food source Clovers and **alfalfa** are not only valuable as forage plants, but furnish an excellent hay Legumes are also of immense value because of their association with nodule-forming **bacteria**, resulting in a considerable accumulation of nitrogenous substance, which is later liberated into the soil, greatly enriching it Other members of the family yield valuable **dyes**, **gums** and **resins**, and **oils**; many are sources of timber

The leaves of many genera of legumes are interesting because of their ability to move In many of them the leaflets fold together at night, so that the blade of the leaflet is vertical Of particular interest in this connection is the Sensitive plant, *Mimosa pudica*, the leaves of which respond very quickly to external stimuli A light blow will cause the many leaflets to fold together, and the whole section of the compound leaf to bend down A sudden breeze or change of temperature will produce the same result Recovery from the shock is gradual When stimulated by a series of successive shocks, the plant recovers more and more slowly each time. (R M W)

PEAFOWL, PEACOCK. Aves, Galliformes *Pavo.* Large birds (**Aves**) of the Oriental region, related to the pheasants and Guinea fowls They are beautifully colored and the males have gorgeous tail feathers They are kept to a limited extent as ornamental birds for the garden but are scarcely to be regarded as domesticated Several species are known (A W L)

PEANUT. *Arachis hypogaea* Leguminosae A native legume of South America which is now widely cultivated in warm climates throughout the world The plant is a bushy annual with pinnately compound leaves and rather showy yellow flowers After fertilization, the flower stalk elongates greatly and bends downward so that the ovary is pushed into the ground There it develops into the familiar peanut with its two or more seeds The total peanut crop harvested in the United States in 1932 was over a billion pounds Much of the crop is roasted in the shell and so marketed Large quantities are ground for peanut butter, or crushed for peanut oil (R M W)

PEAR. **Rose Family.**

PEARL A gem formed by **bivalve mollusks**, particularly by several marine species known as pearl oysters Pearls are formed as a protection against the irritation caused by foreign objects, either parasites or bits of gravel, which lodge inside the shell A fold of soft tissue envelops the foreign particle and deposits layer after layer of nacre on it, similar to the mother-of-pearl lining the shell

Pearl oysters occur in all of the tropical seas, but the ancient center of pearl fishing is at Ceylon Pearls of considerable value are also taken from the fresh-water **mussels** caught for the button industry in the Mississippi River system A large majority of fresh-water pearls, however, are poorly shaped or of undesirable color, and many are too small to be of much value (A W L)

PEAT. **Coal.**

PEAT MOSS. **Bryophytes.**

PEA WEEVIL. Insecta, Coleoptera A **beetle** which attacks growing peas in the pod The most effective control measures are to avoid planting infested seed or to fumigate it with **carbon disulfide** before planting (A W.L)

PEBA. Mammalia, Edentata The nine-banded **armadillo**, *Dasypus novemcinctus*, found from southern Texas and New Mexico to Argentina (A W L)

PECCARY. Mammalia, Artiodactyla Animals of two species related to the Old World swine but differing in the three-toed hind feet and in other anatomical features. The collared peccary or muskhog, *Dicotyles tajaca*, ranges from the southwestern United States to southern South America, and the white-lipped peccary, *D labiatus*, is found only from British Honduras to Paraguay The latter species is gregarious, living in bands of large size Its vicious nature makes it dangerous to encounter, although a single animal is too small to trouble a human being The collared peccary lives singly or in small groups and is inoffensive (A W.L.)

PECORA. An obsolete term for the group of hoofed animals known as **ruminants.** (A.W.L.)

PECTINE. A comblike organ of a pair found on the under surface of the second abdominal segment of **scorpions.** They are supposed to be accessory organs of reproduction. (A.W.L.)

PEDIATRICS. That branch of medicine which is concerned with the prevention, diagnosis, and treatment of the diseases and disorders of children. (R.S.M.)

PEDICELLARIA. Minute pinchers on the surface of starfishes (**Asteroidea**). Pedicellariae are modified spines formed with two or more apposed jaws. They may be stalked or **sessile** and may have the jaws crossed like the blades of scissors or merely in contact. They vary greatly in form in different species. (A.W.L.)

PEDIPALPI. The **whip scorpions,** an order of **Arachnida.**

PEDUNCLE. A stalk, either of an organ or of an entire animal. The stalks by which **brachiopods, crinoids,** and similar **sessile** animals are attached to the supporting surface are peduncles. For the use of this term in botany, see **Flower.** (A.W.L.)

PEEWIT. Aves, Charadriiformes. 1. The black-headed **gull,** *Larus ridibundus.* 2. The common European **lapwing,** *Vanellus vanellus,* a bird related to the plovers. (A.W.L.)

PEGMATITE. The term pegmatite, derived from the Greek word meaning joined together, was first applied by Haüy in 1822 to a peculiar interpenetrating growth of **quartz** and **feldspar** sometimes called graphic granite from its resemblance to written characters, particularly those of the Hebrew language. Pegmatite is also used to designate those coarse-grained dikes and sheets, chiefly of **granite** or syenite, that are apophyses of **stocks** or **batholiths,** or of the residual magma, during their congealation. The individual minerals may often reach great size. Granite pegmatites are chiefly composed of alkali **feldspar** and quartz with some **muscovite** or **biotite,** but may carry such minerals as **tourmaline, topaz, beryl, fluorite, apatite, garnet, lepidolite,** etc.

The general characters of pegmatite **dikes** suggest that they are the solidified products of the residue of the **magma** which is rich in volatile matter and water vapor, and because of the abundance of **mineralizers,** remain liquid at relatively low temperature. These physical-chemical conditions permit the maximum opportunity for the growth of large crystals. (R.M.F.)

PEKAN. **Marten.**

PEKING MAN. **Paleontology of Man.**

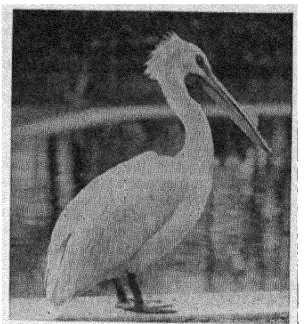
PELAGIC. Living in the water independent of the bottom and shores. The word applies to both the **plankton** and the **nekton.** It is usually applied only to marine animals but is used to some extent for freshwater forms. (A.W.L.)

PELECANIFORMES. The **pelicans, cormorants, gannets,** and related birds. An order made up of swimming and wading species, many with long necks and legs. (A.W.L.)

PELECYPODA. **Lamellibranchiata.** The name Pelecypoda for the bivalve mollusks is now widely used but according to the rules of nomenclature the older name, Lamellibranchiata, should be retained. (A.W.L.)

PELE'S HAIR. A fibrous basic, natural glass (**tachylite**). The congealed liquid lava blown out of volcanoes. Type locality, the Hawaiian Islands. (R.M.F.)

PELICAN. Aves, Pelecaniformes. Widely distributed birds (**Aves**) of few species. They are large with long necks, short legs, and webbed toes. The beak is very



Pelican. (Courtesy of E. R. Sanborn and *N. Y. Zool. Society.*)

long and the lower mandible bears a flexible pouch which can be distended to accommodate a large amount of food. They live principally on fish but also eat other aquatic animals.

The common pelican of North America, *Pelecanus erythrorhynchos,* is chiefly white with orange beak and feet during the breeding season. It frequents inland waters. (A.W.L.)

PELITE. The general term proposed by Naumann for **argillaceous** sediments containing minute fragments of quartz. Principally used as a textural term, especially when applied to fine-grained volcanic ashes, or **tuff.** Compare and contrast with **bentonite.** (R.M.F.)

PELLAGRA. A deficiency disease resulting from lack of **Vitamin B_2** or G. This disease was first described by Gaspar Casal in 1735. It is a common disease in Europe, Egypt, and in Central America, and is sometimes seen in the southern portion of the United States. The largest outbreak in this country was between 1907–1915 and resulted in a large mortality. The disease occurs mostly among the poorer classes.

This disease is due to a restricted diet and lack of vitamin G. Those afflicted are accustomed to a vegetable diet low in **protein** and made up largely of **carbohydrates.** It will not affect individuals who partake of a varied diet.

A condition similar to pellagra develops in **alcoholics** who substitute alcohol for a large portion of their diet. What food they do eat is usually of a carbohydrate nature, with only a small portion of protein.

The symptoms of the disease appear gradually and affect primarily three of the bodily systems, the skin, digestive tract, and nervous system.

The skin on the neck, hands, and feet becomes dark, raw and scaly, and eventually becomes red with a lifeless scarred appearance. There is diarrhea and the mouth is sore and ulcerated. **Hydrochloric acid** is frequently absent from the stomach.

The symptoms referable to the nervous system are depression, tremor, muscular cramps, and, in marked cases, weakness and paralysis. Mental symptoms are common in the severe form of the disease, and consist of confusion, hallucinations, illusions, and even dementia.

The treatment of pellagra is the same as of **beri-beri** and is similar to that of **pernicious anemia.** Liver injections and eating of a varied diet, especially those **foods** rich in vitamin G, as yeast, peas, beans, milk, eggs, meats, and whole-grain cereals, are curative. (R.S.M.)

PELORUS. The pelorous, or "dumb compass," is an instrument used on board ship for taking bearings of external objects. It consists fundamentally of a circular plate, heavily ballasted and mounted in gymbals. This plate has two pairs of indicators, one pair parallel to the keel of the ship and the other perpendicular to the keel. Concentric with the circular plate, and capable of being rotated independently of each other about a vertical axis, are a graduated dial plate and an alidade or arm for reading angles. The dial plate is graduated in a manner similar to the **compass card** and may be clamped to the circular plate in any desired position. The alidade carries sighting vanes and the line through these vanes passes through the axis of rotation of the instrument carrying indicators at each end which may be read on the dial plate.

The instrument may be used to eliminate **compass errors** from bearings by setting the dial circle relative to the keel indicators on the circular plate so that they give the true course. The external object is then lined up through the sighting vanes on the alidade and the indicator on the alidade will give the true bearing as read on the dial plate. (W.K.G.)

PELUDO. Mammalia, Edentata. The hairy **armadillo** of Argentina, *Tatu pilosa.* (A.W.L.)

PELVIS. Literally, a basin. Commonly applied to the bony pelvis of man, which is a compact pelvic girdle comparable to that of vertebrates generally (**skeletal system**). The human pelvis is properly the basin-like abdominal cavity containing the **viscera**, supported by the bony pelvis, which is composed of the hip bones on either side, and in front, and the **sacrum** and **coccyx**. The pelvis rests upon the lower extremities, and supports the spinal column. Within the pelvis are found the rectum, bladder and generative organs. There are certain sexual differences in the pelvis. The female pelvis is lighter, more slender, with a cavity that is larger, less funnel-shaped, and shorter. When the female pelvis resembles the male type or is deformed by bony disease such as rickets, childbirth is interfered with and either made difficult or impossible by the vaginal route.

The pelvis of the **kidney** is the principal cavity, which receives the urine from all subordinate divisions and discharges it to the **ureter.** (A.W.L., R.S.M.)

PEN. An internal horny plate found in the **squids.** It is a vestige of a portion of the shell, which was well developed in related **cephalopod** mollusks that are now extinct. (A.W.L.)

PENCIL STONE. Pyrophyllite.

PENDULUMS. We shall here consider only gravity pendulums, leaving **torsion pendulums** and **magnetic pendulums** to be discussed separately. Let a rigid body of mass M swing on an axis which is located at distance r above its center of mass, and with respect to which axis the **moment of inertia** of the body is I. This motion is mathematically not simple, but if the amplitude of swing is small, certain terms in the differential equation of motion may be disregarded and the remaining equation readily solved. The solution gives as the period of the complete oscillation

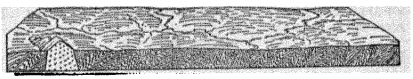
$$T = 2\pi\sqrt{\frac{I}{Mgr}},$$

in which g is the acceleration of a freely falling body. Huygens found experimentally, what may be proved theoretically, that for any given period of oscillation greater than a certain minimum there are two different distances r for which I/r, and hence T, has the same value. If these two distances are laid off on opposite sides of the center of mass, the two points resulting are "conjugate points" (center of suspension and center of oscillation). Denoting the whole distance between these points by l, the period of swing when the pendulum is suspended at either of them is

$$T = 2\pi\sqrt{\frac{l}{g}}.$$

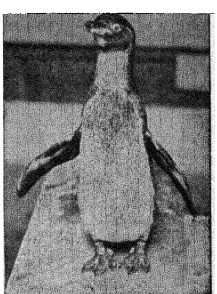
This is the same as the period for an "ideal simple pendulum," i.e., a single particle of mass m suspended by a weightless thread of length l, for which $r = l$, and $I = ml^2$. Kater utilized this principle in his well known reversible pendulum (See **Kater's Pendulum**). It was Huygens who first adapted the pendulum to regulate a mechanism for keeping time and thereby gave us the clock. (L.D.W.)

PENEPLAIN. Meaning nearly a plain. A physiographic term implying a broad flat erosional surface which has been finally developed regardless of the structure, relative hardness, and solubility of the rocks of the region. In the case of widespread **unconformities** the plain of **erosion** which truncates the subjacent deformed rocks and underlies the superjacent formations is an ancient peneplain. Local topographic features which rise above the peneplain are called monadnocks, after the type, Mt. Monadnock, in New England. (R.M.F.)



Block diagram showing a peneplain [illegible] by a monadnock of more resistant rock. (After W. M. Davis.)

PENGUIN. Aves, Sphenisciformes. Flightless marine birds (**Aves**) of the south temperate zone and the Antarctic. They have short legs, webbed toes, and paddle-like wings which are used in swimming. The beak is strong. On land the penguins walk in an erect position with a curiously human air. They swim and dive with exceptional skill and eat fish almost exclusively. The King Penguin is *Aptenodytes longirostris.* (A.W.L.)



Galapagos penguin.
(Courtesy of *N. Y. Zool. Soc.*)

PENICILLIUM. Ascomycetes.

PENIS. A projecting, protrusible, or erectile organ of the male animal, used in the act of **copulation** to introduce the seminal fluid into the genital passages of the female.

In the insects the organ is a fleshy duct enclosed in a chitinous sheath called the oedeagus. In the vertebrates it develops as a fold in the wall of the cloaca and may be no more than a grooved protuberance of this simple origin. The penis of mammals, however, is a complex organ formed by the union of two external folds of tissue. The space between is enclosed as a continuation of the **urethra** and serves as a common duct for the **excretory** and **reproductive systems.** The organ is composed of soft tissue, including some erectile tissue, in three cylindrical bodies. This tissue becomes engorged with blood under certain stimuli and makes the entire organ rigid. When relaxed the terminal portion of the penis is retracted into an enveloping fold of skin called the prepuce, or foreskin.

Special intromittent organs of all animals are known by this name but they are not at all uniform in origin in the different phyla. (A.W.L.)

PENNSYLVANIAN PERIOD. A period of the **Paleozoic** era A systemic term first proposed by H S Williams in 1891. Type locality, Pennsylvania The period began about 250,000,000 years ago The term Pennsylvanian is roughly equivalent to the more general term Upper **Carboniferous** In Britain this system is referred to as the Coal Measures During this period there were many oscillations of sea level with relatively rapid alternations of marine and terrestrial sediments and fresh-water swamp deposits in which were formed important **coal** beds The principal occurrence of the formations of this system are in the Allegheny Plateau region of the eastern United States, westward to the Ohio River There is an abundance of plant fossils, including the non-flowering plants *Calamites, Equisetum* ("horse tails"), and the progenitors of the modern **ferns** These earliest known "forests" harbored the earliest known **insects** and **spiders** The oldest known **amphibians** inhabited the swamps and lowlands Among the marine life, the highest order appears to be the ancestors of the modern **sharks** As in the case of the **Mississippian** formations, the essentially terrestrial, **clastic** sediments of eastern North America grade westward into marine **limestone** deposits, which in turn grade upward into sediments of **Permian** Age The principal marine invertebrate fossils are **brachiopods** (especially the genus *Productus*), **pelecypods**, and **cephalopods** (including **nautiloids**, **goniatites**, **ceratites**, and **ammonites**) **Foraminifera**, especially the genus *Fusilina*, were also common Mountain building began in Europe in early Pennsylvanian time, accompanied with great volcanic activity In eastern North America these deformative movements culminated, in the late Pennsylvanian and early Permian time, in the folding and uplift of the Paleozoic formations of the **Appalachian Geosyncline** (R M F)

PENNYROYAL. Mint Family.

PENSTOCK. Some considerable surface distance usually separates the intake works and **turbines** in a medium or high head hydro-electric project Even where an open **canal** is employed to carry the water from the forebay of a diversion **dam** to intake works located near the plant, there is still a considerable span to be bridged by a closed water conduit of the pressure type This water conduit is called the penstock, and is always circular in form because that shape is best adapted to withstand internal pressure There are many engineering problems, both hydraulic and mechanical, to be met and solved in connection with these penstocks The hydraulic problems of water hammer and surging are chiefly the result of the inherent momentum of large, rapidly moving masses of water, the mechanical problems are the result of large sizes and weights of pipes used for penstocks, the rugged profiles over which they are laid, and the necessity of making many joints which will be water-tight under high pressure Penstocks are constructed from wood stave pipe, reinforced concrete, welded and riveted steel pipe, and banded steel pipe, the latter used only for the lower sections of very high-head developments The penstock may be either buried, partially exposed, or completely exposed If completely exposed, it rests on concrete or timber saddles The trend of present practice is toward the use of exposed penstocks because of their greater accessibility and longer life Exposed pipe is more liable to have ice form in it in the winter, and it also is subjected to larger temperature variation, making it absolutely necessary to provide expansion joints

It is common practice in this country to proportion the penstock so that the sum of the value of energy lost annually in penstock friction and the annual fixed and operating costs of the pipe line is a minimum When all the required data are obtainable this does not prove to be a difficult problem

Penstocks are commonly designed to meet the stress put upon them by designing for the static head, allowing for dynamic conditions by using a factor of safety of two on the elastic limit of the steel used In other cases it has been the static head plus water hammer introduced by rapid closing of the turbine gates.

Valves to stop the flow of water are always installed in a penstock at its upper end High-head plants have a valve at the lower end also so that water can be shut off from the turbine in less time than it would take to close the upper valve and drain the penstock The penstock valve will stop the flow of water if a failure is experienced by either the penstock or the turbine, and it also serves to unwater the turbine for inspection and repair. (F T M)

PENTADACTYL APPENDAGE. The form of **vertebrate** appendage which is regarded as the fundamental terrestrial limb, from which all of the specialized appendages of animals above the fishes have been derived

The two pairs of vertebrate limbs, pectoral and pelvic, are similar in structure and both are attached to the girdles of corresponding name (**skeletal system**) Each girdle consists, in the primitive state, of three pairs of bones meeting at the articulation of the limbs On each side of the body one bone extends toward the back and two toward the middle of the body below. The skeletal structure of the limbs includes a single bone in the segment next to the body, followed by two bones. Then follows a group of small bones, and last five divergent series of moderately long bones which extend into the digits Of the more constant bones in the pectoral girdle of vertebrates with limbs, the dorsal bone is the scapula and the two ventral are an anterior clavicle (of dermal origin) and a posterior coracoid This girdle may contain a procoracoid between the last two bones The bones of the pectoral appendage are, in the order described above, the humerus, the ulna and radius, the carpals, the five metacarpals of the hand and the five series of phalanges in the digits In the pelvic girdle of vertebrates with limbs the dorsal bone is the ilium and the two ventral are an anterior pubis and a posterior ischium The bones of the appendage are the femur, the tibia and fibula, the tarsals, the metatarsals and the phalanges

Specialized appendages such as the wings of birds, flippers of marine mammals, and the legs of the hoofed species, show either a simplification or a slight increase in complexity of the skeletal system and in some cases a consolidation by webbing of the digits or a still more compact fleshy union between them In all of these cases, however, the basic pentadactyl structure is still present (A W L)

PENTASTOMIDA. Wormlike **arthropods** of a few parasitic species, sometimes regarded as an order of the class **Arachnida** but more often as a distinct class The known species live in the **respiratory system** or body cavity of reptiles and mammals. Also called Linguatulida

The adult has an unsegmented anterior region bearing two pairs of claws and a segmented body whose subdivisions are not metameric The **larvae** resemble certain mites They are shorter than the adults and their claws are borne at the ends of leglike prominences (A W L)

PENTLANDITE. The mineral **sulfide** of **iron** and **nickel** corresponding to the formula (Fe,Ni)S It is **isometric**, appears in granular masses, hardness, 3 5–4, specific gravity, 5 0; color, bronze yellow Opaque Occurs with **pyrrhotite, millerite, niccolite,** etc The best known deposit of **pentlandite** is at Sudbury, Ontario, Canada, where it is associated with a nickel-bearing **pyrrhotite.** (E S C S)

PENTOSANS. Carbohydrates.

PENTOSES. Carbohydrates.

PENTRAMITES. Invertebrate Paleontology.

PEPPER. *Piper nigrum* Piperaceae The pepper plant, *Piper nigrum,* is a woody climbing shrub, which is indigenous in India It is aided in climbing by the **adventitious roots** which are formed at the nodes The ovate leaves are evergreen. The flowers are minute, without petals, and borne in slender **spikes.** The **fruit** is a bright red berry less than a quarter of an inch in diameter Each berry contains a single seed On drying the **pericarp** becomes black and wrinkled

The berries are gathered before they are ripe and dried, usually by the sun The dried berries are separated from the stem and ground, producing black pepper. If the pericarp is removed from the berry, leaving the seed and **endocarp,** the ground product is known as white pepper The pericarp may be removed by using mature berries and soaking them to soften the pericarp Or machines may rub off the dried pericarp, a method used in western countries Pepper is one of the most extensively used of all spices White pepper is less pungent than black, and hence not so conspicuous when used in cooking Pepper is grown mostly in British India and in the Malaysian regions Propagation is usually by cuttings, which begin to fruit within four or five years, after which they bear continuously but somewhat irregularly for many years

Related to *Piper nigrum* is *Piper Betle,* a perennial creeping vine native to Java, but widely grown in tropical Asia From its leaves is prepared a chew with the nut of the **Areca** palm *Piper Cubeba* is another species, also native of Java and the Molucca Islands, which yields a volatile oil which is used medicinally and even in some brands of cigarettes

See also Capsicum in the **Potato Family.** (R M.W.)

PEPPERMINT, OIL OF. Volatile Oils.

PEPSIN. Enzymes.

PEPTIDES. Aldehydes, Ketones, and Related Compounds.

PEPTONES. Aminoacids, Polypeptides, and Proteins.

PERCH. Pisces, Teleostei 1 The yellow perch, ringed perch, or common perch, *Perca flavescens,* a fresh-water food fish (**Pisces**) which lives in lakes and streams from Iowa to South Carolina and northward into Canada Introduced on the Pacific Coast 2 The pike-perch, *Stizostedion vitreum,* a related species also known as the wall-eye, glass-eye, wall-eyed pike, and jack salmon It is a valuable food fish of the great Lakes basin, the Mississippi valley, and the northeastern states to Virginia 3 Several marine fishes, some of large size, found in the seas of the Oriental and Australian regions and the Mediterranean Some ascend rivers They are related to the sea basses (A W L)

PERCHLORIC ACID AND PERCHLORATES. Perchloric acid ($HClO_4$) is a colorless, fuming, oily liquid, miscible with water, volatile under diminished pressure with safety (at 18 mm, volatilization temperature 16° C) or by distillation of the dilute solution (70% $HClO_4$ or less) at atmospheric pressure There is a maximum constant boiling point 203° C (760 mm) at 73% $HClO_4$ (distillate) for mixtures of perchloric acid and water Cold dilute perchloric acid reacts with such metals as **zinc** and **iron,** yielding **hydrogen** gas and the corresponding perchlorate in solution, is stable from the point of view of oxidation and reduction (except that **iodine** is oxidized to **periodic acid,** with liberation of **chlorine, ferrous** salt solutions to **ferric, titanous** salt solutions to **titanic**) Concentrated hot perchloric acid, on the other hand, is a powerful oxidizing agent, exploding violently in contact with charcoal, paper, alcohol; causes serious wounds in contact with the skin

Prepared by distilling **ammonium** perchlorate with **nitric** and **hydrochloric** acids

Metallic perchlorates are soluble in water, except that **potassium** perchlorate is slightly soluble Potassium perchlorate is, however, insoluble in alcohol containing perchloric acid, a property made use of in the qualitative recognition and quantitative estimation of potassium in salt solutions Perchlorates, when heated, evolve oxygen and leave the chloride as a residue—potassium perchlorate decomposes at 400° C. (R K S)

PERCUSSION. Kinetics.

PERFUMES. Odorous constituents of plants usually occur as an essential or **volatile oil,** which upon separation is a highly aromatic liquid, and almost always a very complex mixture of substances Some of these substances are easily destroyed by heating **Alcohols** and **phenols, aldehyde** and **ketones,** phenolethers and **esters**—especially esters—are represented among the known constituents Information of scientific character in the field of odorous chemicals seems to be more specific than general. Very slight differences in constitution often change notably the odorous character of substances, e g, the contrasting odors of acetic and butyric acids (CH_3COOH, C_3H_7COOH, respectively), and of acetaldehyde and propionaldehyde (CH_3CHO, C_2H_5CHO, respectively) Whereas the odors of the paraffin aldehydes from C_3 to C_6 are disagreeable, the paraffin aldehydes from C_7 to C_{14}, inclusive, and the corresponding alcohols are used in traces as desirable odorous additions to a number of perfumes

The naturally occurring odorous constituents are found distributed in various parts of various plants, as illustrated below·

Part of the Plant	Plant Supplying Odorous Material
Flowers	Cassia, carnation, clove, hawthorn, hyacinth, heliotrope, jasmin, jonquil, lilac, orange, rose
Flowers and leaves	Lavender, rosemary, violet
Leaves	Bay, cinnamon, eucalyptus, geranium, peppermint, wintergreen
Barks	Cassia, cinnamon
Woods	Camphor, cedar, sandalwood, pine
Roots	Angelica, sassafras
Rhizomes	Ginger, orris, citronella, lemongrass
Fruits	Bergamot, grapefruit, lemon, lime, orange
Seeds	Almond, anise, clove, juniper, nutmeg
Gums, oleoresins	Myrrh, Peru balsam, storax, tolu

Musk is obtained from the dried secretion of the preputial follicles of the male musk deer, now found only at high elevations in the Himalaya Mountains, and ambergris from the diseased intestines of the whale

Since most of the odorous substances are volatile and easily vaporized at 100° C, the simplest procedure for their separation from the plant material is distillation with steam in cases where the odorous material is not thereby injuriously affected Rose, orange blossom, lavender, peppermint and other odorous principles are obtained in this way—but not those of the citrus fruits

The citrus oils are obtained by expression or squeezing the rinds, thus rupturing the oil cells of the fruits, and collecting the oil These oils are injured by heating

To obtain the odorous substances of roses and many other flowers, there is a method of absorption by beef and pork fats, called enfleurage when conducted with thin layers of fat at ordinary temperatures, and maceration when fat is melted at about 65° C The product, called pomade, is treated with alcohol to extract the odoriferous material.

Finally, extraction by the use of a volatile solvent, especially for flowers and leaves, is practiced After evaporation of the solvent, the residue is known as a concrete When this concrete is further treated with alcohol, in which solvent the odorless and colored materials are insoluble, and the resulting solution separated from the solvent alcohol, the residue is known as an absolute

Various substances are used as fixatives, which have little or no odor value themselves, but serve to make odors with which they are mixed less volatile, accordingly available over a longer period of time, and in some cases sweeten the odor

Some of the individual odorous chemicals that have been identified, and material in which each is contained are as follows

Odorous Chemical	Material in Which Contained
Benzaldehyde	Bitter almond
Phenylethyl alcohol	Rose
Vanillin	Vanilla
Eugenol	Clove
Citral (geraniol aldehyde)	70% in lemongrass oil 8% in lemon oil
Methyl salicylate	Wintergreen
Ethyl salicylate	Wintergreen, superior
Amyl salicylate	Clover blossom
Benzyl alcohol, formate, propionate	Synthesized
Benzyl acetate	Jasmin
Geraniol esters	Rose
Citronellol esters	Rose
Methylphenyl acetate	Gardenia
Ethyl-, amyl-, benzylphenyl acetates	Synthesized
Linalyl alcohol	Lavender
Linalyl acetate	Bergamot
Phenylacetic aldehyde	Hyacinth
Terpineol	Lilac
Methyl anthranilate	Grapes
Isobutyl-, isoamylsalicylate	Synthesized
Cinnamic aldehyde	Synthesized
Cinnamic alcohol	Storax
Methyl, ethyl, amyl, cinnamyl cinnamate	Synthesized
Anisic aldehyde	Mayblossom
Ionone	Violet
Phenol-, diphenyl oxide	Geranium
Beta-naphthol ethyl ether	Orange blossom
Acetophenone	Synthesized
Para-methylacetophenone	Synthesized
Benzylideneacetone	Sweet pea
Coumarin	Tonka, new mown hay
Isoeugenol	Carnation
Heliotropin	Heliotrope
Hydroxycitronellal	Lily, lilac
Ethyl protocatechnic aldehyde	Vanilla
Gamma-undecalactone	Peach
Methyl, ethyl, isobutyl, amyl benzoates	Synthesized

Odorous materials are widely utilized in perfumes and cosmetics, in flavoring extracts and essences, and in soaps The blending of natural and artificial odorous substances to produce high grade perfumes is an art The introduction of traces of a given substance often causes desirable or undesirable results out of all proportion to the amount of material added, and requires for success one who is expert in the art (See **Volatile oils.**) (R K S)

PERIANTH. Flower.

PERICARDIAL CAVITY. A portion of the body cavity (**coelom**) containing the heart In the fishes it is the entire **thoracic** part of the cavity but in air-breathing vertebrates the thoracic region also contains the lungs The cavity surrounding the heart of insects is called the pericardium. It is a division of the **haemocoele.** (A W L)

PERICARDIAL SINUS. The **pericardial cavity** or pericardium of invertebrates (A W L)

PERICARDITIS. Inflammation of the **pericardium** which occurs as the result of inflammation spread through the **blood** stream, by direct extension from neighboring organs, or as the result of injury, as a stab wound When infection is present the membranous walls of the pericardium become roughened and inflamed and the amount of fluid in the sac is greatly increased In time the amount of fluid is so great that it interferes with the function of the **heart** and it then is removed by means of a needle. The fluid may become purulent and in such a case surgical drainage must be done Pericarditis is often present in acute rheumatic fever in children, it is also not an uncommon complication of pneumonia and is almost always fatal

The symptoms of pericarditis often may be masked by the disease to which it is secondary The main symptoms are pain in the chest, rapid feeble pulse, and shortness of breath The temperature is elevated and the appearance of the patient is anxious, with pallor of the skin Terminal pericarditis may occur in any chronic or acute illness and is usually not diagnosed (R S M)

PERICARDIUM 1 The cavity surrounding the **heart** of **insects** and other invertebrates, also called the pericardial sinus 2 The cellular lining of the **pericardial cavity** in vertebrates and other animals, in which this cavity is a part of the **coelom.** The human pericardium is composed of two layers The inner layer is adherent to the heart Between the layers there is about one-half ounce of a thin liquid, the pericardial fluid, which serves as a cushion and prevents friction of the beating heart (A W L, R S M)

PERICARP. Fruit.

PERICYCLE. A layer or cylinder of thin-walled **parenchyma** cells which occurs external to the **xylem** and **phloem.** It is bounded externally by the cells of the cortex, or by the endodermis (R M W)

PERIDERM. Lenticels.

PERIDOTITE. The term peridotite is derived from Peridot, the French word for **olivine.**

It is a coarse grained igneous rock related to **gabbro,** which consists of **olivine** and **pyroxene** in varying proportions Certain peridotites contain **spinel, chromite,** or **mica** as accessories A variety of peridotite made up of **hornblende** and olivine is called cortlandtite because originally described from the township of Cortlandt (not Cortland), N Y, on the Hudson River south of Peekskill This rock was formerly called Hudsonite but abandoned as the term hudsonite had been previously applied to a variety of the mineral **pyroxene** found in St Lawrence County, N Y

Rocks consisting essentially of olivine alone are known as dunites, the name coming from the occurrence of this rock in the Dun mountains of New Zealand. In the United States it is found in North Carolina, South Carolina, and Georgia, where corundum is associated with the dunite in commercial quantities The olivine of peridotites alters readily to the mineral **serpentine,** often to such an extent that the rock itself is called a serpentine As mentioned above the peridotites may contain **chromite** or other valuable minerals, often to such an extent that they may be commercially exploited, for nickel, platinum, and precious garnet

Kimberlite from which diamonds are secured is commonly called a mica peridotite, but is more closely related to the **lamprophyres.** (E S C S)

PERIGYNY. Fruit.

PERIHELION. Perihelion is the point in the orbit of any member of the **solar system** when the object is closest to the sun Since the orbits are all conic sec-

tions with the sun at one focus, perihelion must lie on the line of apsides of the conic

In orbits of satellites and other objects which are referred to primaries other than the sun, terms similar to perihelion are used to indicate points in the orbit closest to the primary For example, the point in the moon's orbit closest to the earth is known as perigee, the corresponding point in an orbit of a satellite of Jupiter is known as perijove, etc (W K G)

PERINEUM. The diamond-shaped space at the base of the torso, between the coccyx behind and the arch of the pubic bones in front It is bounded by the thighs on each side This area comprises the floor of the pelvic cavity It contains many important muscles which are pierced by the rectum, urethra and in the female by the vagina. (R S M)

PERIOD. In geology, a major sub-division of an Era. The formations which belong in any one period are spoken of as a System. (R M F)

PERIOD LUMINOSITY LAW. Cepheids.

PERIODIC ACID AND PERIODATES. Periodic acid (H_5IO_6) has been isolated as a colorless solid, melting point about 130° C, and at 138° C begins to decompose, metaperiodic acid (HIO_4) being formed and at higher temperatures iodine pentoxide plus oxygen plus water $H_4I_2O_9$ and H_8IO_8 have been reported as fairly well established in identity, in solution the evidence points to the presence of HIO_4

Prepared by reaction of iodine and perchloric acid.

Sodium periodate ($Na_2H_3IO_6$) is formed by reaction of sodium iodate plus sodium hydroxide plus chlorine (sodium chloride also formed), and the periodate separates as crystals from the medium In solution, it is stated, periodate gradually forms ozone (See Oxygen) and iodate at the ordinary temperatures

Metallic periodates are solids, slightly soluble in water Periodates, when heated, evolve oxygen with simultaneous formation of iodate, which is decomposed at higher temperatures Periodate in acid solution oxidizes hydrosulfuric acid or sulfurous acid to sulfuric acid, oxalic acid to carbon dioxide, manganous to manganate, and with hydrogen peroxide yields oxygen and iodate (R K S)

PERIODIC FUNCTIONS. If $f(x+p) \equiv f(x)$ for every value of x, where p is a constant, then $f(x)$ is said to be periodic, with period p

The trigonometric functions are periodic functions, the sine and cosine have a least period of 2π, and the tangent and cotangent have a least period of π

The exponential function has a pure imaginary period $2\pi i$

The elliptic functions are doubly periodic functions (L L S)

PERIODIC LAW. This "law" states that the chemical and physical properties of elements are a periodic function of the atomic number of the elements (See Chemical Composition.) (R K S)

PERIOPOD The thoracic appendages of crustaceans, behind those which are associated with the mouth (A W L)

PERIOSTEUM. The tough fibrous membrane which covers the surface of the bones of the body except on their joint surfaces It is tightly adherent to the bone surface and it is from this membrane that new bone regenerates (R S M)

PERIOSTITIS. Infection, acute or chronic, of periosteum. It may occur following injury to the bone or it may be a complication of such diseases as septaecemia, typhoid fever or syphilis. In the acute form, abscess formation may develop (R S M)

PERIOSTRACUM. The outer layer of the shell of brachiopods and mollusks. In the molluscan shell it is formed of a horny organic material called conchiolin, associated with the prismatic middle layer of the shell It is also organic material in the brachiopods but here it is separated from the prismatic layer of the shell by a thin layer of calcium carbonate (A W L)

PERIPATUS. Onychophora.

PERIPROCT. The surface of the body immediately surrounding the anus It is applied especially to the sea urchins (Echinoidea) which have two leathery areas in the otherwise rigid body wall, one the peristome surrounding the mouth and the other the periproct on the upper surface (A W L)

PERISARC A chitinous (chitin) sheath surrounding the stalks and branches of the colony in the hydrozoan coelenterates and in some cases forming cupped expansions around the polyps. (A W L)

PERISSODACTYLA The odd-toed ungulates, an order of hoofed mammals in which the axis of the foot passes through the middle digit This digit is larger than the others and is symmetrical The order contains the horses and related species, the rhinoceroses, and the tapirs. (A W L)

PERISTALSIS A wavelike series of muscular contractions progressing along the walls of the intestines, which serve to propel the contents along the intestinal tract (R S M)

PERISTOME The region surrounding the mouth The term is used chiefly of the ciliated (cilia) zone surrounding the mouth in some of the one-celled animals and the leathery portion of the body wall of sea urchins (Echinoidea) in which the mouth opens. (A W L)

PERISTOMIUM. A modified segment or segments behind the mouth in some of the segmented worms (Polychaeta) It bears tentacles and other sensory organs and in some forms is modified as a collar In the species which live in tubes this collar may form a funnel leading to the mouth or a fold which secretes additions to the tube (A W I)

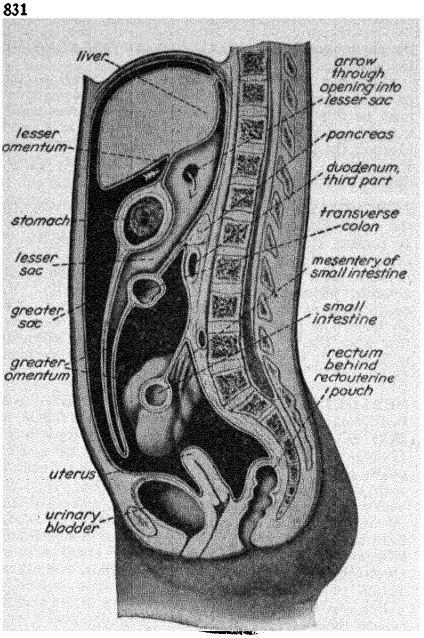
PERITONEUM. The epithelial lining of the body cavity (coelom) In the higher vertebrates the lining of the abdominal cavity in particular The corresponding tissue in the pleural and pericardial cavities of the thorax is called the pleura and the pericardium, respectively The peritoneum is a thin layer of tissue made up of flat cells (See figure at top of page 831) (A W L)

PERITREME. A plate surrounding the external opening (spiracle, stigma) of an air tube (trachea) in some of the arthropods The term is applied to certain mites and insects (A W L)

PERITRICHIDA. Ciliophora.

PERIWINKLE. Mollusca, Gasteropoda Marine snails with a thick conical spiral shell They live in shallow water, in the tidal zone, and along the shore Some of the many species are very widely distributed and the genus *Littorina* is represented in all parts of the world An edible species has been introduced into the United States and is now common on the Atlantic coast north of Delaware Bay (A W L)

PERLITE. Pearlstone. An unusual form of siliceous lava composed of small spherules of about the size of bird shot or peas It is grayish in color with a soft pearly luster The spherules often show a concentric structure and are believed to be formed as a result of a peculiar spherical cracking developed while cooling They may be confused with oölites which are classified as concretions (E S C S)

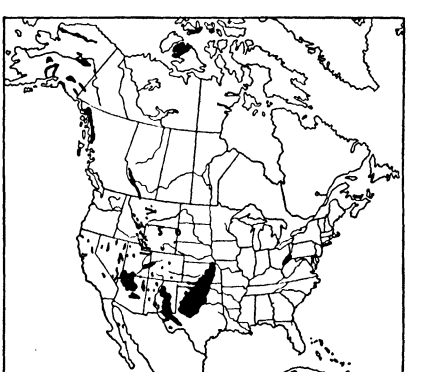


Diagrammatic median section of female body to show the abdominal cavity and the peritoneum on vertical tracing. (Cunningham, *Textbook of Anatomy*, Oxford Press.)

PERMALLOY. Magnetism; Alloys.

PERMEABILITY. Magnetism.

PERMIAN PERIOD. The name of a geologic period. Type locality, Province of Perm, Russia. The formations of this system were first studied and described by R. I. Murchison, in 1841. The Permian period began about 230 million years ago, and lasted for about 30 million years. Only the upper Permian appears to be represented in North America. Eastern North America was undergoing uplift and erosion during this period, while the seas invaded the West from the Arctic and Gulf. Increasing uplift of the continents and mountain building culminated in the **Appalachian Revolution** (U. S.) and the **Hercynian Revolution** (Europe). Increasing aridity and widespread equatorial continental glaciation are disclosed by **tillites** in Australia, Tasmania, New Zealand, India, South America, and Massachusetts. Some of the fossil animals and plants appear to be the progenitors of Mesozoic forms, but a number of marine invertebrates became extinct, including the **trilobites, eurypterids, primitive insects, goniatites,** etc. The fossil fishes are similar to those of the Pennsylvanian. The **Amphibia (Stegocephalians)** are approaching extinction. The first fossil reptiles occur in the Permian, including such highly specialized forms as the **Cotylosaurs** (sail-backed lizards). Important **index fossils** are the fern-like genera, *Sphenopteris* and *Glossopteris*. The distinctly latitudinal distribution of animals and plants between Africa and South America has suggested that the North Atlantic was separated from the South Atlantic by a great east-west continent called **Gondwana Land.** Also during this period the Mediterranean was greatly expanded to the west with easterly and south-easterly outlets into the Pacific. (R.M.F.)



Map showing known areas of outcrops (surface distribution of Permian strata in North America).

PERMINVAR. Magnetism.

PERMUTATIONS. If we have given a set of things, it is often important to know how many different groups or selections can be made by taking some or all of the things of the set, when we take account of the order of arrangement in each group, and when we do not consider the order of arrangement.

Each different arrangement in a definite order which can be made of all or part of a given set of elements is called a permutation.

We are generally concerned with the number of permutations of n things r at a time.

The number of permutations of n things taken r at a time is denoted by many different symbols by different writers; the most commonly used are ${}_nP_r$, $P_{n,r}$ and $P(n,r)$.

The number of permutations of n different elements taken r at a time is given by ${}_nP_r = n(n-1)\ (n-2)\ \ldots\ (n-r+1)$, ($r$ factors on the right).

The number of permutations of n different elements taken n at a time is

$${}_nP_n = n(n-1)\ (n-2)\ \ldots\ 3.\ 2.\ 1 = n!$$

If, of n things, p are alike, of one kind, q of another kind, r of another, and so on, the number of permutations of these things taken all together is $\frac{n!}{p!q!r!}$ (L.L.S.)

PERONIUM. An ectodermal thickening at the base of a tentacle in some of the jellyfishes. (**Scyphozoa,** order Narcomedusae.) (A.W.L.)

PEROVSKITE. The mineral perovskite is **calcium titanate** $CaTiO_3$, probably **isometric.** It has a cubic **cleavage;** is brittle; hardness, 5.5; specific gravity, 4.; luster, adamantine; color, various shades of yellow to reddish brown or nearly black; transparent to opaque. It is found associated with **chlorite** or **serpentine** rocks occurring in the Urals, Baden, Switzerland, Italy, etc. It was named for a certain Von Perovski. (E.S.C.S.)

PERPETUAL MOTION. The idea of a mechanism which, once started, would operate indefinitely is very old and has been the subject of much discussion and much ridicule. It has never been realized in human invention; yet its impossibility is practical rather than fundamental. It lies in our inability to free moving

bodies completely from friction and hence from the dissipation of energy. If one could get away from or neutralize the earth's gravity and other fields of force, so that objects experimented with would not need material support, and if the air and other gases could be completely eliminated from the experimental enclosure, a sphere, for example, set spinning, would continue to spin Nature approximates these conditions in such mechanisms as the solar system and the atom, but man has hitherto failed to duplicate her arrangements The only other alternative is to discover an inexhaustible source of energy to supply the loss due to dissipation The energy from radioactive materials has been used to operate a scientific toy called a "radium clock," but this supply falls off exponentially with time Solar and cosmic radiation seem inexhaustible, but have not been directly utilized on a large scale Meanwhile we continue to draw upon apparently limited stores of energy to carry on the activities of what, after all, promises to be only a temporary physical world (L D W)

PERSEIDS. The Perseids furnish the most reliable of all **meteor showers.** While the **Leonids** have provided some very brilliant displays in the past, about three times each century, their appearance in the intervening years is not at all striking On the contrary the Perseids make their appearance during August of each year. Because of the fact that the Perseid showers never are as striking as the Leonids, when at their maximum, we should not expect to find them referred to so frequently in the ancient writings Extensive search has been made through the old records, however, and we find mention of the Perseids as far back as 830 A D The first determination of the **radiant point** in the **constellation** of **Perseus** was apparently made in 1834

In appearance the members of the Perseid shower are as striking as those from any other radiant point Coming as they do during the month of August, when the nights are warm, they are seen by large numbers of people who are always impressed by the relatively slow motion, distinctly reddish appearance, and trails, frequently of several seconds duration, which characterize the members of this swarm (W K G)

PERSEUS. (Map, page 306) This is a rich and brilliant **constellation** of the northern sky Since it lies right in the milky way it presents many beautiful fields for the opera glass or the small telescope This is particularly true of the bright star Alpha Persei, which lies in the midst of a very rich and beautiful field

The star **Algol** (Beta Persei) is the famous **eclipsing variable** whose striking changes in light intensity caused the Arabs to name it the demon star

In Perseus is to be found the famous double star **cluster** which is one of the finest objects in the whole sky for an observer with a small telescope On a clear moonless night, using a relatively low power on the instrument, any observer will be well repaid for his search for this wonderful object (W K G)

PERSIMMON. Diospyros. Ebenaceae

PERSONAL EQUATION. In making measurements of any character every observer, no matter how skilled he may be, is bound to make certain errors. These errors are of two kinds: accidental errors which will be small in the case of a good observer and which will be distributed at random in accordance with the **laws of probability;** and systematic errors or errors which are always in the same direction and of approximately the same magnitude As an example of systematic errors we may cite the case of the observation of the transit of a star across the **reticle** of a **meridian circle.** In this case a good observer will always press the **chronograph key** either slightly too early or slightly too late, depending upon the observer

The value of the systematic error is known as the personal equation of the observer Personal equation must be determined empirically for each observer under a variety of different observing conditions For a good observer the personal equation remains remarkably constant over long periods of time and may be applied directly to any observation. (W K G)

PERSPIRATION. Sweat A secretion formed by the **sweat glands** of the skin of some of the mammals It consists chiefly of water with small quantities of other materials in solution The dissolved substances include fatty acids, **urea, sodium** and **potassium** chloride, phosphates, lactic acid, and cholesterin By evaporation at the surface of the skin the sweat plays an important part in the regulation of body temperature when the surrounding air is too warm for adequate radiation It is also important as an excretory medium. (A W L)

PERSULFURIC ACID AND PERSULFATES. Per (mono) sulfuric acid, "Caro's acid" (H_2SO_5 or HOO SO_2OH) and perdisulfuric acid "persulfuric acid" ($H_2S_2O_8$ or $HOSO_2O$ OSO_2OH) are solids of melting points 45° C and 65° C, respectively (the latter melting with decomposition) Both acids combine vigorously with a hissing sound with water, and they cause blackening of paper, sugar and paraffin by separation of carbon. Both acids are formed (1) by reaction of chlorosulfonic acid and water, depending upon the ratio, (2) by **electrolysis** of **sulfuric acid** under proper conditions Better yields of persulfate as **ammonium** persulfate ($(NH_4)_2S_2O_8$) are obtained by electrolysis of ammonium sulfate under proper conditions Permonosulfuric acid may also be made by reaction of **hydrogen peroxide** and **sulfur** trioxide or anhydrous sulfuric acid

Permonosulfuric acid oxidizes (1) **hydriodic acid** instantly to **iodine,** (2) **hydrochloric acid** to **chlorine,** (3) **aniline** to nitrobenzene, (4) **ferrous** salt solution to **ferric,** (5) **sulfurous acid** to sulfuric acid, but (6) does not reduce **permanganate,** (7) does not give yellow coloration with titanic salt solutions, (8) does not give blue coloration with **dichromate** solutions of these reactions Perdisulfuric acid shows only oxidation of ferrous salt solution to ferric

Persulfates oxidize (1) potassium iodide slowly to iodine, (2) manganous salt solution to manganese dioxide, (3) manganous salt, in the presence of silver nitrate, to permanganate, but (4) do not give yellow coloration with titanic salt solution, (5) do not give blue coloration with dichromate solutions

The following properties of persulfates aid in their identification Persulfates decompose in water to form ozone, which liberates iodine from starch-iodine paper (thus persulfates differ from percarbonates and perborates) Persulfates do not react with permanganate or with chromic acid (thus they differ from peroxides). (R.K S.)

PERTURBATIONS If there were only two bodies in the universe and if each of these was a homogeneous sphere, the orbit of one relative to the other, or the orbits of both relative to the common center of gravity of the system, could be completely determined by the solution of the **two body problem** In reality, however, there are many more than two bodies in the universe and none of them are homogeneous spheres, with the result that the determination of accurate orbits becomes a problem of tremendous complexity.

Within the **solar system** it fortunately happens that the attraction of one body is dominant, i e, the attraction of the sun upon any object is far greater than the attractions of all of the other planets combined. In the cases of **satellites,** the attraction of the primary

is preponderant. In such cases a close approximation to the true orbit may be obtained by neglecting the attractions of other objects and obtaining a preliminary orbit by the methods of solution of the two body problem

Using the **Keplerian** ellipse thus obtained it is possible to find at any instant, to a high degree of approximation, the distance of the object from other members of the solar system and hence the attractions of these other objects The effects of these attractions in changing the motion of the object under consideration may be computed, a second approximation to the true position may be obtained, and this used to obtain more accurate values to the attracting forces Usually the second approximation is sufficiently accurate for all practical purposes

The influences which the attractions of the other members of the solar system have on the motions of the object under consideration are known as perturbations In the case of nearly circular orbits, as in the case of the motions of the planets about the sun, it is possible to obtain, in the form of infinite series, an analytic expression for the perturbations Such a solution is known as general perturbations If the orbit is highly eccentric, as in the case of many comet orbits, it is not possible to obtain any general analytic expression and the perturbations are known as special perturbations

Due to perturbations the orbits of objects have both slow steady changes in the elements, known as secular perturbations, and also relatively short oscillations about an average value, which are known as periodic perturbations In actual practice it is customary to list both the secular and periodic perturbations in tables from which the accurate position of the planet at any desired instant may be computed In the case of the perturbations of the Moon, one of the most complicated of all perturbation problems, E W Brown's tables of the Moon fill three quarto volumes totalling more than 360 pages

Perturbations have played an important part in astronomical discovery After the planet **Uranus** had been discovered and accurately observed, the preliminary orbit, plus perturbations from all known objects, did not accurately represent the observed positions These deviations could only be explained on the basis of another planet outside of the orbit of Uranus, accurate computations were made and the planet **Neptune** discovered Deviatoins of observed positions of Neptune from those computed from the orbit stimulated the search which led to the discovery of the planet **Pluto.** In the case of the planet **Mercury** a perturbation in the longitude of perihelion in the orbit could not be explained on the basis of gravitational theory This led to a fruitless search for a planet between Mercury and the sun The perturbation was later explained on the basis of the **theory of relativity** and was one of the early triumphs of this theory (W K G)

PERTUSSIS. Whooping Cough.

PESSARY. A device made of metal or rubber which is placed in the **vagina** to support the **uterus,** or to correct muscular relaxation or malposition of the uterus, when it cannot be corrected by other means (R S M)

PETALITE The mineral petalite, **lithium aluminum silicate,** $LiAl(Si_2O_5)_2$ is **monoclinic,** although crystals are rare, this mineral usually occurring in cleavable, **foliated** masses, whence the name petalite from the Greek meaning a *leaf* Its hardness is 6–6 5, specific gravity 2 39–2 46, luster, vitreous, colorless to white or gray but may be greenish or reddish, is transparent to translucent Petalite has been found in Sweden, on the Island of Elba, and in the United States at Bolton, Massachusetts, and Peru, Maine It is interesting to note that lithium was first discovered in this mineral (E S C S)

PETALOID AREA. A flowerlike arrangement of pores on the upper (aboral) surface of some of the sea urchins (**Echinoidae**) (A W L)

PETALS. Flower.

PETIOLE. Leaf.

PETIT MAL. Transient unconsciousness not accompanied by convulsions. One of the two principal types of **epilepsy.** (R S M)

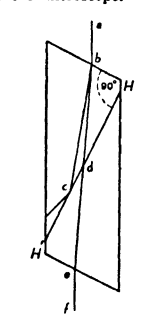
PETREL. Aves, Procellariiformes Marine birds (**Aves**) related to the albatrosses They are powerful fliers and have the feet webbed for swimming The group includes the fulmars and shearwaters as well as several forms which bear the name petrel There are many species and many of them bear one or more names in sailors' vernacular The Cape pigeon, *Daption capensis,* is a well-known petrel of the Southern Hemisphere and the little stormy petrel of the North Atlantic, *Hydrobates pelagicus,* under the name Mother Carey's chicken is probably the most familiar of all to ocean travelers. (A W L)

PETRIFACTIONS. Paleontology.

PETROGENESIS. That branch of **petrology** which deals with the origins of rocks Practically a synonym for petrology unless, as is usually the practice, confined to the **igneous** (and possibly the **metamorphic**) **rocks.** (R M F)

PETROGRAPHIC MICROSCOPE. A type of **microscope** especially adapted for used by the mineralogist and petrologist As compared with the ordinary high powered microscope, the petrographic microscope has the following additional apparatus.

1. A polarizer, or apparatus for **polarizing** light
2. An analyzer, or apparatus for analyzing the rays of light after they have passed through the polarizer, and the thin section of rock which is being examined
3. A rotating stage, which rotates about an axis which is the line of sight of the microscope.

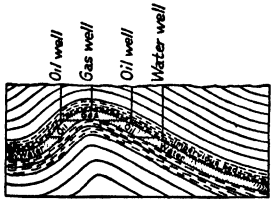


The polarizer, sometimes called the **Nicol prism,** is described as "a cleavage rhombohedron of **calcite** (variety, Iceland spar) having four large and two small rhombohedral faces opposite each other, which is modified in the following manner

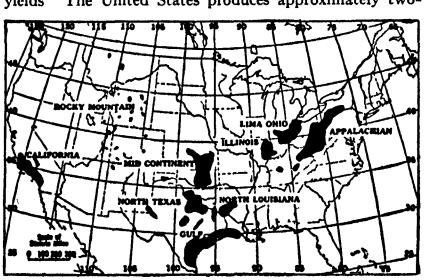
"In place of the latter planes, two new surfaces are cut, making angles of 68° (instead of 71°) with the obtuse vertical edges. These then form the terminal faces of the prism In addition to this, the prism is cut through in the plane *HH'*, the parts then polished and cemented together again with Canada balsam A ray of light, *a b,* entering the prism, is divided into two rays polarized at right angles to each other One of these, *b c,* on meeting the layer of balsam (whose refractive index is less than that of the ray *b c*) suffers total reflection, and is deflected against the blackened sides of the prism and extinguished The other, *b d,* passes through and emerges at *c,* a completely polarized ray of light, that is, a ray with vibrations in one direction only, and that direction of the shorter diagonal prism" Dana (R M F)

PETROGRAPHY. The branch of **petrology** that has to do with the study and systematic description, both **macroscopic** and microscopic, of the mineral composition, texture and structure of rocks. (R M F)

PETROLEUM. Petroleum and its associated natural gases are mixtures of **hydrocarbons**, or mixtures of many chemical compounds consisting chiefly of the elements, carbon and hydrogen, which have been derived from buried organic matter The old term, **mineral oil**, used to distinguish this product from whale oil, is a misnomer because petroleum, like **coal**, is of organic origin In common with coal, however, petroleum is procured from the ground, and is a natural concentration of energy easily expended but not reproducible except in terms of geologic time Whatever may be the original sources of materials from which petroleum is formed, it is generally believed that petroleum in commercial amounts from wells, has migrated into the porous formations (**oil sands**) where it is obtained from oil pools in favorable underground structures Like coal, the products of **oil wells** are extremely variable, there being no such thing as a common **crude** The physical chemistry of petroleum is exceedingly complex and intimately connected with the technology of the **cracking**. Practically speaking, the product of oil wells may range all the way from **natural gas**, through natural **gasoline** and petroleum, to **asphalt** and **paraffin** When an oil reservoir is tapped by means of a drilled well, the pressure is relieved and the gas comes out of solution forcing the oil to the surface The pressure and gas content are, therefore, exceedingly important in the production of petroleum, the deeper wells usually producing the largest and longest yields The United States produces approximately two-



Structure section to show a typical occurrence of gas, oil, and water in an anticlinal structure (After U S Geological Survey)



Map showing the principal oil fields of the United States. (Modified after Geological Survey of Kansas)

thirds of the world production of crude petroleum First class powers which have no petroleum, or a great deficiency thereof within their sovereign territory are: Great Britain, Italy, Japan, France and Germany. (R M F)

PETROLOGY. Petrology is that branch of geology which deals with the rocks forming the **lithosphere** or "crust" of the earth The term is derived from the Greek, meaning rock and reason, hence a more comprehensive term than **petrography**, which deals only with systematic descriptions of rocks, including their mineral composition, texture, structure, and occurrence. Petrology includes petrography and also methods of classification as founded on systematic description and genetic theories, both experimental and theoretical Important branches of petrology are **geochemistry** and **geophysics.** (R M.F)

PETROMYZONTIA. Cyclostomata.

PETROSILEX. A term frequently encountered in the older literature which refers to those very fine grained crystalline aggregates which microscopic studies have revealed as devitrified glasses, and may in general be classified as **felsites.** (E S C S)

pH. Reactions Involving Recombination of Ions.

PHACOLITH. A lens-shaped mass of **igneous** rock found either in the trough or crest of a folded structure It is believed that the shape and position of a phacolith is determined by the **orogenic** conditions, and that the folding is not a result of their intrusion The term phacolith comes from the Greek words meaning lens and stone (E S C S)

PHAGOCYTE A cell of the multicellular animal's body which is capable of ingesting foreign particles In the **sponges** and **coelenterates** and to a limited extent in other more complex animals digestion is carried on wholly or in part by this process In many animals **bacteria** and particles of dead **tissues** or **cells** are engulfed by such cells Phagocytes are amoeboid (**Pseudopodium**) in action and some of them move about in the tissue to which they belong by this means Others are in fixed tissues, carrying on their amoeboid processes at the free end only Phagocytes may be a part of the endodermal lining of the enteric cavity or wandering cells derived from endoderm, or they may be mesodermal In the connective tissues and **blood** mesodermal phagocytes occur, and in the lining of the circulatory system cells may act as phagocytes

Large phagocytes are called macrophages, a term which includes wandering cells of the connective tissues The opposite, microphage, is rarely met In the blood of vertebrates all white cells (leukocytes) are phagocytic to some extent, the lymphocytes least of all (A W L)

PHAGOCYTOSIS. The ingestion of bacteria and other foreign particles by **phagocytes** in the bodies of complex animals The process is an important part of the defense of animals against microorganisms which cause disease and is also a means of disposing of cells which have served their purpose, such as worn out red **blood** corpuscles (A W L)

PHALANGER. Mammalia, Marsupialia. Pouched mammals of an extensive family found only in the Australian and Oriental regions They are small or medium animals with thick woolly fur Some resemble mice or squirrels superficially and all are arboreal With the one exception of the koala they have prehensile tails

In addition to the true phalangers the group includes the cuscuses, the flying phalangers, long-snouted phalangers, and several other forms The **koala** is an aberrant species (A W L)

PHALANGIDA. The **harvestmen** or daddy long-legs, an order of **Arachnida.** (A W L)

Phalangida.

PHALANX, PHALANGES. The small bones of the toes and fingers of **vertebrates.** (A W.L.)

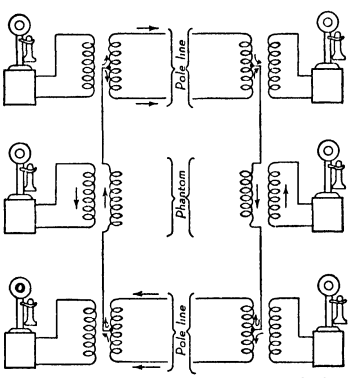
PHALAROPE. Aves, Charadriiformes. Wading birds (**Aves**) of several species, with long legs, lobed toes, and

a moderately long beak. The red (*Phalaropus fulicarius*) and northern (*Lobipes lobatus*) phalaropes breed throughout the northern part of the northern hemisphere, and both the Old and New Worlds have their own species as well Wilson's phalarope (*Steganopus tricolor*) of North America is one of our most beautiful waders The male is gray above, chiefly white below, and has a broad chestnut stripe on the side of the neck and the female is black shading into chestnut below The winter plumage is less bright Phalaropes migrate into the southern hemisphere in winter (A W L)

PHANEROCRYSTALLINE. An adjective applied to an **igneous rock**, the essential constituents of which are distinguishable with the unaided eye Compare with **macroscopic.** The term is derived from the Greek word meaning visible, plus crystalline (R M F)

PHANEROZONIA. Starfishes with one or two rows of large plates along the margins of the rays An order of the class **Asteroidea.** (A W L)

PHANTOM CIRCUIT. Two metallic communication circuits can be made to do the work of three by the addition of certain equipment Since the third circuit has no wires definitely set aside to its use, it is called a phantom circuit The phantom circuit may be ob-



Illustrating a circuit "Phantomed" on two standard circuits (arrows give current flow when phantom is in use)

tained by using repeating or **impedance** coils A set-up of a phantom circuit sent over two side circuits by phantom repeating coils is shown in the accompanying figure The instantaneous direction of current in the phantom circuit is shown by arrows The repeating coils are **transformers** which are tapped at their electrical center, so that the current in the phantom circuit divides equally in those coils If the current flow in the side lines is equal, and moving oppositely so far as the side line circuit is concerned, their voltages will neutralize, and no induced currents will be present in the side circuits. Thus the side circuit is not affected by the phantom Good results depend on the use of side circuits which are identical electrically Transposition is necessary in the side circuits to prevent **cross-talk.** (F T M)

PHARMACOPEIA. A book containing a list of the **drugs** used in medicine with their formulas, descriptions, chemical tests for identification, purity, and dosage The United States Pharmacopeia is revised and re-issued every ten years under the supervision of a national committee (R S M)

PHARYNGEAL CLEFT. Gill slit.

PHARYNGEAL POUCH. A lateral pouch of the vertebrate **pharynx** which joins a depression in the outer surface of the body wall to form a **gill slit** in all forms which have these openings In mammals the pouches form in the embryo without breaking through to the exterior

Pharyngeal pouches are also important as the source of adult anatomical structures The first pair persist as the cavities of the middle ears and their connections with the pharynx become the **Eustachian tubes.** The palatine **tonsils** arise in the walls of the second pair The third and fourth pairs give rise to dorsal and ventral outgrowths which become the **parathyroid** and **thymus** glands, respectively A pair of small postbranchial bodies are interpreted by some anatomists as outgrowths of the fourth pouches and by some as the vestiges of a fifth pair of pouches (A W L)

PHARYNGITIS. An acute respiratory infection in which the greatest amount of inflammation is found in the **pharynx.** With the ordinary head cold, and always with **tonsillitis,** the pharynx cannot help but be involved It occurs in acute and chronic forms

The principal symptoms are tickling and irritation causing cough Pain is present on swallowing When the lower portion of the pharynx is involved, **laryngitis** is present producing hoarseness The constitutional symptoms of pharyngitis are rarely severe as there is usually only slight fever and malaise The treatment is similar to that of **coryza** and tonsillitis (R S M)

PHARYNX. 1 A muscular portion of the alimentary tract (**digestive system**) of invertebrates of various **phyla,** between the mouth and the **oesophagus.** In some species it acts as a suctorial organ The pharynx of flatworms is lined with ectoderm, as is the portion of the tubular tract of other invertebrates which receives this name In some species the region can be everted through the mouth as a proboscis, and in some of the marine annelids (**Polychaeta**) its lining bears teeth which are brought into position to catch prey when it is everted

2 The pharynx of **vertebrates** is a region of the endodermal part of the gut just behind its union with the ectoderm of the oral cavity It is always associated with the **respiratory system** In the lower **chordates, cyclostomes,** fishes (**Pisces**), and **larval amphibians,** its lateral walls are perforated by gill-slits and in the air-breathing vertebrates the lungs arise from its ventral wall The nasal passages are dorsal to the mouth, hence the respiratory passages from nostrils to lungs must cross the alimentary tract, and the pharynx remains common to both systems The **Eustachian tubes** enter in the back portion of the pharynx on either side The upper portion is called the nasopharynx and is located directly behind the nasal passages The lower portion is divided into two parts, the oropharynx which is behind and continuous with the mouth, and the laryngo-pharynx which is continuous with the larynx and esophagus

In man and other vertebrates, the pharynx is important as the source of ductless glands and other structures which arise from the pharyngeal pouches. (R S M, A W L)

PHASCOLOGALE. Dasyure.

PHASE. In wave motion, phase measures the moment when any specified part of wave motion repeats itself. This word, and derivatives of it, have a prominent part in the phraseology of the electrical engineer In alternating current practice, phase refers to the position of the alternating current wave at a given instant taken with respect to a chosen reference point The reference point is usually taken where the wave form goes through its zero point midway between the two extremes of amplitude Phase is also used here to denote the number of currents in an alternating current system, as single-phase,

two-phase, three-phase, etc. The three-phase system is standard, and in it the waves differ in phase by 120 electrical degrees The phase angle is the angle between an alternating current and its voltage If an alternating current and its voltage are said to be in phase, their reference points coincide in point of time

In optics, and hence in astronomy, the term phase has an important usage If a spherical object is illuminated by a beam of approximately parallel light only one hemisphere will be illuminated and be visible to an external observer. As the angle between the lines from the source of light to the object and to the observer changes the amount of illuminated hemisphere visible to the observer will change This will produce a change in the apparent shape of the illuminated object, and the change is known as change of phase The change of phase of an illuminated object is, perhaps, best illustrated in the case of the **moon** and the reader is referred to the article on that subject for details and definitions regarding phase changes.

Theoretically, all the **planets** undergo phase changes since the directions in which they are observed relative to the sun are continually changing In the case of **Venus** and **Mercury**, since their **orbits** lie inside the orbit of the earth, the phase change goes through the complete cycle The other planets all have their orbits outside of that of the earth and can never reach a crescent phase In the case of **Mars** the phase angle may be as great as 47°, at which time Mars presents a distinctly gibbous phase as seen through the telescope The **asteroids** are too small to present an appreciable disk even in the largest telescopes and hence the phase change as such cannot be observed These objects do show a distinct change in brightness with change in phase angle, a circumstance which has given rise to the hypothesis that they may be spherical objects The distances of the planets outside of the asteroids are so great that the phase angle becomes practically imperceptible In the case of **Jupiter** a slight darkening is observed at the limb away from the sun when the planet is at quadrature, but nothing has ever been observed for **Saturn, Uranus, Neptune** or **Pluto.**

The changes in appearance of the rings of Saturn, due to the fact that the plane of the rings does not lie in the plane of the **ecliptic**, are frequently referred to as the change of phase of the rings (F T M, W K G)

PHEASANT. Aves, Galliformes Game birds (**Aves**) native to the Old World, especially of southeastern Asia and the high altitudes of China and Tibet The males of many species are gorgeously colored and have much longer tails than the females

Pheasants are raised in large numbers for game both in Europe and in North America In some parts of the United States the ring-necked pheasant, *Phasianus colchicus*, has apparently become established after some years of careful protection The introduction of other species has met with little success although the golden and silver pheasants are listed as introduced species in the fauna of Oregon and Protection Island, Washington. All of these species are Chinese

The group includes many species with the name pheasant, in addition to the true pheasants of the genus *Phasianus* Other forms are the tragopans or horned pheasants, the blood pheasants, the monals, the fire-backed pheasants, eared pheasants, golden pheasant, jungle fowls, and argus pheasants Some of the Indian species bear the names kallege and pukra

The ruffed **grouse** of North America is known in the southern states as a pheasant but with no scientific reason (A W L)

PHELLOGEN. In most **dicotyledons** this is a **tissue** of living **cells** developed either from the cells of the epidermis or **from** cells lying just beneath the epidermis, or in the case of **roots**, sometimes formed from cells of the **pericycle.** It is a secondary meristematic tissue, from which cork tissue or phellem and phelloderm are formed. (R M W)

PHENACITE. The mineral phenacite is an **orthosilicate** of **beryllium** corresponding to the formula Be_2SiO_4 It is **hexagonal** but the crystals are usually **rhombohedral** in habit It has a conchoidal **fracture**, is brittle, hardness, 7 5–8; specific gravity, 3 , luster, vitreous, colorless to yellowish or reddish, sometimes brown, transparent to translucent Phenacite is found in **pegmatites** with **topaz, quartz** and **microcline**, and occurs also in **emerald**-bearing **mica schists** of the Ural Mountains It is found also in France, Norway, Switzerland, Africa, Brazil, and Mexico, and in the United States in Oxford County, Maine, Carroll County, New Hampshire, and in Chaffee and El Paso Counties in Colorado It derives its name from the Greek meaning deceiver, as it resembles quartz and topaz with which it is associated It is sometimes spelled phenakite It has been somewhat used as a gem (E S C S)

PHENOCLAST. A textural term proposed by R M Field in 1916 for coarsely graded **clastic sedimentary rocks** in which the largest or "show" particles or fragments are referred to as phenoclasts, regardless of their shape or composition The term implies that the larger constituents of the glomerate have been derived from prelithified rock Rounded fragments are called pebbles or spheroclasts, which when lithified by means of matrix (sand and clay) and cement form a conglomerate Angular fragments are called angulclasts (Field), which when lithified by means of matrix (sand and clay) and cement form a **breccia** (R M F)

PHENOCRYST. A textural term proposed by Iddings in 1892 for macroscopic crystals which are relatively much larger than the crystalline matrix of the **igneous** rock in which they occur Rocks which have phenocrysts are called **porphyritic** The term phenocryst is derived from the Greek, meaning *show*, and crystal. (R M F)

PHENOL. (For phenols, see article below on **Phenols and Quinones.**) Phenol, carbolic acid, hydroxybenzene (C_6H_5OH), is a colorless solid of characteristic odor, poisonous, and corrosive to the skin, melting point 41° C, boiling point 182° C, slightly soluble in water at 20° C (8 3 grams phenol per 100 grams solution), but at 68 3° C, critical temperature, each layer contains 33 4 grams phenol per 100 grams solution and the layers are miscible, upon cooling the change is reversible, very soluble in ether and miscible in all proportions with alcohol, glycerol, chloroform, absorbs water on exposure to the atmosphere and acquires a reddish color on exposure to air Phenol reacts (1) with **sodium** hydroxide, yielding sodium phenate (C_6H_5ONa), which with **carbon dioxide** forms phenol plus sodium carbonate (phenol insoluble in **sodium** carbonate or sodium hydrogen carbonate solution), (2) with **phosphorus** pentachloride, yielding chlorobenzene plus phosphorus oxychloride, (3) with **bromine** (or chlorine) in water, yielding 2,4,6-tribromo- (or chloro-) phenol, white precipitate, melting point 96° C (chloro- 68° C), (4) with **zinc** heated, yielding **benzene** (C_6H_6) distillate plus zinc oxide residue, (5) with **ferric** chloride solution, yielding violet solution, (6) with **sodium** nitrate plus concentrated **sulfuric acid**, yielding para-nitrosophenol ($C_6H_4(OH)(NO)(1,4)$), brown when cold, blue upon warming, red upon pouring into water, blue upon addition to this of excess sodium hydroxide (Liebermann's reaction), (7) with **nitric acid** (and concentrated sulfuric acid) yields nitrophenols (para- $C_6H_4(OH)(NO_2)(4)$, ortho- $C_6H_4(OH)(NO_2)(2)$, 2,4-di- $C_6H_3(OH)(NO_2)_2(2,4)$, 2,4,6-tri- $C_6H_2(OH)(NO_2)_3(2,4,6)$, this last substance known as "picric acid" made in this way is an important high explosive Phenol is obtained (1) from coal tar, in the fraction distilling between 170° C and 230° C. The

reaction with sodium hydroxide is applied in the recovery, followed by treatment with carbon dioxide, and distillation of the separated phenol, (2) from benzene sulfonic acid ($C_6H_5SO_3H$) by heating with sodium hydroxide or calcium hydroxide, (3) from chlorobenzene by heating under pressure with sodium hydroxide in the presence of diphenyl oxide, (4) of scientific interest is the reaction of diazobenzene upon boiling, whereupon phenol is formed Phenol gives a violet coloration with solutions of ferric salts Phenol is used (1) as an antiseptic, germicide, and disinfectant, (2) in the manufacture of certain dyes, (3) in the manufacture of picric acid (For Phenols, see **Phenols and Quinones.**) (R K S)

PHENOLOGY. A biological science which deals with the relations of living things to physical conditions in the environment depending on latitude, longitude, and altitude Zones in which similar conditions prevail are populated by similar animals and within a given zone the same periodical fluctuations are to be expected Such zones are indicated on phenological maps by **isophanes** (A W L)

PHENOLPHTHALEIN. **Phthalic acid.**

PHENOLS AND QUINONES. Phenols (containing hydroxyl group, —OH, attached to a benzenoid carbon) are characterized by a wide variety of chemical reactions, illustrated by reference to **phenol** There are several types of phenols, depending upon the number of **hydroxyl** groups contained (1) monohydroxy, e g , phenol (C_6H_5OH), cresol ($CH_3C_6H_4OH(2)$), betanaphthol ($C_{10}H_7OH(2)$), (2) di-hydroxy, e g , resorcinol ($C_6H_4(OH)_2(1,3)$), (3) tri-hydroxy, e g , pyrogallol ($C_6H_3(OH)_3(1,2,3)$) Phenols possess acidic properties, although in very slight degree, and give rise to ethers and esters Upon regulated oxidation 1,4- and 1,2-dihydroxy phenols yield para- and ortho-quinones, respectively. Thus,

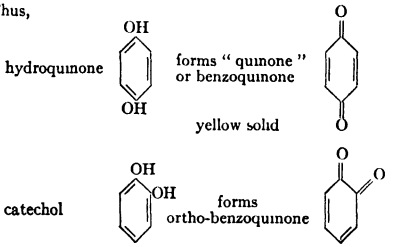
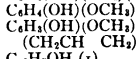
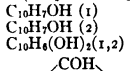
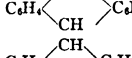
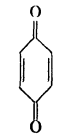


TABLE OF SELECTED REPRESENTATIVE PHENOLS

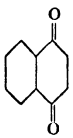
	Phenol	Formula	Melting Point °C	Boiling Point °C
1	Phenol* (carbolic acid)	C_6H_5OH	41	182
2	Ortho-cresol (2-hydroxyl toluene)	$CH_3C_6H_4OH$ (2)	30	191
3	Meta-cresol (3-hydroxyl toluene)	$CH_3C_6H_4(OH)$ (3)	12	203
4	Para-cresol (4-hydroxy toluene)	$CH_3C_6H_4(OH)$ (4)	34	203
5	Ortho-ethyl phenol (1-ethyl-2 hydroxybenzene)	$C_2H_5C_6H_4(OH)$ (2)	−18	207
6	Meta-ethyl phenol (1-ethyl-3-hydroxybenzene)	$C_2H_5C_6H_4(OH)$ (3)	−4	214
7	Para-ethylphenol (1-ethyl-4-hydroxybenzene)	$C_2H_5C_6H_4(OH)$ (4)	46	219
8	1,2-Dihydroxybenzene (catechol)	$C_6H_4(OH)_2(1,2)$	105	245
9	1,3-Dihydroxybenzene (resorcinol)	$C_6H_4(OH)_2(1,3)$	110	276
10.	1,4-Dihydroxybenzene (hydroquinol)	$C_6H_4(OH)_2(1,4)$	170	286
11	1,2,3-Trihydroxybenzene (pyrogallol)	$C_6H_3(OH)_3(1,2,3)$	133	293 dec
12	1,3,5-Trihydroxybenzene (phloroglucinol)	$C_6H_3(OH)_3(1,3,5)$	219	subl dec .
13	1,2,4-Trihydroxybenzene	$C_6H_3(OH)_3(1,2,4)$	141	
14	Para-para-biphenol	(4) $OHC_6H_4C_6H_4OH$ (4)	272	subl
15	Thymol (5-methyl-2-isopropyl phenol)	$C_6H_3(OH)(CH_3)(5)(CH(CH_3)_2)(2)$	51	
16	Carvacrol (2-methyl-5-isopropyl phenol)	$C_6H_3(OH)(CH_3)(2)(CH(CH_3)_2(5)$		237
17	Guaicol (2-methyoxyphenol)	$C_6H_4(OH)(OCH_3)$ (2)		
18	Eugenol (2-methoxy-4-allyl phenol)	$C_6H_3(OH)(OCH_3)$ (2) $(CH_2CH\ CH_2)(4)$		254
19	Alpha-naphthol	$C_{10}H_7OH$ (1)	96	280
20	Beta-naphthol	$C_{10}H_7OH$ (2)	122	286
21	1,2-dihydroxy naphthalene	$C_{10}H_6(OH)_2(1,2)$	60	
22.	Anthranol (9-hydroxy anthracene)		170 dec	
23.	Anthrol (1) (1-hydroxyanthracene)		151 dec.	
24	Anthrol (2) (2-hydroxyanthracene)		200 dec	

* Discussed separately under Phenol

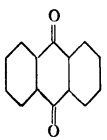
The commonly encountered quinones are of the para type, thus,



benzoquinone (1,4), yellow solid



naphthaquinone (1,4), yellow solid



anthraquinone (9,10), yellow solid

Hydroquinone plus benzoquinone forms the complex known as quinhydrone, dark green solid Quinhydrone or benzoquinone is readily reduced to hydroquinone (e g , by **sulfurous acid**) Quinhydrone, hydroquinone, or **aniline** ($C_6H_5NH_2$), which is commonly used to produce benzoquinone, is readily oxidized to benzoquinone (e g , by **sodium** dichromate plus **sulfuric acid**) When **naphthalene** or alpha-naphthylamine ($C_{10}H_6(NH_2)(1)(OH)(4)$) is similarly oxidized, naphthaquinone is obtained, and **anthracene** similarly yields anthraquinone (9,10)

The higher phenols are soluble in water, and in alkaline solution usually absorb **oxygen** and act as reducing agents, e g , pyrogallol in alkaline solution is used to estimate the percentage of oxygen in gas mixtures, and in photography as a developer As reducing agents these phenols generally react with alkaline **cupric** tartrate (Fehling's solution), and with ammonio-**silver** nitrate (Tollen's solution) Phenols produce a characteristic color with **ferric** chloride solution

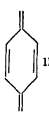
Quinones stand alone among the compounds of carbon-hydrogen-oxygen in possessing, as a class, marked color, para are yellow, ortho red It is believed that the benzenoid structure gives place to the quinoid structure  in this case Quinones, in general, react with **hydroxylamine** or **phenyl-hydrazine** to form mono- and dioximes or mono- and diphenylhydrazones of characteristic properties, e g , melting point

TABLE OF SELECTED REPRESENTATIVE QUINONES

	Quinone	Color	Formula	Melting Point ° C	Boiling Point ° C.
1	Benzoquinone (quinone)	Yellow	$C_6H_4(O)_2(1,4)$	116	subl
2	Ortho-benzoquinone	Red	$C_6H_4(O)_2(1,2)$	60–70 dec	
3	Naphthaquinone	Yellow	$C_{10}H_6(O)_2(1,4)$	125	100 subl.
4	Ortho-naphthaquinone	Red	$C_{10}H_6(O)_2(1,2)$	115 dec	
5	2,6-naphthaquinone	Red	$C_{10}H_6(O)_2(2,6)$		
6	Anthraquinone, 9, 10*	Yellow	$C_6H_4\langle^{CO}_{CO}\rangle C_6H_4$	286	380
7	Ortho-anthraquinone,1,2	Orange	$C_6H_4\langle^{CH}_{CH}\rangle C_6H_2(O)_2(1,2)$	185 dec	
8	Para-anthraquinone,1,4	Yellow	$C_6H_4\langle^{CH}_{CH}\rangle C_6H_2(O)_2(1,4)$	210 dec	
9	Alizarin (1,2-dihydroxyanthraquinone)	Red	$C_6H_4(CO)_2C_6H_2(OH)_2(1,2)$	289 dec	

* Discussed separately under Anthraquinone (R K S)

PHENOMERIDIAN. Isophane.

PHENYL. Radicals.

PHENYLHYDRAZINE. Hydrazine.

PHENYLHYDRAZONES. Hydrazines, Hydrazones, and Osazones.

PHILLIPSITE. The mineral phillipsite is a **zeolite**, a hydrous silicate of **potassium, calcium,** and **aluminum**, of somewhat uncertain formula It is **monoclinic**, forming penetration twins, and sometimes crosses resembling **orthorhombic** or **tetragonal** forms It also may occur in radial groups Phillipsite is a brittle mineral; hardness, 4–4 5, specific gravity, 2 2, luster, vitreous; color, white to light red; translucent to opaque. Like other **zeolites** phillipsite is found in **veins** and cavities in **basalts**, and sometimes in more **acidic** rocks It is believed to be a low temperature mineral Found in Italy, especially in the lavas of Vesuvius and Monte Somma, and in the basalts of Germany, Ireland, and Australia Has been reported from Greenland This mineral was named in honor of the British mineralogist William Phillips (E S C S)

PHIMOSIS. Constriction of the foreskin over the head of the **penis** or **clitoris** so that it cannot be pushed back The condition is corrected by circumcision. (R S M)

PHLEBITIS. Infection of the wall of a **vein.** There are two general divisions (1) Superficial phlebitis, where veins near the surface of the body are involved, and (2) Deep phlebitis where the deep internal veins are in-

volved Any vein in the body may be infected The veins most commonly involved are those of the legs and pelvis Varicose veins are more subject to phlebitis than normal ones With infection of the vein a soft friable clot forms in the involved vessel blocking the blood flow in this portion of the vein In severe cases abscess formation requiring incision and drainage may result

The causes of phlebitis are (1) Stasis, or slowing of the blood stream, as occurs when a patient is confined to bed for a prolonged period, as in severe illness or following an operation, (2) Infection, chronic or acute, in some other part of the body, and (3) Trauma or injury of some kind to the veins This is especially apt to occur following childbirth due to injury to the pelvic veins Any one of the preceding factors or combination of them are sufficient to produce phlebitis

The symptoms of phlebitis are local pain, swelling, redness, and heat, over the site of the infected vein Constitutional symptoms vary, fever and prostration may be marked In some cases the infection spreads and bacteria and infected material are constantly being poured into the blood stream resulting in **septicemia.** At times a piece of clot (*embolus*) breaks loose from the infected vein and is carried into the general circulation to the lung If it is large enough to shut off the main artery to the lung, death results very quickly —at times instantly If smaller, the clot may travel through the main artery to the lung and finally wedge in a smaller arterial branch to the lung If the clot is infected pneumonia results

The treatment of phlebitis is mainly rest in bed with such general treatment as is given any acute infection When the infection subsides the clot in the vein becomes more adherent to the wall of the vein and is then not likely to break loose in the general circulation (R S M)

PHLEBOTOMY. Venesection or withdrawing of blood from a **vein** in the body in order to reduce the venous pressure (R S M)

PHLOEM. The phloem is that part of the plant through which the elaborated food materials move from one part of the plant to another In **stems** the phloem forms a considerable portion of the **bark,** and is found outside the **cambium.**

In **angiosperms,** the phloem consists of **parenchyma** cells, **fibers,** sieve tubes, and companion cells The parenchyma cells are thin-walled, somewhat irregular in shape, and contain protoplasm The fibers are long, slender, thick-walled cells having no cytoplasm The sieve tubes are long thin-walled cells with a peripheral layer of **cytoplasm,** no nucleus, and a large central **vacuole** The walls are perforated in restricted spots called sieve plates In the more advanced plants these sieve plates occur only at the ends of the sieve tubes, in the more primitive plants they are found both at the ends and along the sides of the cells A companion cell is a small cell, usually much elongated, which is found adjoining a sieve tube It has a dense cytoplasm and a distinct nucleus (R M W)

PHLOGOPITE. The mineral phlogopite is a **magnesium** bearing **mica,** with but little **iron,** corresponding essentially to the formula $H_2KMg_3Al(SiO_4)_3$ **Fluorine** is sometimes present This mica is **monoclinic** like **muscovite, biotite** and **lepidolite** forming prismatic crystals, occasionally very large, and occurring also in scales and plates Its **cleavage** is basal and highly perfect with elastic laminae, hardness, 2 5–3, specific gravity, 2 78–2 85, luster, pearly to submetallic, color, **yellowish** brown, green, white and colorless, transparent to translucent, may exhibit asterism, probably due to minute inclusions Phlogopite is more nearly a characteristic of **metamorphic** than **igneous** rocks although occasionally occurring in the latter if they are rich in magnesia and with but little iron Phlogopite is found especially in Rumania, Switzerland, Italy, Finland, Sweden and Madagascar where it occurs in the crystalline limestones in huge crystals In the United States it occurs in New York State at Edwards, Hammond, DeKalb, Monroe and, in New Jersey, at Franklin In Canada it is found at many places in Ontario and Quebec

The name phlogopite comes from the Greek word meaning, like fire, referring to the copper-like reflections often observed in the reddish brown varieties

Phlogopite is in demand commercially by the electrical industry for use as an insulator (E S C S)

PHOEBE. Aves, Passeriformes One of the smaller species of North American birds (**Aves**) belonging with the pewees and kingbirds in the group known as **fly-catchers** It builds its nest commonly on beams below bridges and in deserted buildings Also called the pewit Both names are descriptive of its call Two related species of the western half of the continent and the southwestern states respectively, are the Say phoebe, *Sayornis saya,* and the black phoebe, *S nigricans* (A W L)

Phoebe, *Sayornis phoebe* Dusky brown above, head darker, with a crest Yellowish white below Inconspicuous white wing bars

PHOLIDOTA. A small order of mammals containing only the scaly anteaters or **pangolins** of the Malay archipelago, Africa, and southeastern Asia (A W L)

PHONODEIK. Musical Sounds

PHONOGRAPH. Sound Recording.

PHONOLITE A dense extrusive rock, the equivalent of a **nephelite syenite** The name is derived from the Greek word meaning *sound,* referring to the brilliant metallic ringing sound emitted by certain phonolites when struck Most if not all of the "clink stones" of the older literature were phonolites (E S C S)

PHORONIDEA A group of marine animals of uncertain relationship They live in tubes at the bottom of the ocean and are slender animals with a **lophophore** bearing a series of tentacles about the mouth In this feature they resemble **Bryozoa** and **Brachiopoda** As in the Bryozoa, the alimentary tract is sharply bent Phoronids have a closed tubular **circulatory system** and red **blood** They have sometimes been grouped with the primitive chordates but are usually placed as a separate **phylum** (A W L)

PHOSGENE, CARBONYL CHLORIDE. Carbon

PHOSGENITE The mineral is a rare **chloro-carbonate** of lead **found** with **cerussite** (E S C S)

PHOSPHATE Phosphoric Acid

PHOSPHINES AND RELATED COMPOUNDS. Phosphines are compounds of **phosphorus** and **hydrogen** By replacement of one or more hydrogen atoms a wide variety of derivatives can be formulated, many of which are known A table showing the relationship of these compounds is given on the following page, and some of their reactions are described

TABLE SHOWING PROPERTIES OF PHOSPHINES AND RELATED COMPOUNDS

PHOSPHINES AND THEIR ALKYL-SUBSTITUTION COMPOUNDS	FORMULA	M P. °C.	B P °C.	RELATED OXYGEN COMPOUNDS	FORMULA	M P °C	B P °C.
Phosphine ...	PH_3	−134	−87				
	$PH_2\ PH_3$	−10	57 (735 mm.)				
	$(P_4H_2)_3$	Yellow solid, ignition temperature 160° C					
Methyl phosphine	CH_3PH_2		−14	Methyl phosphinic acid	$CH_3PO(OH)_2$	105	
Ethyl phosphine	$C_2H_5PH_2$		25	Ethyl phosphinic acid	$C_2H_5PO(OH)_2$		
Phenyl phosphine	$C_6H_5PH_2$		160	Phenyl phosphinic acid	$C_6H_5PO(OH)_2$		
Dimethyl phosphine	$(CH_3)_2PH$		25	Dimethyl phosphinic acid	$(CH_3)_2PO(OH)$	76	
Diethyl phosphine	$(C_2H_5)_2PH$		85	Diethyl phosphinic acid	$(C_2H_5)_2PO(OH)$		
Trimethyl phosphine	$(CH_3)_3P$		42	Trimethyl phosphine oxide	$(CH_3)_3PO$		
Triethyl phosphine	$(C_2H_5)_3P$		128	Triethyl phosphine oxide	$(C_2H_5)_3PO$	53	243
Tetramethyl phosphonium iodide	$[(CH_3)_4P]I$						
Tetraethyl phosphonium iodide	$[(C_2H_5)_4P]I$						

Representative reactions of phosphines and their derivatives are as follows

Mono-substituted phosphines oxidized (by **nitric acid**) to mono-substituted phosphinic acids

Di-substituted phosphines oxidized (by nitric acid) to di-substituted phosphinic acids

Tri-substituted phosphines

(1) oxidized (by nitric acid) to tri-substituted phosphine oxides (not easily reduced)

(2) with **chlorine** to tri-substituted phosphine dichlorides

(3) with sulfur to tri-substituted phosphine sulfides

(4) with carbon disulfide to tri-substituted phosphine carbon disulfide addition compounds

(5) with methyl (etc.) iodide to tetra-substituted phosphonium iodides

(6) with ethyl azide to tri-substituted phosphine ethyl amine ($CH_3)_3P\ NC_2H_5$) plus nitrogen gas (N_2)

Tetra-substituted phosphonium iodides with **silver** oxide form tetra-substituted phosphonium hydroxides $[(CH_3)_4P]OH$)

Tetra-substituted phosphonium hydroxides when heated yield tri-substituted phosphine oxides ($(CH_3)_3PO$), plus hydrocarbon (e.g., CH_4)

Benzene plus phosphorus trichloride in the presence of **aluminum** chloride forms phenyl dichlorophosphine (phosphenyl chloride ($C_6H_5PCl_2$), (boiling point 225° C.), plus hydrogen chloride

Phenyldichlorophosphine plus water forms phenyl phosphinous acid ($C_6H_5P(OH)_2$)

Phenyl phosphinous acid plus hydrogen peroxide forms phenyl phosphinic acid ($C_6H_5PO(OH)_2$)

Phenyldichlorophosphine plus hydrogen forms phenyl phosphine $C_6H_5PH_2$.

Phenyldichlorophosphine plus phenyl phosphine forms phosphobenzene ($C_6H_5P\cdot PC_6H_5$), melting point 149° C, yellow solid (similar to azo-compound. Chromophore group —P P—)

Phosphinobenzene ($C_6H_5PO_2$) similar to nitrobenzene ($C_6H_5NO_2$) (R K S)

PHOSPHORESCENCE. A term commonly applied to the production of light by living things and to the resulting luminosity of ocean water when small luminous animals are abundant in it. Luminosity of animals is only superficially like that of phosphorus, however. It results from the oxidation of organic compounds in some animals, including the common **fireflies**, and is probably never a true phosphorescence as this term is defined by the physicist (See **Luminescence**.)

Phosphorescence of the ocean is often due to a multitude of luminous one-celled animals although a limited show of light may result from larger animals of many forms. Animals capable of producing light are known in every **phylum**. (A W L)

PHOSPHORIC ACID AND PHOSPHATES. Phosphoric acid (H_3PO_4) is a colorless solution, commercially of strength 50% H_3PO_4 (specific gravity at 17.5° C., 1.340), 75% H_3PO_4 (specific gravity at 17.5° C., 1.588), 93% H_3PO_4 (specific gravity at 17.5° C., 1.800). A solution of phosphoric acid of 64% strength has minimum freezing point of −85° C. Phosphoric acid 100% may be made by the proper admixture of **phosphorus** pentoxide and water. Conversely, by concentration of phosphoric acid solution in a vacuum or by heating to 140° C., orthophosphoric acid (H_3PO_4) is obtained as a solid, melting point 42.3° C. When heated at 250° C., pyrophosphoric acid ($H_4P_2O_7$) is obtained (salts tetra- and dipyrophosphates), and at a red heat metaphosphoric acid, "glacial phosphoric acid" (HPO_3) (salts monometaphosphates) melting point 40° C., which upon cooling yields a glassy solid.

Phosphoric acid reacts with such metals as **magnesium**, **zinc**, or **iron**, yielding **hydrogen** gas and the corresponding phosphate in solution. Phosphoric acid is (1) a remarkably stable acid from the point of view of oxidation and reduction, and is frequently desirable to use on that account, (2) an esterification agent (See **esters**), e.g., **glycerol** esterified to glycerophosphoric acid ($C_3H_5(OH)_2\ OPO(OH)_2$), ethyl alcohol to triethyl phosphate ($(C_2H_5O)_3PO$), boiling point 216° C., (3) a non-volatile acid upon heating, e.g., with **sodium** chloride or nitrate, **hydrogen chloride** or nitric acid, respectively, is volatilized and sodium dihydrogen phosphate remains as a residue when slight excess phosphoric acid is used; diethyl phosphoric acid ($(C_2H_5O)_2PO(OH)$), boiling point 59° C.

In order to obtain phosphoric acid from **calcium** phosphate the latter may be subjected to either of two

treatments, (1) by addition of the proper amount of **sulfuric acid**, calcium phosphate is transposed to calcium sulfate, insoluble, plus phosphoric acid solution. This reaction is followed by separation of the solution by sedimentation or filtration, and subsequent evaporation, (2) by addition of **silicon** oxide and **carbon** and subjection to **electric furnace** temperature, phosphorus volatilized and the vapor may be burned in air to form phosphorus pentoxide By solution of the oxide, various phosphoric acids of strengths up to 75–90 per cent H_3PO_4 are obtained

The uses of phosphoric acid have been suggested by the chemical reactions previously cited, and the largest quantities are used as an acid to prepare phosphates

Dilute phosphoric acid reacts with **hydroxides** to form three series of phosphates (the acid is tribasic), e g, monosodium dihydrogen phosphate (NaH_2PO_4), disodium (mono) hydrogen phosphate (Na_2HPO_4), trisodium phosphate (Na_3PO_4), depending upon the ratio of acid to base reacting The tribasic and dibasic phosphates, other than those of **sodium, potassium, ammonium**, are insoluble, monobasic phosphates are soluble Tricalcium phosphate, when treated with the proper ratios of sulfuric acid, yields phosphoric acid (H_3PO_4), monocalcium phosphate ($Ca(H_2PO_4)_2$), dicalcium phosphate ($CaHPO_4$), with accompanying calcium sulfate in each of the three cases Phosphates are dissolved or transposed by **nitric acid, hydrochloric acid, sulfuric acid**, phosphoric acid (except those of **lead, tin, mercury, bismuth**), and **acetic acid** (except those of lead, **aluminum, ferric**) Upon heating, tribasic phosphates are stable, dibasic phosphates lose water to form pyrophosphates, monobasic phosphates lose water to form metaphosphates, and in such reactions ammonium volatilizes at high temperatures resembling hydrogen, e g, sodium ammonium hydrogen phosphate (dibasic) upon heating yields sodium metaphosphate residue Common tests for metaphosphate are as follows

1 Addition of **magnesium** salts to boiling solution of metaphosphate produces no precipitate (difference from orthophosphate)
2 **Silver** nitrate forms a white precipitate (difference from orthophosphate)
3 **Albumin** is coagulated by aqueous solution of the free acid (difference from pyrophosphate and orthophosphate)

Common tests for pyrophosphate are as follows:
1 Silver nitrate gives white precipitate
2 Does not coagulate albumin

A common test for orthophosphates is·
Silver nitrate gives a yellow precipitate. (R K S)

PHOSPHORITE. Phosphorite or **phosphate** rock is the term applied to accumulations of **calcium** phosphate in nodular or compact masses often associated with **limestones** The phosphates are derived in part from marine **invertebrates** which secrete shells of phosphate of calcium, and largely from the bones and excrement of vertebrates While some phosphorite deposits are doubtless original, others are secondary, resulting from the leaching out of the original phosphates and their subsequent deposition elsewhere Phosphorite is found in the United States in Florida, Idaho, Montana, South Carolina, Tennessee, Wyoming and Utah; also in Russia, France, Algeria, the West Indies and elsewhere Phosphate rock is economically valuable in the manufacture of **fertilizers** (E S C S)

PHOSPHOROUS ACID AND PHOSPHITES. Phosphorous acid (H_3PO_3, or H_2PO_3H) is a white soluble solid, melting point ~1° C

Phosphorous acid is used in solution, and is usually a reducing agent, e g, in air changes to **phosphoric acid**, with hot concentrated **sulfuric acid** yields phosphoric acid plus **sulfur** dioxide, with **copper** sulfate yields finely divided copper metal, with **silver** nitrate yields finely divided silver metal, with **permanganate** after some time yields manganous, but occasionally is an oxidizing agent, e g, **zinc** plus dilute sulfuric acid yields phosphine

Phosphorous acid is formed by reaction (1) of **phosphorous** trioxide and water, (2) of phosphorous trichloride and water (**hydrogen chloride** evolved, and probably pyrophosphorous acid ($H_4P_2O_5$) first formed) The solution is evaporated to 180° C, and then cooled, whereupon phosphorous acid crystallizes

Sodium phosphite (disodium phosphite, Na_2PO_3H) and sodium hydrogen phosphite ($NaHPO_3H$) are formed by reaction of phosphorous acid and sodium hydroxide solution in the proper proportions, and then evaporating Sodium phosphite dry, upon heating, yields sodium phosphate and sodium phosphide

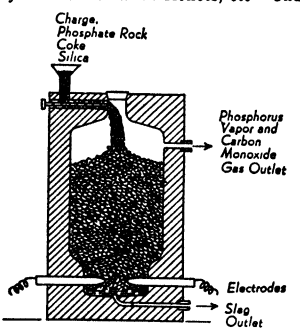
As an esterification agent (See **Ester**), phosphorous acid forms, with ethyl alcohol, triethyl phosphite ($(C_2H_5O)_3P$), boiling point 156° C An unsymmetrical, related compound ($(C_2H_5O)_2(C_2H_5)PO$ is known. (R K S)

PHOSPHORUS. Symbol P Atomic number. 15 Atomic weight 31 02

The chemical element phosphorus is known in four different forms, namely, (1) yellow phosphorus, density 1 82, melting point 44 1° C, ignition temperature in air 34° C (preserved under water), boiling point 280° C, reactive with warm **sodium** hydroxide solution, (2) red phosphorus, density 2 20, melting point 590° C at 43 atmospheres pressure, **ignition** temperature 260° C, not reactive with warm sodium hydroxide solution; (3) violet phosphorus, density 2 36, melting point about 600° C, ignition temperature 260° C, insoluble in solvents, (4) black phosphorus, density 2 70, incombustible Of these varieties, yellow phosphorus is soluble in **carbon disulfide**, and when the solution is allowed to evaporate spontaneously in air, the residual phosphorus burns spontaneously Volatilized phosphorus condenses as the yellow variety Yellow phosphorus reacts with **chlorine, sulfur, nitric acid** (yielding phosphoric acid), sodium hydroxide solution (yielding sodium hypophosphite plus phosphine gas)

Phosphorus was discovered by Brandt in 1669 No isotope, but of single atomic form 31

Phosphorus is an important element in plant nutrition, e g, in the form of phosphate, and in animal nutrition, especially in bone formation To maintain health, a phosphorus balance must be maintained in the body, that is, intake must equal excretion Phosphorus plays a part in complex chemical processes in the body about which little is known It is important in bone formation and here it is linked up with **calcium, vitamin** D and sunlight It is present in the **blood** stream and its concentration remains fixed unless changed by disease such as in **rickets**, etc Under normal conditions a varied ordinary diet supplies this element in sufficient quantity. Phosphorus is exten-



Manufacture of elementary phosphorus in electric furnace

SCHEME SHOWING THE INTERRELATIONSHIPS OF PHOSPHORUS-CONTAINING SUBSTANCES

Phosphines Organic phosphines Phosphonium compounds	PHOSPHORUS		Phosphorus trioxide	Phosphorus tetroxide	Phosphorus pentoxide
		Hypophosphorous acid	Phosphorous acid	Hypophosphoric acid	Phosphoric acid Ortho, pyro, meta
		Metallic hypophosphites	Metallic phosphites	Metallic hypophosphates	Metallic phosphates Insoluble phosphorite, apatite in nature Soluble organic phosphates
			Organic phosphites	Organic hypophosphates	Organic phosphoric acids Phosphoproteins in proteins Phosphinic acids and phosphine oxides
	Phosphobenzene				Phosphinobenzene

sively used as phosphate in **fertilizers**; as sulfide in ignition tips for friction matches, and as red phosphorus in safety matches Yellow phosphorus is poisonous, and in contact with the skin causes dangerous wounds A striking phenomena is the phosphorescence exhibited when yellow phosphorus is heated in boiling water and the vapors condensed A phosphorescent region is visible at the place of condensation

Phosphorus occurs as calcium phosphate (**phosphorite**, phosphate rock, $Ca_3(PO_4)_2$) in Florida, and Northern Africa (**apatite**, $Ca_3(PO_4)_2$ $CaCl_2$ or CaF_2) in Quebec, and in the ash of bones Calcium phosphate is treated in an **electric furnace** with **silicon** oxide and **carbon** (Diagram, page 841), whereupon there is formed calcium silicate fused **slag** (drawn off as liquid), **carbon monoxide** gas, and phosphorus vapor, which last is condensed to yellow phosphorus and collected under water

Red phosphorus is made by heating yellow phosphorus out of contact with oxygen, under pressure, and in the presence of trace of **iodine** at a temperature of about 200° C , violet phosphorus, by allowing red phosphorus dissolved in molten **lead** at 580° C under pressure to crystallize, black phosphorus, by heating yellow phosphorus at 200° C under very high pressure (12,000 kilograms per square centimeter or 165,000 pounds per square inch)

Acids Phosphorus is a constituent of several acids In increasing order of oxidation the following are those which do not contain carbon hypophosphorous acid (H_3PO_2), **phosphorous acid** (H_3PO_3), hypophosphoric acid ($H_4P_2O_6$), **phosphoric acid** (H_3PO_4) Glycerophosphoric acid is $C_3H_5(OH)_2PO(OH)_2$

Bases phosphine (PH_3) resembles **ammonia** chemically, phosphonium hydroxide (PH_4 OH) resembles **ammonium** hydroxide chemically

Bromides phosphorus tribromide, phosphorus bromide (PBr_3), colorless liquid, boiling point 173° C , fumes in air, made by reaction of **bromine** and phosphorus, under control of kind of phosphorus, temperature and solvent (e g , carbon disulfide) to regulate the rate of the reaction, phosphorus pentabromide, phosphoric bromide (PBr_5), yellow solid, fuming in moist air, phosphorus oxybromide ($POBr_3$), white solid, melting point 56° C , boiling point 193° C

Chlorides phosphorus trichloride, phosphorous chloride (PCl_3), colorless liquid, boiling point 73 5° C , fumes in air, made by reaction of **chlorine** and phosphorus, under control of kind of phosphorus, temperature and solvent (e g , carbon disulfide) to regulate the rate of the reaction, phosphorus pentachloride, phosphoric chloride (PCl_5), yellow solid, fuming in moist air; phosphorus oxychloride ($POCl_3$), colorless liquid, melting point 1° C , boiling point 107° C These compounds are important reagents in organic chemistry to replace by halogen, hydroxyl (OH) that is attached to **carbon**, e g , benzoic acid into benzoyl chloride

Hydrides · phosphine (PH_3), colorless gas, of characteristic odor, poisonous, boiling point —86° C , burns in air by heating when pure to 100° C (ordinarily contains diphosphorus tetrahydride inflammable at room temperature), made by reaction of yellow phosphorus and **sodium** hydroxide solution heated, accompanied by diphosphorus tetrahydride (P_2H_4), colorless liquid, boiling point 57° C , spontaneously inflammable in air, accompanies phosphine as prepared above, removable by condensation upon cooling

Iodide phosphorus diiodide (P_2I_4), orange solid, melting point 110° C , phosphorus triiodide (PI_3), red solid, melting point 61° C , decomposes upon heating, with water it forms **phosphorous acid** and hydriodic acid

Nitride phosphorus nitride (P_3N_5), white solid, reactive with warm water to yield phosphate plus **ammonia**

Oxides phosphorus trioxide, phosphorous oxide (P_2O_3). white solid, melting point 22 5° C , boiling point 173° C , formed by reaction of phosphorus and a deficiency of air, dissolves in cold water to form **phosphorous acid**, phosphorus tetroxide (P_2O_4), white solid formed by heating phosphorus trioxide in a sealed tube at about 440° C , reactive with water to form a mixture of phosphorus and **phosphoric acids**, phosphorus pentoxide (P_2O_5), white solid, sublimes at 347° C , excellent dehydrating agent, absorbs water avidly, made by burning phosphorus in excess of air or oxygen.

Phosphides many metallic phosphides have been described, some seven phosphides of **tin**, and six of **copper** Formed by reaction of the metal plus phosphorus Reactive with water or acid to form phosphine or phosphonium salt When sodium phosphite or sodium hypophosphite is heated, sodium phosphide is formed along with phosphate

Sulfide phosphorus and **sulfur** do not react at low temperatures, nor in **carbon disulfide** solution, but, upon heating with caution, three sulfides of phosphorus have been formed, namely, P_4S_3, P_4S_7, P_4S_{10} (or P_2S_5) of melting points, 172° C , 303° C , 280° C , respectively. Tetraphosphorus trisulfide (P_4S_3), non-poisonous, not attacked by atmospheric moisture, is used to replace yellow phosphorus on match tips

Other compounds of phosphorus are discussed as follows:

Esters See **Phosphoric acid and Phosphates; Hypophosphoric acid** and **Hypophosphites; Phosphorous acid and Phosphites.**

Glycerophosphoric acid. See **Phosphoric acid and Phosphates.**
Hypophosphates See **Hypophosphoric acid and Hypophosphates.**
Hypophosphites See **Hypophosphorous acid and Hypophosphites.**
Hypophosphoric acid.
Hypophosphorous acid.
Phosphates See **Phosphoric acid and Phosphates.**
Phosphines.
Phosphine oxides. See **Phosphines and Related Compounds.**
Phosphinic acids. See **Phosphines and Related Compounds.**
Phosphinobenzene. See **Phosphines and Related Compounds.**
Phosphites See **Phosphorous acid and Phosphites.**
Phosphobenzene. See **Phosphines and Related Compounds.**
Phosphonium-compounds See **Phosphines and Related Compounds.**
Phosphoproteins See **Aminoacids, Polypeptides and Proteins.** (R K S)

PHOSPHORUS POISONING. This type of poisoning, whether by accident, or intent, is less common since the advent of safety matches which do not contain **phosphorus** It is still used in many of the rat and vermin pastes The mortality in untreated phosphorus poisoning is very high since the phosphorus has a special affinity for liver cells, which it destroys. The symptoms are early gastro-intestinal irritation, and abdominal pain and collapse If the patient lives two or three days, evidence of liver damage appear such as marked **jaundice** Later, drowsiness, delirium and coma appear, and death occurs in a day or two In the early stages it can be treated by stomach washing with dilute solutions of **hydrogen peroxide** followed for a period of time by a diet rich in **carbohydrates**, given by mouth and by vein in large doses. This is done because the sugar has a protective effect on the liver and many cases are saved by this form of treatment which would otherwise die (R S M)

PHOTOCHEMISTRY. When certain substances are subjected to light a chemical change is produced The production of an image in the photographic plate is possibly the most familiar instance of this, but the reaction of **photosynthesis** in the green leaf of the plant operates on the largest scale Conversely, the production of light from the heat developed in chemical reactions is a common occurrence The burning of **magnesium** metal in air produces a high temperature and light of high actinic value which is utilized in photography

In photochemical reactions **light** supplies the **energy** necessary for the activation of the reacting **molecules** (Grotthus, 1818, and Draper, 1839) Sometimes the light waves which are absorbed by a body produce only an increase in temperature, sometimes **fluorescence** as in the cases of eosin and fluorescein, and sometimes chemical change The reaction of **hydrogen** and **chlorine** in light was studied by Bunsen and Roscoe (1862), and they discovered that the amount of chemical change is proportional to the intensity of the light and to the length of time of exposure to the light The first law of photochemistry (Draper-Grotthus) states that light that is absorbed causes chemical change. The energy of light is measured in quanta

$$E = Nhc/\lambda$$

N is Avagadro's number
h is Planck Constant
c is velocity of light.
λ is wave length of light.

Photochemical processes are of two kinds—primary and secondary The primary process in a photochemical reaction is limited by the Einstein law to the absorption of one quantum by a molecule or atom A knowledge of the spectrum of the reactants is necessary to determine what happens in this process The **molecule** may be disrupted into fragments or an **electron** may be excited from a lower orbit to a higher one Which of these events takes place can often be determined by spectroscopic studies The secondary process deals with the fate of the molecular fragments or of the excited molecules The excited molecule may emit its extra energy as light—causing fluorescence, it may lose it by transferring it to other molecules as thermal energy, or it may cause a chemical reaction On the other hand the molecular fragments may either recombine to give the original reactant or cause further chemical reactions The study of the quantum yield (which is the number of molecules reacting divided by the number of quanta absorbed), is used as a means of formulating the secondary processes If the quantum yield is less than one, fluorescence, deactivation or recombination of fragments must take place If the quantum yield is unity every photon absorbed decomposes one molecule When the quantum yield is greater than unity (and in some reactions it may be as high as a million) chain reactions are involved The classical example of such a reaction is the combination of hydrogen and chlorine The primary reaction is Cl_2 and light $\rightarrow 2Cl$ The chain propagation reactions are

$$Cl + H_2 \rightarrow HCl + H$$
$$H + Cl_2 \rightarrow HCl + Cl$$

creating a cycle which is only stopped by

$$Cl + Cl \rightarrow Cl_2$$
$$H + H \rightarrow H_2$$

Since the last two processes are slow compared to the two before them, one quantum of light can bring about a combination of a million molecules of hydrogen and chlorine (R K S)

PHOTOCONDUCTIVITY. Many substances exhibit a marked increase in electric conductivity when illuminated Thus gases may be ionized by light as well as by ultraviolet radiation or x-rays But the term photoconductivity is commonly applied to crystals which, ordinarily very poor conductors, become distinctly conducting under the action of light

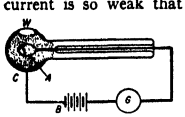
The most noted example of this phenomenon is found in **selenium**, whose photoconductivity has been known since its discovery in 1873 by May Unfortunately selenium is far from typical in its manifestations of the property, and the hundreds of researches on it have given many conflicting data It has finally been recognized, from the work of Gudden and Pohl, that photoconduction is of two general types primary or true photoconduction, which is the direct result of radiation penetrating the substance, and secondary effects set up by the photoconduction itself. The case is somewhat analogous to the primary and secondary ionization of a gas, so much utilized in **photoelectric cells** The fact that in selenium the several secondary effects quite obscure the primary photoconduction is what has occasioned so much confusion The primary photoconduction current in a crystal is in general proportional to the intensity of the illumination, the secondary is not, and, in the case of "light-negative" selenium, may actually neutralize the primary and render the crystal less conductive than when in the dark Some crystals, said to be "idiochromatic," are photoconductive in the pure state, while others, called "allochromatic," acquire the property only by reason of impurities or of exposure to suitable radiation.

Films of photoconductive selenium provided with electrodes, and called "selenium cells," have found practical application in the past They have now, however, been superseded largely by photoelectric and **photovoltaic cells.** (L D W.)

PHOTOELASTICITY. This badly chosen term refers to certain changes in the optical properties of isotropic, transparent dielectrics when subjected to stresses For example, a block of glass, free from optical flaws, exhibits "forced" **double refraction** when put under compression or tension parallel to one of its dimensions If the block is placed between crossed **Nicol prisms**, the field will remain dark so long as the glass is in its normal condition, but as stress is applied, colored fringes will appear which are characteristic of the internal deformations of the glass In 1893 Marsten adapted this principle to the study of elastic stresses in glass or celluloid models of structural parts, and in 1913 Coker developed an apparatus, using circularly- instead of plane-polarized light, for the same purpose Maris analyzed the altered polarization by means of a **compensator**

Ewell discovered that torsion imparts to a dielectric cylinder a certain amount of optical activity, i e, the property of rotating the plane of polarized light. The rotation is in the opposite direction to the torsion, and varies approximately as the fourth power of the torsion (L D W.)

PHOTOELECTRIC CELL. A device for utilizing the photoelectric effect to control the current in an electric circuit (See **Photoelectric Phenomena**), popularly called "electric eye" Such cells are usually designed for use with visible light The only metals which have proved practicable for this purpose are **sodium, potassium, caesium,** and **rubidium** They are volatile and can thus be deposited by condensation in thin films on the negative electrode of a two-electrode tube, thus rendering it sensitive When such a tube, in circuit with a battery, is exposed to light, photoelectrons are thereby released, and a photoelectric current is established and flows so long as the light shines on it. The cells are of various designs, typical of which are (1) a spherical bulb with the sensitive cathode lining the greater part of the inside surface and the anode supported at the center, (2) a bulb having part of the inner surface cathode-coated, and the anode an open mesh supported in front of the sensitive coating, (3) a cylindrical tube having as cathode a sensitized strip of metal along the axis, and surrounded by the open-mesh anode Some cells are evacuated, but they are usually filled with an inert gas to "magnify" their effect by secondary ionization Each cell has its own characteristic dependence of photoelectric yield upon wave length and voltage, which must be determined by experiment Usually the photo-current is so weak that it must be "stepped up" by a suitable thermionic amplifier or relay in order to be of use



Photoelectric cell
Total length is 9 inches, bulb diameter is 1 2 inches

The connections which are shown in the accompanying figure explain a simple photo-tube Light falling through the window strikes the active material coating the inside of the tube The immediate emission of electrons causes the current to flow between the anode and the cathode under the influence of the electromotive force set up by battery B The quantity of current is necessarily small, and is indicated by galvanometer G It may, in some cases, be desirable to connect a resistance in the circuit to prevent the current becoming excessive in gas filled tubes The tubes' are either filled with an inert gas such as argon, or are highly evacuated The small output of the tube can be increased by an amplifying tube, or tubes, until a current is obtained sufficient to operate a magnetic relay.

Among the simple applications of such tubes are the automatic opening of a door through the interception of a beam of light by a person approaching it, the same actuating a photo-cell, and through relays operating an electric door opener. Many other practical and interesting uses of the photo-tube have been found, and new uses are constantly being discovered The ultra-sensitive cell is reactive to "dark light," due to body heat, and is admirably suited for incorporation in burglar alarm systems By reflecting these invisible rays from several mirrors until eventually they are focused on the photo-tube, a certain area may be so completely protected that it is impossible for a person to walk around in it without varying the photo-tube output and setting off an alarm

The photo-tube is also the basis of a system of transmitting pictures by wire, and is an important part of most **television** circuits In transmitting pictures by wire, light is passed through a transparent film containing the picture, the same being mounted on a transparent cylinder which rotates and progresses axially, so that a source of light being focused on a tube located on the axis of the drum traces a helical path on the picture In this way the entire surface is scanned There results, then, an electric current of intensity which is dependent upon the light passing through the film This current is used to modulate an alternating carrier wave, by means of which it can be transported long distances At the receiving end a light-sensitive film, mounted on a similar and synchronized drum, receives light from a source in proportion to the impulses received The whole action might be compared to the unwinding of a thread from one spool, and the rewinding of it on another, but instead of thread, we have light of varying intensity at either end, the same being convertible to a variable electric current stretching between the transmitter and receiver (L D W, F T M)

PHOTOELECTRIC PHENOMENA. Our knowledge of what is known as the photoelectric effect dates from the observation of Hallwachs (1888), who found that a negatively charged body may be discharged when **ultraviolet** radiation falls upon it in a vacuum We are now mostly interested in the photoelectric effect of visible light, but the general theory applied to radiation of all higher frequencies Every solid electric conductor is supposed to contain numerous free electrons which wander about among the atoms from which they have been detached Ordinarily they do not leave the conductor because of the attraction of the positive atoms about them If, however, such a wandering electron encounters a quantum of radiation, it may receive therefrom sufficient kinetic energy to tear itself loose from the attraction and pass out of the conductor, it then becomes a "photoelectron" (Some physicists have assumed that these electrons come from the orbital system of the atom instead of being originally free, but this is now considered doubtful) If there is a suitable electric field between the conductor and neighboring conductor, the electrons thus released pass across from one to the other, thus setting up a photo-electric current

The emission of photoelectrons is subject to certain well known laws For every conductor there is a photoelectric **work function** p, which represents the kinetic energy which the electron must have in order to escape Obviously the radiation quantum responsible for the emission must have at least this energy; and if it has more, the electron, taking it all, escapes with a surplus These facts are embodied in the Einstein photoelectric equation $\frac{1}{2}mv^2 = h\nu - p$, in which ν is the frequency of the radiation, h is the Planck constant, and m and v are the mass and speed of the emitted electron This expresses the excess kinetic energy after an electron, receiving the quantum $h\nu$, passes the surface with energy loss p (See **Quantum Theory** and **Planck's Law**) It follows that radiation of lower than a certain frequency, called the photo-

electric threshold frequency, and equal to p/h, cannot cause photoelectric emission from the given conductor For most metals p is so great that none but the highest frequencies give any result There are only seven (**sodium, potassium, caesium, rubidium, lithium, barium, strontium**) which react to visible light

The "photoelectric yield" of a metal, ie, the emission per unit radiant flux of a given frequency, varies largely with the metal, the condition of its surface, its potential, and the presence of surface films Careful studies of these factors are necessary in the design or the selection of a **photoelectric cell** for any given purpose Closely allied phenomena are **photoconductivity** and the **photovoltaic effects** (L D W)

PHOTOGENIC ORGAN. An organ that produces light In all known cases of light production a complex substance, probably a **protein**, known as luciferin, is oxidized in the production of light The action may take place inside the cell or outside The marine protozoon, *Noctiluca*, for example, contains scattered granules which become luminous under the proper stimulus, and the marine worm, *Chaetopterus*, has gland cells at the surface of the body which produce a luminous secretion

Among the more complex animals, including the **fireflies** and various fishes, photogenic organs are more complex and are extremely varied in form

The production of light has been interpreted in various ways It may be incidental to some normal reaction in the body, it may be a warning to other animals, it may serve to attract prey, and it may be for recognition, particularly in connection with mating (A W L)

PHOTOMETRY. The measurement of luminous intensity, of luminous flux density, or of **illumination** is known as photometry The intensity of a light source may be expressed in candles or other arbitrarily defined source-units (See **Candle Power**), while luminous flux density and illumination are expressed in lumens per unit area of cross section or of surface A "lumen" is the amount of light or luminous flux received upon a unit surface, all points of which are at a unit distance from a concentrated source of one spherical candle intensity

Photometers are of many types Those used for flux-density and candle-power measurement are ordinarily designed to compare the unknown with a known source by balancing in some way the flux densities from the two sources The most common representatives of this type are the various forms of **bench photometer, of wedge photometer, of polarization photometer,** and of **integrating photometer** An important aspect of light-source photometry is the study of the distribution of luminous intensity in different directions,—a variable which the integration photometer is designed to average Direct indications of luminous flux density or of illumination are afforded by photometers utilizing the **photoelectric cell,** the **selenium cell,** or the photronic cell (See **Photovoltaic Effects**) **Spectral energy distribution** is analyzed by means of various types **spectrophotometer**

Since the energy of **radiation** is not at all equally stimulating to the optic nerve, we must recognize two different measures of its intensity (1) the luminous flux density, in lumens per square centimeter of cross section, corresponding to the visual sensation evoked, and (2) the actual flow of power, in watts, per square centimeter, called the radiant flux density The ratio of the one to the other for any wave length is the "visibility factor" for that wave length, while for the whole of any emission (all wave lengths) the corresponding ratio is called the "luminous efficiency" of the emission The efficiency of a light source is expressed in lumens of visible output per watt of input power For example, 10 lumens per watt would be typical for modern incandescent lamps such as are in domestic use

The problem of determination of the brightness of the stars and other objects external to the earth will be found discussed under the heading of **Stellar Photometry** (L D W)

PHOTON. Light.

PHOTOPHORESIS. Very fine solid or liquid particles suspended in a gas or falling through a vacuum are sometimes given a unidirectional motion by a strong beam of light, and the motion is called photophoresis If the particles move with the light, the effect is said to be positive, if against the light, it is called negative Positive photophoresis is usually ascribed to **radiation pressure,** or regarded as the resultant of radiation pressure and the **Crookes radiometer** effect of the surrounding gas Negative photophoresis, observed in fine suspended particles of sulfur or selenium by Ehrenhaft (1917), is thought by some to be due primarily to the radiometer effect If there is present also a strong electric or magnetic field, the motion may have a component in the direction of the field (L D W)

PHOTORECEPTOR. A sensory organ which responds to the stimulus of light waves **Eyes** are the most familiar organs of this kind but many one-celled animals are sensitive to light and some of the more complex forms have the surface of the body sensitive to it True eyes serve for the formation of a visual image whereas the more simple photoreceptors merely indicate the luminosity of the animal's surroundings In some cases adjustment to light is necessary and the simple light-sensitive organ is adequate for the initial step in the animal's orientation Eyes serve the very different purpose of enabling the animal to perceive objects about it and are not primarily associated with its adjustment to light Man depends to an extreme degree on his vision but his skin is sensitive to light in an entirely different way which becomes evident only in the degree of pigmentation (A W L)

PHOTOSPHERE The intensely bright portion of the sun which is visible to the unaided eye is known as the photosphere In reality it is a layer not more than a few hundred miles in thickness which marks the boundary between the dense interior gases of the sun and the cooler, more attenuated gases which go to make up the solar atmosphere The photosphere radiates with a continuous **spectrum** and the application of the **laws of radiation** indicates that its temperature is about 5750° K

In appearance the photosphere is brilliantly white, somewhat brighter at the center than at the limb, and is distinctly granular in character These granules are in reality very large, as much as several hundred miles in diameter, and are relatively short lived, photographs taken at intervals of less than a minute showing distinct changes Larger irregular bright areas known as faculae may be frequently seen Spectroscopic analysis of the light from the faculae indicates that they are masses of heated gases which are rising out through the photosphere to the atmosphere

Spectroheliographic studies of the photosphere show the presence of areas of hydrogen and calcium vapor, known as flocculi which are somewhat smaller than the faculae and larger than the "granules"

The **sun spots** are relatively dark areas which appear on the photosphere (W K G)

PHOTOSYNTHESIS. This is the process which occurs in the green cells of plants and results in the formation of sugar (See **Carbohydrates**) from **carbon dioxide** and water. The process can only occur when **chlorophyll** is present and in light.

The water which is needed for photosynthesis is absorbed directly through the walls of the cells in all lower plants, in higher plants it is absorbed from the soil by the roots and carried through the conducting tissue to the green cells The carbon dioxide enters the cell in solution in water, as carbonic acid In the leaves of higher plants, the carbon dioxide gas passes through the **stomata** of the epidermis Within the leaf it diffuses through the intercellular spaces to the surface of the cells These cells are constantly moist with exuded water, in this the carbon dioxide gas dissolves and passes inward through the **cell** walls into the **protoplast** of the cell Within the cell are the chloroplastids, small green bodies of various shapes At the surface of these bodies the union of carbon dioxide and water occurs The details of this union are as yet not understood It is a complex process which goes on in a series of stages, the first stable product formed is apparently some form of sugar Several theories have been advanced to explain the intermediate stages which lead to the formation of sugar

One theory, advanced by Von Baeyer, was that the carbon dioxide and water molecules were first broken up and then combined to form formaldehyde (See **Aldehydes**), six molecules of the formaldehyde then combined, forming **glucose**, a simple sugar Considerable opposition to this theory arose, for formaldehyde, even in very small quantities, is poisonous and would kill the protoplasm around it Those defending this theory explained that the formaldehyde present in the cell at any time was a very minute quantity which was immediately changed into sugar, and so did not damage the plant At present this formaldehyde theory has many adherents Willstater and Stoll, two German chemists, have sought to explain how the formaldehyde is formed According to them carbon dioxide, water and chlorophyll all unite to form a loose chlorophyll-carbonic acid compound Light energy absorbed by the chlorophyll causes this chlorophyll-carbonic acid compound to become a chlorophyll-formaldehyde-peroxide, which is acted on by an **enzyme** which frees the chlorophyll, forming formaldehyde and oxygen Six molecules of the formaldehyde then combine to form glucose, a simple sugar It is recognized that this is not a proof but only an attempt to explain what happens in a process which is known to be very complex The glucose formed is at once changed to starch, an insoluble substance, so that there is no such change in the osmotic (See **Osmosis**) properties of the **cytoplasm** as would result if the glucose remained and accumulated as soluble sugar The oxygen formed in this process diffuses out of the leaf through the **stomata**, and accumulates in the atmosphere This is an important result of photosynthesis, since all animals, as well as plants, require oxygen in order to live

The starch which is deposited in the cells in which photosynthesis occurs does not remain there indefinitely At night, when photosynthesis ceases, the starch is changed back into soluble sugar This is carried from the cells in which it is formed to all parts of the plant Much of it is used as a source of energy for the living cells of the plant Some is changed into **fats**, **proteins** or other substances which are then stored in various parts of the plant, especially in seeds, root and stem

It is calculated that every square meter of leaf surface produces daily one gram of carbohydrate In itself this seems a very small quantity When one considers, however, the total number of leaves on a plant, and the total number of plants existing, it becomes apparent that the total quantity formed is immense Two plants alone, **sugar cane** and **sugar beets**, yield millions of pounds of sugar each year, which is but a small fraction of the total carbohydrate produced All life, plant as well as animal, is absolutely dependent on this process for all food, directly or indirectly (R M W)

PHOTOTROPISM. Movement in plants, and also Tropism.

PHOTOVOLTAIC EFFECTS. Several possibly related but very imperfectly understood phenomena are classified under this term They are characterized by the creation of an **electromotive force** through the incidence of **light** Two cases only will be described

The first, discovered by Becquerel and known as the Becquerel effect, employed an electrolytic cell, for example, one with silver electrodes coated with silver iodide and immersed in dilute sulfuric acid The electrodes being exactly alike, nothing happened so long as the cell was in the dark or even when it was uniformly illuminated But if one electrode was illuminated more than the other, the cell set up an electromotive force

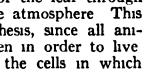
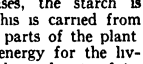
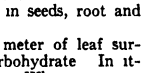
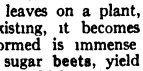
A recent type of photovoltaic cell, developed by Lange and much studied, has for one electrode a copper plate, covered by a thin layer of its own oxide (a semiconductor) This "blocking layer" of oxide is, in turn, sputtered with a film of conducting metal, such as aluminum, so thin that it is nearly transparent, but still capable of acting as an electrode Such an assemblage, in the dark, acts as a **rectifier** But when light falls on the copper oxide layer, the cell also produces an electromotive force of its own, and if placed in a circuit, causes a current nearly proportional to the illumination The uses of this device promise to be many For example, a form known commercially as the "photronic cell," coupled with a sensitive millammeter, is now used as a direct reading **illumination photometer** (L D W)

PHOTRONIC CELL. Photovoltaic Effects

PHREATIC. The term proposed by Daubree in 1887 for the waters of the **ground water** reservoir, as distinct from the underground waters above the water table, called **vadose** (R M F)

PHRENIC NERVES. The nerves that control the **diaphragm** Each half of the diaphragm, the right and the left, is supplied by its own nerve In tuberculosis of the lung it is sometimes advisable to temporarily paralyze the diaphragm on the side where tuberculosis is present This diminishes movement of the infected lung This is done by making an incision in the lower part of the neck through which the nerve runs on its way to the diaphragm The nerve is crushed and does not regenerate for six months or more (R S M)

PHTHALEINS. Phthalic Acid.

PHTHALIC ACID, PHTHALATES, AND PHTHALEINS. Ortho-phthalic acid, benzene-ortho-dicarboxylic acid ($C_6H_4(COOH)_2(1,2)$) is a white solid, melting point 191° C, decomposes, insoluble in cold but soluble in hot water, when heated loses water to form phthalic anhydride  , a white solid, melting point 128° C, boiling point 285° C Reacts with **phosphorus** pentachloride to form phthalyl chloride  , which further reacts with aluminum chloride to form unsymmetrical phthalyl chloride  Both chlorides react (1) with **zinc** plus **acetic acid** to form unsymmetrical phthalide  , and (2) with **benzene** plus **aluminum**

chloride to form unsymmetrical-diphenylphthalide phthalophenone ($C_6H_4<^{C(C_6H_5)_2}_{CO}>O$).

Phthalic anhydride reacts (1) with **ammonia** to form phthalimide ($C_6H_4<^{CO}_{CO}>NH$), white solid, melting point 238° C., which latter compound reacts (a) with **potassium** hydroxide in alcohol to form potassium phthalimide ($C_6H_4<^{CO}_{CO}>NK$). When potassium phthalimide is treated with an alkyl halide, e.g., ethyl iodide, ethyl phthalimide ($C_6H_4<^{CO}_{CO}>N\cdot C_2H_5$) is formed, from which the primary **amine**, ethyl amine ($C_2H_5NH_2$) may be obtained (plus phthalic acid) by heating with fuming **hydrochloric acid** (Gabriel's synthesis for primary amines), (b) with sodium hypochlorite, to form sodium anthranilate ($C_6H_4<^{NH_2}_{COONa}$), which yields, upon treatment with an acid, anthranilic acid ($C_6H_4<^{NH_2}_{COOH}$); (2) with phenol to form phthaleins, e.g., (a) **phenol** plus phthalic anhydride at 120°, in the presence of sulfuric acid concentrated, forms phenolphthalein ($C_6H_4<^{C<^{C_6H_4\cdot OH(4)}_{C_6H_4\cdot OH(4)}>O}_{CO}$), white solid, melting point 261° C., soluble in alkali to form a red solution, and used as an indicator to determine the neutral point in **titrating** acidic or basic solutions, (b) resorcinol plus phthalic anhydride, similarly, forms resorcinolphthalein, fluorescein ($C_6H_4<^{C<^{C_6H_3<^{OH(4)}_{O(2)}}_{C_6H_3<^{O(2)}_{OH(4)}}>O}_{CO}$) dark yellow solid, decomposes above 290° C., dissolves in alkali to yellow-red solution, which exhibit green fluorescence when dilute. When fluorescein and **bromine** react tetra-bromofluorescein ($C_6H_4<^{C<^{C_6HBr_2<^{OH(4)}_{O(2)}}_{C_6HBr_2<^{O(2)}_{OH(4)}}>O}_{CO}$) is formed, the **potassium** salt of which is known as eosin, and used as a red dye for wool and silk, (c) N-diethyl-meta-aminophenol plus phthalic anhydride, similarly, forms N-diethyl-meta-aminophenol phthalein, rhodamine

($C_6H_4<^{C<^{C_6H_3<^{N(C_2H_5)_2(4)}_{O(2)}}_{C_6H_3<^{O(2)}_{N(C_2H_5)_2(4)}}>O}_{CO}$)

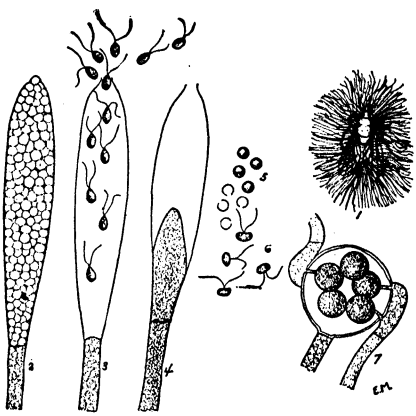
a red dye.

Ortho-phthalic acid is made by oxidation of **naphthalene** (1) with **sulfuric acid** fuming heated, in the presence of mercuric sulfate, (**sulfur** dioxide also formed, and recovered), (2) with air in the presence of vanadium pentoxide at 450° to 520° C. Ortho-phthalic acid is also formed when **benzene** compounds, containing carbon ortho-substituted groups, are oxidized. Ortho-phthalic acid is used in the manufacture of **indigo** and other dyes. (R.K.S.)

PHTHISIS. Pulmonary **tuberculosis.** (R.S.M.)

PHYCOMYCETES. The Phycomycetes form a group of **fungi** so diverse in habit as to suggest **polyphyletic** origin, quite probably from several different groups of green **algae**, to which many of them show remarkable similarity. Simpler members of the Phycomycetes consist of but a single cell, while other species have a well-developed branching **mycelium**, always composed of **hyphae** possessing no cross-walls. Many species grow in water and are known as water molds. Others grow out of water. Among the latter are some of the common destructive **parasites.**

In the water-inhabiting species reproduction by asexual **zoöspores** is common. These zoöspores are produced in **zoösporangia**, which are cut off by cross-walls from the ends of the otherwise non-septate



Saprolegnia. Stages in development. 1, fungus growing on a dead fly in water; 2, sporangium with newly formed spores; 3, sporangium discharging zoospores; 4, formation of new sporangium; 5, resting stage following first motile stage 3; 6, second motile stage following resting stage 5; 7, fertilization of eggs in oogonium.

mycelium. Each zoöspore possesses two apical **cilia**, by means of which it swims about for a time. After this it becomes quiet and secretes around itself a cell wall. From this it may escape as a second type of zoöspore possessing two laterally inserted cilia. After a period of quiescence and wall-formation this second zoöspore puts out a germ tube which develops into an extensive mycelium. The significance of the two kinds of zoöspores, which do not appear in all species of water molds, is not entirely understood. In the non-water inhabiting Phycomycetes asexual reproduction is by means of conidia, minute cells formed in chains or in large masses borne in various ways on the tips of special branches called conidiophores. The conidia are discharged in the air and are borne about by air-currents.

Sexual reproduction occurs in many Phycomycetes, varying considerably in the different orders, and is a basis for the separation of this group of fungi into two subclasses, the Oömycetes and the Zygomycetes. In the first the sexual cells are distinctly unlike in size, or heterogamous, while in the second they are alike or isogamous. Seven orders are recognized in the Phycomycetes, three of them being important. One of these is the Water-molds or Saprolegniales, the members of which are aquatic and closely resemble certain algae, but are without **chlorophyll.** These fungi include **saprophytes** living on both animal and plant remains, and **parasites**, many of the latter being serious pests in aquaria and fish hatcheries, attacking both

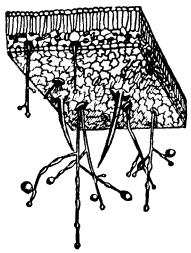
fish and eggs. Sexual reproduction is by means of **oögonia** and **antheridia**, although in many species antheridia seem to be functionless and in other species completely lacking. In such cases the oögonia develop without the aid of antheridia, such development being called parthenogenesis. The oögonia are rounded bodies cut off from the tips of hyphae. The antheridia, when present, appear as branches from the hypha which bears the oögonium. These branches grow up around the oögonium into which they develop lateral fertilization tubes penetrating the oögonial wall. When mature, the contents of the oögonium break up to form several spherical eggs, each of which is reached by a fertilization tube. Through this tube a nucleus passes from the antheridium to the egg, where it unites with the egg nucleus. Subsequently a thick wall is formed around each egg, which then passes through a prolonged resting period. Germination of this resting cell is by a germ tube.

The similarity between green algae such as *Vaucheria* species and the Water molds has been frequently noted, and suggests a relationship between them, and lends support to the idea that the Phycomycetes have developed from such green algae through the loss of their chlorophyll and the assumption of a saprophytic habit. According to another theory, the simpler members of the Phycomycetes fall into a line of evolution which starts from non-pigmented unicellular organisms called Flagellates and gradually gives rise to the whole series of Fungi today existing.

A second order of Phycomycetes is made up of parasites on higher plants, many of them being of great importance because of the injury they do to cultivated crops. This order is the Peronosporales, and contains fungi known as Blights and Downy Mildews. In this order the mycelium is composed of hyphae which penetrate between the cells of the host plant tissue, sending into those cells short absorbing tubes called haustoria. Asexual reproduction in this order is by means of conidia, which in some genera are borne in chains in extensive areas beneath the epidermis of the host plant, and liberated by the breaking of this epidermis, and in other genera by conidia borne on the tips of the branches of hyphae which extend outward above the epidermis of the host. These conidia are scattered by the wind and, if they reach a suitable host, give rise to several small laterally biciliate zoöspores; the latter form germ tubes which penetrate the tissues of the host plant, thus causing new infections. Sexual reproduction occurs in the deeper tissues of the infected plant and is very similar to that occurring in the Water-molds. However, each oögonium develops only one egg. This egg is fertilized within the host tissues and remains there until the latter disintegrate. After this the egg germinates, giving rise to biciliate zoöspores or in some species producing a mycelium directly.

Many members of this order are of great importance, because of their parasitic nature. One of these is the Downy Mildew of Grapes, *Plasmopara viticola*, which was introduced from America into Europe where it became a grave menace to the grape vines. This unfortunate introduction, however, led to the discovery of a control, **Bordeaux mixture**. Originally this mixture was used as a spray to grape vines along the highway as a means of preventing pilfering. It was noticed that the plants so treated were not infected by the fungus, while others were. So the treatment was extended and led to a control of the fungus.

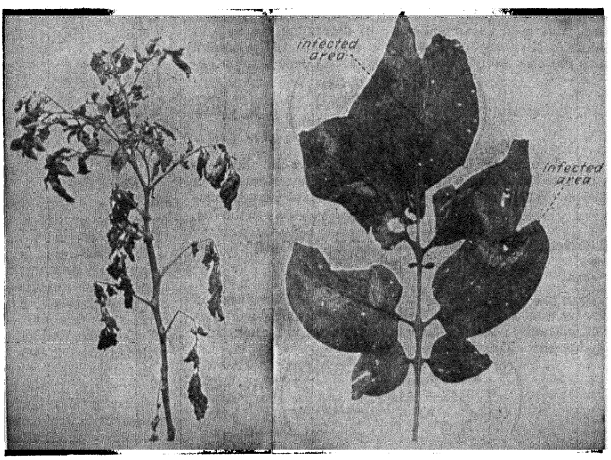
A second serious disease caused by one of the Peronosporales is Potato Blight, due to *Phytophthora infestans*. This fungus attacks the entire plant and in serious cases may completely kill all parts above ground. It appears as a white mold on the under surface of leaves. This whiteness is caused by the abundant conidiophores. It is this disease which caused the great potato famine in Ireland in 1845. Frequent spraying with Bordeaux mixture is an effective control.



Perspective view of potato leaf with conidiophores of *Phytophthora infestans* protruding from stomata and bearing conidia.

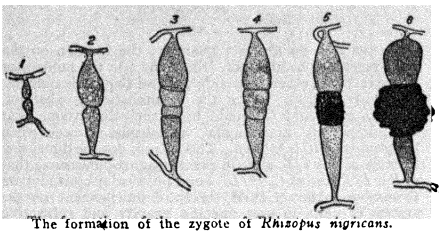
Damping off is another disease caused by fungi of this order. The casual organisms are species of the genus *Pythium*, which attack the stems of seedling plants near the level of the ground and so weaken them that they fall over and the plant dies. Since moisture favors the growth of this fungus, partial control is obtained by aeration and the avoidance of high humidity.

A third order of Phycomycetes is the Mucorales, and contains the familiar black mold of bread. *Rhizopus nigricans* is a very common species. In this fungus there is an extensive much-branched colorless mycelium which spreads over and within the substratum. Short branches of the mycelium penetrate the substratum and extract from it nutrient materials; erect branches from the mycelium terminate in sporangia, or spore-bearing bodies. The spores of *Rhizopus* are minute spherical bodies produced in immense numbers. When mature they are scattered far and wide. Exposure of a piece of moistened bread anywhere will soon demonstrate how widely scattered and abundant these spores must be: seldom does such a piece of bread



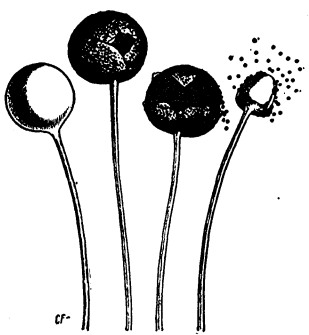
Left, a potato plant affected with late blight; right, potato leaves showing infected areas. (From *New York Agricultural Experiment Station*, Geneva, Bulletin 241.)

fail to nourish a luxuriant growth of this Black mold. Sexual reproduction in this order is entirely unlike that in the two described earlier. In this group, tips of



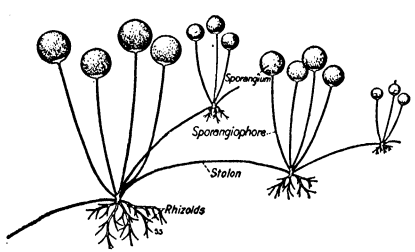
The formation of the zygote of *Rhizopus nigricans*.

branches from two different plants come together. Each tip enlarges considerably and becomes densely filled with protoplasm. A wall forms, cutting off the tip of each branch, after which the walls between the two tips break down and their contents fuse. The result-



Sporangia of *Rhizopus* of different ages.

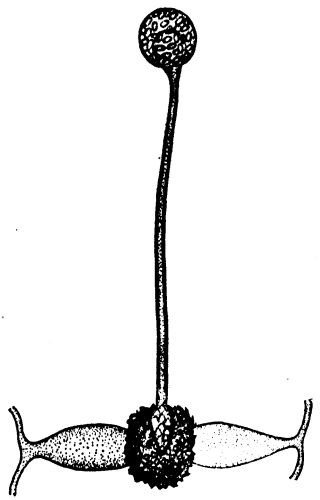
ing cell, called a zygospore, enlarges conspicuously and becomes invested in a thick dark-colored wall. This zygospore usually undergoes a prolonged resting period before germinating. Nuclear fusion in pairs occurs during the formation of the zygospore. Zygospore forma-



Rhizopus. Plant spreading by stolons and bearing sporangia on sporangiophores.

tion occurs in a similar fashion in other members of the Mucorales.

In many species, zygospores are formed but rarely. One reason for this is that many species are heterothallic, that is, require the union of hyphae from two plants which look exactly alike but are of very different nature. These hyphae must come from spores which are likewise different, and are usually described as + and — hyphae; often the terms female and male are applied to them, the +, or female, strain showing a more vigorous habit. Species in which the spores are all alike are called homothallic; in these, zygospores are readily formed between hyphae from a single spore, or branches of the same mycelium. Many species in the Mucorales show much-branched conidiophores and are objects of rare beauty when observed with a microscope.



Mucor, a fungus closely related to *Rhizopus*.

One other order of Phycomycetes is worthy of mention. This is the Entomophthorales, many members of which grow parasitically on insects. One species in the genus *Empusa* attacks house flies, resulting in the death of large numbers of flies. Dead flies are often attached to window panes by the numerous hyphae present, and surrounded by a white halo of conidia.

The remaining orders of Phycomycetes are unimportant water-inhabiting forms of little importance to man. (R.M.W.)

PHYLACTOLAEMATA. Ectoprocta.

PHYLLITE. A **metamorphic rock** intermediate between **slate** and **schist** and characterized by a crinkly surface with the development of much **mica** or micaceous minerals such as **chlorite**. Phyllites may be white due to the presence of **sericite**, green if **chlorite** is present, or red or black due to various organic and mineral substances. Phyllite as a term is derived from the Greek word meaning a leaf, referring to the **cleavage**, though this physical property is much better developed in slates and some schists. Some phyllites are highly **metamorphosed** clay sediments, others represent metamorphosed tuffs, and even felsites, also phyllites have been formed by **mylonitization** of **graywackes**, **granites**, and other rocks. (E.S.C.S.)

PHYLLOPODA. Crustacea.

PHYLLOPODIUM. A form of the biramous appendage of crustaceans in which the general structure is in broad thin plates, with thin walls. They are often associated with the mouth and function in feeding and in respiration. In a few forms they are swimming appendages. (A.W.L.)

PHYLLOTAXY. Leaf.

PHYLLOXERAN, PHYLLOXERID. Insecta, Homoptera A sucking insect related to the plant lice and scale insects The many species make up a subfamily which, with the adelgids, constitutes the family Phylloxeridae They differ from the aphids in that all females lay eggs and from the scales in their more complex structure, including the four wings of the winged stages

The most important phylloxerid is a species which attacks grape vines, working on the leaves and roots It once threatened to ruin the vineyards of France and has destroyed millions of acres of vines The use of roots of certain American grapes which are not seriously harmed by the pest has greatly lessened the danger from its attack Tender varieties are grafted onto the resistant roots (A W L)

PHYLUM. A principal subdivision of the animal kingdom Classification (A W L)

PHYSICAL CHEMISTRY. Physical chemistry is that branch of chemistry which deals with the theoretical aspects of chemistry using as its basis the ultimate particles of matter and their fundamental laws as formulated by physics Whereas the latter science treats of properties which are common to all matter and energy, physical chemistry is primarily concerned with an interpretation of differences found among the various species of matter The subject matter of physical chemistry is usually divided into the following topics Properties of **gases**, Properties of **liquids**, Properties and structure of **solids**, Theory of **Equilibrium**, Theory of Dilute **Solutions**, Theory of electrical **conduction** in liquids, **Ionization**, Ionic Equilibria, **Thermochemistry** and **Thermodynamics**, Velocity of Reactions, **Photochemistry**, **Catalysis** (R K S)

PHYSICAL MAGNITUDES AND PHYSICAL EQUATIONS Physics is a quantitative science, dealing primarily with things measurable and expressible in units There are hundreds of these physical magnitudes, some simple, some requiring elaborate definition Many obvious relations exist between them, for example pressure (or any stress) is the ratio of a force to an area Careful study reveals that most physical magnitudes have their measures so defined that they may be expressed in terms of not more than three elementary or fundamental magnitudes, combined in various ways As to which magnitudes should be regarded as fundamental, custom has fixed the choice upon length, mass, and time In the **c g s system**, for example, these respective magnitudes are represented by the centimeter, the gram, and the second, and all other physical units of the system are expressible in terms of these Thus the unit of speed is 1 centimeter per second, of area, 1 square centimeter, of force (the dyne), 1 gram-centimeter per second per second, etc This analysis may be generalized so as not to depend upon any specified system of units Thus if length be denoted by L, mass by M, and time by T, the "dimension formula" for speed becomes L/T, for area L^2, for force ML/T^2, etc The derivation of such relationships, called "dimensional analysis," is a highly important item in theoretical physics

In order that two physical quantities may be equal, or that one may be added to or subtracted from the other, it is obvious that they must have the same makeup and be expressible by the same combination of fundamental units. It follows that in an equation expressing relationship between physical magnitudes, both members and all terms of each member must have the same dimension formula For example, the total area of a right circular cone of altitude h and having a base of radius r is $a = \pi r^2 + \pi r\sqrt{r^2 + h^2}$, each term of which has the dimension formula L^2 (since π is abstract) Again, the phase angle ϕ of an **alternating current** of frequency n (per second) in a circuit of resistance R (ohms), inductance L (henrys), and capacitance C (farads) is given by

$$\tan \phi = \frac{4\pi^2 n^2 LC - 1}{2\pi nRC}.$$

Since tan ϕ is an abstract quantity, the fraction on the right must also be abstract Since the 1 in the numerator is abstract, the other term $4\pi^2 n^2 LC$ and the whole numerator must be also, hence the denominator is abstract. That is n, R, and C should have such dimensions that the component fundamental magnitudes cancel when the product nRC is formed This is true, for the dimension formula of n is $1/T$, and (in electromagnetic measure) that of R is L/T, and of C, T^2/L Some physical magnitudes are themselves abstract, and therefore independent of the system of units in use, **specific gravity** and **refractive index** are in this class (L D W)

PHYSICAL MEASUREMENTS. Physical quantities have practical significance only as they are capable of measurement and of expression as bearing definite numerical ratios to appropriate units In some cases this comparison can be made directly, as by applying a yardstick to the length of a room More often the quantity to be measured is incapable of such direct attack, and must be determined by means of known relationships to other quantities which are observable. Thus an electric current can be measured only by appealing to certain of its effects, for example, it can be made to form an electrochemical deposit for an observed time and the mass of the deposit then weighed. Likewise, the observable change in volume of mercury is a convenient "measure" of change in temperature

Most physical units are expressible in terms of certain primary standards, which are units of the fundamental magnitudes, length, mass, and time, sometimes in connection with the properties of specified substances. In most physical measurements these primary standards are the **meter**, the **kilogram**, and the mean solar day Other "derived" units are defined in terms of these or of multiples or aliquot subdivisions of them (**centimeter, gram;** cf **C.G.S. System**) Thus the **density** of a substance may be expressed in gm/cm^3, the **watt** of power is 10^7gm cm^2/sec^3 The centigrade degree is 1/100 of the temperature interval between the freezing and boiling points of water, which is subdivided on the basis of some specified temperature measure such as the pressure or the volume of a gas, the electrical resistance of a wire, etc, and these in turn must be determined in units appropriate to the respective magnitudes When the measurement of a physical quantity gives its value in terms of the quantities used in defining its fundamental units, the measurement is said to be "absolute" This is the case, for example, with the measurement of electric current by observing the **force** with which a **magnetic field** of known intensity acts upon the conductor carrying the current See **Abampere.**

In all physical measurements, the instruments used must be "calibrated", that is, the relation of each subdivision on the instrument scale to the unit of the quantity measured must be ascertained If each subdivision corresponds to exactly one unit, the instrument is said to be "direct reading", this is usually true, for example, of **ammeters** and **voltmeters**, but seldom of **galvanometers**

Various instrumental principles have become standard in physics We have, for example, many instruments utilizing the **vernier**, the **micrometer**, or the **optical lever** principle There are also certain well known general observational methods, some of which are designed to minimize errors In the method of "substitution," a quantity is determined by substituting for it a known quantity which produces the same effect. In the very common "differential method," the quantity required is the difference between two actually measured quantities. The "null" or "balance" method consists in ad-

justing the apparatus so that the indicator of the measuring instrument reads zero, as the galvanometer used with a **Wheatstone bridge.** In the "cumulative method" a large multiple of the quantity sought is measured, e.g., the thickness of a sheet of paper may be found from that of a thousand sheets. The "coincidence method" is useful in measuring periodic phenomena, as in comparing the periods of two pendulums by observing how often the swings coincide. "Compensation" applies to any method in which an error is made to neutralize itself, as in double weighing (See **Weighing Methods**). Many other schemes, often highly ingenious, are in common use in physical laboratories. See **Errors of Measurement.** (L.D.W.)

PHYSIOGRAPHIC PROVINCES. Physiography.

PHYSIOGRAPHY (GEOMORPHOLOGY). The description and interpretation of the surface features or topographic pattern of the earth. The scientific interpretation of scenery. The science of physiography is one of the major subdivisions of the earth sciences. The term is sometimes loosely used as synonymous with geography, hence the recent tendency to use geo-

Map of North America, showing its main political and physical divisions.

morphology in its place. Since the scenery of any region is fundamentally the present stage of its geologic history, it naturally follows that a discussion of the origin of the topographic or scenic features must include not only an account of the processes of **erosion** and **deposition** which are now active, or have been active in the region, but also the manner in which the agents of erosion have been affected or controlled by the stratigraphy and structure. The relatively modern science of Geomorphology is peculiarly American in its origin and development, and the United States has been divided into a number of physiographic provinces whose natural boundaries have little or no relation to the political or state boundaries. (R.M.F.)

PHYSIOLOGY. A division of biological science which deals with the normal functions of the living body. General physiology is a science which treats of the underlying physical and chemical foundations of vital processes. Physiology in the usual sense is concerned with the more evident vital processes themselves, analyzed to some extent in terms of physics and chemistry but without any attempt to reduce them generally to purely physico-chemical fundamentals.

Physiology, especially the physiology of man, deals with many details of the processes which maintain a normal state of vital activity within the body. Among them the maintenance of a normal internal environment is intimately associated with blood chemistry and the circulation. The maintenance and utilization of reserves of material, the action of **enzymes, nervous coordination,** and **chemical coordination** by **hormones** are other important factors. The response of organs to coordinating influences is also involved in this subject. The **all-or-none law** bears upon this topic.

Much of the material of physiology is associated with the organ systems. It is briefly considered under **contractility, digestion, respiration, circulation, excretion,** and **reproduction.** A limited amount of physiological material is also mentioned under the various organ systems associated with these processes. (A.W.L.)

PHYSIOTHERAPY. An aid to the treatment of the sick or injured by means of physical agents. This includes massage, various forms of light, heat, and electricity, ultra-violet light, air, water, and exercise. Physiotherapy is used extensively in restoring function of wasted, stiff, or contracted muscles after injuries, especially fractures of bones, or after **paralysis,** particularly infantile paralysis. (R.S.M.)

PHYSOPODA. Thysanoptera.

PHYTOMONADIDA. Mastigophora.

PICA, PIKA. Mammalia, Rodentia. Small **rodents** related to the rabbits. They live chiefly at high altitudes, ranging from 11,000 to 19,000 feet, and are found only in the northern hemisphere. Two species of the genus *Ochotona* occur in the mountains of western North America and about two dozen in the Old World. All are compactly built, with small ears and a rudimentary tail. In the Old World they are also called tailless hares or mouse-hares. (A.W.L.)

PICHI. Mammalia, Edentata. The pigmy **armadillo,** *Chlamyphorus,* of Argentina. (A.W.L.)

PICIFORMES. An order of birds including the **woodpeckers, toucans,** and related species. They are found in all parts of the world except the Australian region. Most species nest in holes in trees. (A.W.L.)

PICKEREL. Pisces, Teleostei. Fresh-water fishes (**Pisces**) of three species closely related to the **pikes** and muskellunge. All are North American, living in streams and lakes. They differ from the pike and muskellunge in having both the cheeks and the opercula fully scaled. The little pickerel of the Mississippi Valley and Great Lakes Basin is sometimes called the grass pike, and the true pike is sometimes known as the northern pickerel. All of these species belong to a single genus, *Esox.* (A.W.L.)

PICRIC ACID. Phenols.

PICRITE. A rock which, like **peridotite,** is made up chiefly of **femic** minerals, but contains a little **feldspar,** usually **labradorite.** Sometimes **analcite** is present, in which case the rock is called an analcite-picrite. (E.S.C.S.)

PIDDOCK. Mollusca, Lamellibranchiata. A **bivalve mollusk** that bores in soft rock and floating wood. Especially a European species of the genus *Pholas,* commonly used as bait and in some localities regarded as a delicacy. The family to which these animals belong is near that containing the **shipworms.** Also spelled piddick. (A.W.L.)

PIER. A pier is a **masonry** structure acting in compression, the purpose of which is to support, in a suitable manner, some superstructure such as a **bridge**, a **trestle**, or a wall. Wharves which project into the water to accommodate vessels which berth alongside are also called piers. Piers of this type allow a great many more ships to be docked in a given length of water frontage. The pier may vary from a simple platform-like structure supported on **piles**, to a costly plant which is roofed and walled and provided with elevators, freight storage rooms, passenger waiting rooms, customs inspection facilities, etc. In bridge practice the pier is usually the intermediate support of a multiple span bridge, its function being to support the intermediate ends of the spans and to do so with minimum obstruction to the stream. Such piers are often made of reinforced concrete, though, in earlier days, they were made of ashlar stone masonry. The pier is built with its long dimension parallel to the stream so that it will receive a minimum of impact of floating debris, ice, and other water-borne loads. It must support the dead weight of the bridge, and loads due to wind acting on itself and on the bridge and moving load, traction forces, and live and impact loads. In building construction the wall pier is an enlarged section of the wall similar to a **column** which provides lateral rigidity for the wall and may be used to support beams or trusses. (F.T.M.)

PIEZO-ELECTRICITY AND PYRO-ELECTRICITY. Certain **crystals** manifest the curious property that, when subjected to strain (tension or compression) in certain directions, they develop **electric charges** on surfaces not parallel to the strain. Notable examples are Rochelle salt ($NaKC_4H_4O_6 \cdot 4H_2O$) and quartz (SiO_2), the latter being commonly used because of its mechanical strength and durability. The directions in which strain will produce this effect are called the "electric axes" of the crystal; in quartz there are three, perpendicular to the lateral edges and parallel to the lateral faces. If a block or plate be cut from a quartz crystal as indicated in Figure 1 and squeezed, as in a vise, the opposite faces become oppositely charged. This phenomenon, observed by Haüy in 1782 and rediscovered by Curie in 1880, is known as the piezo-electric effect. It is found that the electric polarization is proportional to the strain. There is also an inverse piezo-electric effect; that is, if the specimen is put between oppositely charged metal plates, it either contracts or expands in the direction of the electric field. These phenomena have been intensively studied in recent years by W. G. Cady and many others.

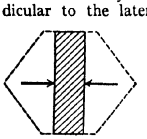


Figure 1.

The heating or cooling of crystals sometimes develops electric charges in similar fashion. In some cases, at least, this may be a secondary result of thermal expansion or contraction, that is, an indirect piezo-electric effect. This phenomenon is known as pyro-electricity.

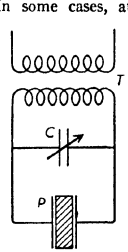


Figure 2.

If a quartz plate is subjected to a rapidly alternating electric field, the inverse piezo-electric property causes it to expand and contract alternately. As an elastic body, the plate has a certain natural frequency of expansion and contraction in the direction of the field, and if the field is made to alternate with the same frequency, the plate responds with a vigorous resonant vibration. This reacts, through the direct piezo-electric property, to augment the electric oscillations. A circuit arranged for this purpose, as in Figure 2, is known as a piezo-electric or crystal oscillator, the crytal itself, *P*, being the piezo-electric resonator; *I* is the oscillation transformer, and *C* a variable condenser. This device is now much used as a **frequency** control in radio generating circuits. (L.D.W.)

PIEZOMETER TUBE. A piezometer tube is a tube which is inserted into a region of fluid flow so as to obtain in the connecting tubing a pressure equal to the static pressure existing in the stream. If the piezometer tube be not carefully located, it will receive some impact or suction by **Pitot** action, and the pressure indicated by it will be in error. For this reason, the piezometer tube location has been the subject of some considerable study. It should open into the stream perpendicular to the thread of the stream, and be made flush with the conduit wall. (F.T.M.)

PIG. Mammalia, Artiodactyla. A group of hoofed animals with two functional and two reduced toes on each foot, all with separate metacarpal or metatarsal bones. They are not ruminants (i.e., they do not chew the cud). The true pigs make up the family Suidae and a closely related family Tayassuidae contains the **peccaries**.

Pigs are native to the warmer parts of Europe and Asia, the Oriental region, and Africa. None occur in North or South America, although feral races have developed in some areas. In these continents the peccaries are the only native piglike animals.

Two of the most peculiar species of pigs are the **babirusa** of Celebes and Boru and the **wart-hogs** of Africa. The former have four tusks in the male sex, all directed upward and recurved. The enormous heads of the wart-hogs, with their wartlike protuberances and stout tusks, make these animals conspicuously ugly. (A.W.L.)

PIGEON. Aves, Columbiformes. The birds (**Aves**) of this order are almost exclusively characterized by the name pigeon or dove, although a few related species of the Old World are known as sand grouse. The extinct dodo also belonged here.

Pigeons and doves have the beak swollen at the tip and covered with soft skin at the base, about the nostrils. In North America the group is represented by the band-tailed, *Columba fasciata*, and red-billed pigeons, *Columba flavirostris*, of the western part of the continent, and by several species of doves of similar distribution. The turtle dove, *Streptopelia*, is the only widely distributed species, although the extinct passenger pigeon, *Eclopistes migratorius*, remains a memory of one of the most abundant and widely distributed birds. Numerous other species are found in all of the faunal regions of the world. They bear the names dove or pigeon, which have no exact scientific distinctness, with the exception of an Australian species called the wonga-wonga. The **dodo** of Mauritius and the **solitaire** of Rodriguez Island, both now extinct, were giant flightless pigeons. The last of these birds disappeared in the late seventeenth and in the eighteenth centuries, respectively. (A.W.L.)

Mourning dove, *Zenaidura macroura carolinensis*. Soft olive brown above, buff-gray below, white tips to outer tail feathers.

PIGMENTATION IN ANIMALS. The accumulation of colored materials in living things which is partly or wholly responsible for the characteristic **coloration** of different species. Pigments also serve special purposes in the body. In these functions the presence of color may be entirely incidental to the chemical composition of the material.

Pigments are important in visual organs. Here im-

pervious black or dark brown deposits insulate the sensitive nerve endings against all light except that which is transmitted by the lens or cornea In the eyes of some **arthropods** the pigment is redistributed to admit more light when the surrounding illumination is dim than when it is bright A similar result is gained in the vertebrate eye by the muscular adjustment of the pigmented iris to change the size of the pupil through which light is admitted Still another pigment, the visual purple (rhodopsin) is found in the rods of the retina of the vertebrate eye It is bleached by light and resumes its color in darkness, it is associated with the sensitivity of the eye

Pigments in the superficial layers of the body are also useful in some animals, independently of the relations discussed under coloration A familiar example is the protective pigment deposited in the human skin as a protection against **ultraviolet light** The deposition normally follows excessive exposure to sunlight or to other sources of ultraviolet, and the deposits are lessened when exposure is reduced These deposits are in the form of granules of melanin in the cells of the innermost layer of the **epidermis** and in branching cells called melanoblasts in the underlying dermis The pigment loses its granular form and becomes diffuse as the epidermal cells move toward the surface Melanoblasts are possibly active in the formation of the pigment granules The pigmentation of hair is not thoroughly understood but both granular and diffuse pigments have been reported

A definite relation also exists between the normal illumination of the body and pigmentation in other animals, but the nature of the relation is not always known and a definite value to the animal need not exist A familiar example is the dark upper surface and light lower surface of fishes, whether the upper surface is dorsal, as in most species, or lateral, as in the **flatfishes.** Lack of pigment in fishes of subterranean waters is closely associated

Pigmentation of **insects** has been shown in several cases to respond to light Lessened illumination may result in deeper colors, and some observers have secured the same result by moderate increase of light Extreme changes, however, have resulted in decreased pigmentation in some experiments. Humidity and temperature also effect the depth of pigmentation in some insects, and may modify the pattern

Incidental colors like the pink flush of human skin result from the presence in the body of the respiratory pigments, haemocyanin and haemoglobin, and waste products Protein wastes deposited in the superficial tissues of insects are one source of color and the bile pigments of vertebrates, formed by the liver in the modification of haemoglobin, are a source of color in some organs

The entire subject is closely associated with the chemistry of the living organism on the one hand and with coloration and mimicry on the other (A W.L)

PIGMENTS IN PLANTS. Among higher plants, whether moss, fern, or flowering plant, green is the outstanding color Many colors besides green are found in plants, especially in the flowers and fruits

Colors in plants are due to definite chemical compounds, mostly of complex structure These may be found dispersed in the **cytoplasm,** in the sap of **cells,** or in special bodies called **plastids.**

As it occurs in the green cells of a plant, chlorophyll (See **Pyrrole and Related Compounds**) is not a single pigment, but two very similar pigments called chlorophyll a and chlorophyll b Associated with these are two other pigments, carotin and xanthophyll Chlorophyll a has the empirical formula $C_{55}H_{72}O_5N_4Mg$, and that of chlorophyll b is $C_{55}H_{70}O_6N_4Mg$ The structural formula ascribed to chlorophyll suggests that of haemoglobin of the blood, in which iron is found instead of magnesium The formula for carotin (See **Vitamins**) is $C_{40}H_{56}$ and for xanthophyll $C_{40}H_{56}O_2$ These pigments may be readily removed from the leaf by heating the latter in ether, alcohol, and other organic solvents, in which the pigments are readily dissolved They are not soluble in water A solution of chlorophyll is fluorescent, that is, appears green when held between the observer and light, but deep red when seen in reflected light Chlorophyll has been purified by repeatedly dissolving and crystallizing and is obtained as small dark green crystals Solutions of chlorophyll do not keep well in light Chlorophyll is a substance of some commercial value, large quantities being used in coloring soaps, candles, medicines, and foodstuffs

The manner in which chlorophyll is formed in the cells of a plant is not well understood as yet It is not usually present in the cells of the seed or in the spores As the seedling pushes up into the light it becomes green, light being a very necessary factor for the formation of chlorophyll Chlorophyll is an important factor in **photosynthesis.**

Less is known about the yellow pigments carotin and xanthophyll They are almost invariably found in the **chloroplastids,** along with chlorophyll They also occur in chromoplastids, which are plastids of any color Carotin is soluble in petroleum ether, while xanthophyll is not Solutions of these substances are not broken down by light The yellow color of carrots is due to the presence of large quantities of carotin Lycopin, a compound having the same formula as carotin, causes the red color of ripe tomatoes In brown **algae** another yellowish pigment fucoxanthin occurs along with chlorophyll The function of these several yellow pigments is not known It has been frequently suggested that in some way they play a part in the formation of **carbohydrates** in the plastids

The leaves and stems of many plants contain a pigment, anthocyanin Unlike the other pigments, which are found in definite bodies or plastids, anthocyanin occurs in solution in the cell sap or diffused throughout the cell Anthocyanin is soluble in water, alcohol, and other organic solvents Acidic solutions of this pigment are red, basic solutions usually purplish Similar differences are caused by the nature of the cell sap Several functions have been ascribed to anthocyanin When it occurs in abundance in the leaves of plants it is assumed to protect the tissues from injury by too great light intensity Again it has been held to absorb energy which might otherwise be lost to the plant, and so increase the temperature of the tissues around it The color of flowers, whether due to anthocyanin or to other pigments, is usually considered to attract insects, which are the agents effecting **pollination**

When pigments are completely lacking from the cells of a plant, the latter is white White streaks or patches sometimes occur in the leaves and add greatly to the attractiveness of the plant Not infrequently leaves are borne which are completely white Occasionally all the leaves of a branch are white. Attempts to propagate such white branches are necessarily unsuccessful, since these branches contain no pigment which will enable photosynthesis to take place While attached to the plant, these white branches derive nourishment from normal, green tissues in other branches. (R M W.)

PIGMENTS, PAINTS, VARNISHES. Solid pigments, usually in admixture with a medium of suspension, are widely used (1) in preservative paint coatings, such as those for wood and steel structures and machinery, (2) in decorative paint coatings, either purely artistic as for paintings, enamels, glass, ceramics, or also utilitarian as for interior decoration of walls, floors, furniture, and for automobiles, cars, trucks, (3) in the manufacture of linoleum oilcloth, window shades, book covers, (4) in the manufacture of paper, wall paper, printing inks, writing inks, (5) in plastics such as rubber, celluloid, bakelite, (6) in cosmetics This variety of uses suggests a wide variety of materials adapted for

each purpose, as well as the many different colors involved The sources are mainly inorganic, but a number of organic preparations are also important The properties to be considered for each use are (1) opacity, hiding power, covering power, (2) durability, preservative power, (3) beauty and permanence of color

A convenient classification for the present purpose is that of color

White pigments Any white powdered substance of sufficient permanence in the vehicle to be used and under the conditions to which the finished material is to be subjected, is available (1) **Calcium** carbonate is one of the cheapest white pigments, and is used as such, mixed with linseed oil, in putty (gray), and with water for wall coatings (white) (2) **Zinc** oxide (zinc white) is used in compounding rubber, and in paints yielding a rather hard film, not colored by hydrogen sulfide in the air (3) **Barium** sulfate (**barite**) used as a filler in paints, is not excellent when used alone (4) **Zinc** sulfide (30%) plus barium sulfate (70%), known as lithopone, is prepared by reaction of zinc sulfate plus barium sulfide in water (5) **Lead** basic carbonate (white lead) is widely used as a white paint pigment yielding a rather soft film readily colored brown (lead sulfide) by hydrogen sulfide in the air All lead pigments are poisonous White lead and zinc white are frequently used in admixture (6) Lead basic sulfate (sublimed white lead), made directly from lead ores by roasting in air, may contain 20% lead oxide and 5% zinc oxide, is cheaper than genuine white lead and is frequently mixed with other pigments (7) **Titanium** white (titanium dioxide) is remarkable for its whiteness and high hiding power It finds important use, either pure or in admixture, in enamels for interior work For exterior use, titanium oxide alone "chalks," and is accordingly best used in admixture with other pigments, for example, zinc oxide (8) **Silica**, and china clay, on account of their cheapness, are frequently used in admixture with more expensive pigments

Yellow pigments (1) Cheap, permanent yellow pigments are those of hydrated **ferric** oxide, such as the mineral **limonite**, frequently with clay, known as ochres, yellow, and siennas, yellowish brown These pigments are not affected by an oil medium nor do they affect other pigments, and they furnish a considerable range of tints in the yellow, brown, red range (2) **Lead** monoxide (litharge), brown-yellow, is used in painting steel, as it is slightly basic, thus increasing resistance to corrosion, causes paint oil to dry quickly (3) **Lead** chromate (chrome yellow) is excellent in hiding power and brilliance and permanence of tint Different shades are prepared depending upon conditions of manufacture, e g , light shades by use of acidified solutions in the precipitation Like all lead pigments, the chromate is darkened by hydrogen sulfide (4) **Zinc** chromate is permanent and unattacked by hydrogen sulfide, but not as excellent in tint and hiding power as lead chromate (5) **Arsenic** trisulfide (orpiment) either as the natural mineral or artificially prepared Not permanent to light, affects lead pigments, causing darkening (due to sulfide), and is poisonous (6) **Cadmium** sulfide, very permanent and brilliant, not to be mixed with lead pigments on account of darkening by lead sulfide (7) Gamboge, a **resin**, is used as a water color pigment, in varnishes, and in lacquers for brass (8) **Cadmium** lithopones, made by precipitation of cadmium sulfate and **barium** sulfide or **selenide** (or sulfide-selenide) solutions

Brown pigments (1) Cheap, permanent brown pigments are those of hydrated **ferric** oxide and **manganese** dioxide containing clay minerals Various shades of yellow to brown to red are obtained from a variety of forms found in nature, and darker shades are made by heating these The yellowish-brown forms are known as siennas, and the darker reddish-brown as umbers. Not affected by the oil medium, do not affect other pigments of good hiding power, cheap, wide variety of shades (2) Van Dyck brown or Vandyke brown, by heating cork or woody matter to moderate temperatures out of contact with air, and is usually used in admixture with other pigments.

Green pigments (1) **Chromic** oxide (chrome green) is permanent under atmospheric conditions and at high temperatures, of excellent tint, of permanent color, can be mixed with other pigments, is unaffected by hydrogen sulfide, alkali, or acids Other chrome greens (Brunswick green) are made by mixing chrome yellow and Prussian blue (2) **Copper** greens are copper basic carbonate (**malachite** mineral), copper basic acetate (verdigris), copper basic **arsenite** (Scheele's green), copper acetoarsenite (Paris green, emerald green) These are limited in their satisfactory use due to lack of permanence of color, low hiding power, reaction with sulfide pigments or with moisture, poisonous nature of arsenic compounds (3) Green lakes, by precipitating certain dyestuffs along with inorganic salts, e g , of tin, **aluminum** Used in inks for printing, and for wall finishes

Red pigments (1) **Ferric** oxide (Indian red, Venetian red), either as the mineral **hematite** or prepared by heating ferrous sulfate (alone or with calcium oxide) to the desired temperature Not affected by oil medium, does not affect other pigments, is of good hiding power, cheap, permanent, used in cosmetics, and in glazes (2) Trilead tetroxide (red **lead**), orange-red, causes paint oil to dry rapidly, used largely on structural steel alone or as priming coat (3) **Antimony** trisulfide (antimony vermilion), used in paints (not mixed with lead pigments), and in compounding red rubber (4) Red lakes, by precipitating certain dyestuffs, e g , madder, cochineal, aniline dyes, along with inorganic salts, e g , of tin, aluminum Used in inks for printing, and for wall finishes

Blue pigments (1) Iron **ferroferricyanide** (Prussian blue, Turnbull's blue), used as a paint pigment, in inks, in laundering, permanent with acids, color destroyed by alkalis (2) Ultramarine blue (sodium aluminosilicosulfide), used as a paint pigment, discolored by acids, not used where its sulfide content causes color reaction with other pigments, e g , lead pigments (3) **Cobalt** blue (cobalt aluminate), by heating to a red heat the precipitate obtained by mixing cobalt salt solution, alum solution, and sodium carbonate solution Used in oil or water medium and in glazes, not reactive with other pigments, permanent under atmospheric conditions and at high temperatures (4) **Copper** blue (azurite, copper basic carbonate), color not permanent with sulfides, nor when heated

Black pigments (1) Lamp black (amorphous **carbon**), made by the incomplete combustion of natural gas or petroleum (2) Bone black or drop black, made by the destructive distillation of bones Used as a paint pigment, and in stove polishes (3) Ivory black, made from ivory cuttings as bone black is from bones Reputed the blackest of pigments, expensive Used in high-grade varnishes and enamels (4) Graphite (crystalline carbon), natural or artificial, inert, permanent. Used in protective paints for metals (5) Asphalt Used as a protective varnish on metals, concrete, wood—especially roofing materials

In the manufacture of paints the (1) pigment is suspended in a (2) medium—drying oil, or water—with or without the addition of a (3) thinner or volatile solvent to the drying oil—turpentine, gasoline, benzene are used as thinners—or a (4) drier Driers are added to hasten the hardening of the drying oil **Manganese** borate, red **lead**, litharge, finely divided manganese, **cobalt**, **nickel**, **lead**, and metallic soaps, such as linoleates and resinates of manganese, lead, cobalt, are used as driers. Casein increases the adhesiveness of water paints

Varnishes are similar to paints that contain thinners, in that part (or all) of the medium evaporates The medium may consist of (1) a drying oil, a thinner, and a drier, with or without pigment In the use of paints and varnishes a thin film of the material is formed and left exposed on a surface, and the hardening process

consists in oxidation of the unsaturated drying oil. (2) **Alcohols, turpentine, benzene,** naphtha, **acetone,** tetrahydronaphthalene, **ethyl acetate,** ethylene **glycol,** monoethyl **ether,** in which a **resin,** such as shellac, dammar, copal, sandarac, rosin, synthetic resins of the phenol-formaldehyde type or an **ester,** such as cellulose acetate or cellulose nitrate is incorporated. On exposure, the solvent evaporates, leaving the resin or ester as an adherent film. Some resin films are brittle and not adapted to resist wear, while some ester films are notably permanent and used for such purposes as the coating of automobiles and cloth exposed to the weather.

Paints, varnishes, and lacquers are made for many special purposes. Of special interest may be mentioned (1) shingle stains using creosote oil, or fish oil, (2) luminous paints using radioactive materials such as radium or mesothorium compounds with **barium, strontium,** or **calcium** sulfides or tungstates, (3) linoleum made by mixing specially prepared oxidized linseed oil, rosin, cork dust, and pigments, spreading the mixture on canvas, and allowing to dry. (R.K.S.)

"PIGNOLEA" NUTS. These are the seeds of certain European pines growing in countries bordering the Mediterranean Sea. They are an important food article in European countries; in America they are used mostly as salted nuts and in various candies. (R.M.W.)

PIKE. Pisces, Teleostei. A badly misused name applied in various forms to a number of fresh-water food and game fishes (**Pisces**). They are most abundant in the rivers and lakes of the northern states and Canada. The true pike, *Esox lucius,* is a fish related to the muskellunge. It attains a weight of forty pounds and a length of four feet, and is one of the principal game fishes of the north. This species is also called the northern pickerel, but it differs from the closely related pickerels in having the cheeks scaly but the lower half of the opercula bare. Two other species, the wall-eyed pike, *Stizostedion vitreum,* and the sand pike, *Cynoperca canadensis,* are more closely related to the perch than to the true pike. The former is also called the wall-eye, glass-eye, pike-perch, and jack salmon, and in the south is commonly called the salmon. The sand pike is also known as the sauger or gray pike. The wall-eyed pike is an excellent food and game fish, attaining a weight of twenty-five pounds. The sauger is smaller and less desirable. (A.W.L.)

PIKE-PERCH. Pike.

PILCHARD. Sardine.

PILE. In **foundation** work the pile, often called a bearing pile due to the fact that it carries a direct compressive load, is a postlike member of timber, steel or concrete which is driven into soft ground to support a structure. In case soil conditions are such that an extremely large **footing** or **grillage** is required, piling is used to give sufficient bearing power. Piles are usually necessary for unstable soils and may be used in other types where extremely heavy loads are carried. Formerly, all piling was cut from trees, but, due to the increasing scarcity of timber, especially of the type and size required, reinforced concrete or steel piles are now extensively used.

Many large buildings are constructed on a mat of piles driven on three- or four-foot centers. These are surmounted by a monolithic concrete capping which adds to the bearing power by making available whatever bearing power the soil between the piles may possess. Ordinarily, piles are driven deep enough to reach fairly firm soil. Sheet piling differs from bearing piling in that it is used where a continuous wall is required such as in the **cofferdam.** It may consist of vertical wooden planks driven in close contact or specially rolled steel shapes, having interlocking edges, which are driven so that each individual section is firmly united with adjacent sections. Sheet piling is subjected to **lateral** pressures due to earth or water and if driven in water must withstand the impact of floating debris.

Piles are driven by means of a water jet or by a pile driver. The former method, used in sand or gravel, consists of washing the material away from the end of the pile by means of a jet of water. As the material is displaced the pile sinks by its own weight or is driven by light blows from a pile driver. The drop hammer pile driver is made up of a **casting,** which fits into guides on vertical posts, and the machinery and tackle necessary to raise the hammer. The hammer is raised over the end of the pile and then allowed to fall in the guides by gravity. The force exerted by the hammer dropping upon the end of the pile causes it to sink a certain distance. This force is proportional to the weight of the hammer and also to the drop. The single-acting steam hammer pile driver raises the casting by steam pressure and then allows it to drop by gravity, while in the double-acting type steam pressure raises the casting and increases the force of the blow over that due to gravity. It is preferable to the drop hammer type since it causes less damage to the pile and can deliver more blows in a given period of time. (F.T.M.)

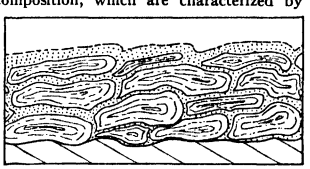
PILE DRIVER. Pile.

PILES. Hemorrhoids.

PILIDIUM. A ciliated (**cilia**) larval form of the **nemertine** worms. It forms as a two-layered saccular structure with a band of cilia around the base and a sensory organ at the apex, resembling in some details the **trocophore** larvae of other animals. The worm develops inside the pilidium and when it breaks out the pilidium perishes. (A.W.L.)

PILL BUG. Crustacea, Isopoda. A small oval terrestrial **crustacean,** commonly found in moist situations at the surface of the ground. They hide in crevices among rocks, under wood, and even invade basements. These forms are also commonly known as sow bugs and wood lice. The pill bugs are properly the species with the power of rolling up into a ball so nearly spherical that it will roll on a slight incline. (A.W.L.)

PILLOW LAVA. Effusive volcanic rocks, generally of **basic** composition, which are characterized by pillow-



Cross-section of pillow lava. (Field, *Outline,* Barnes & Noble.)

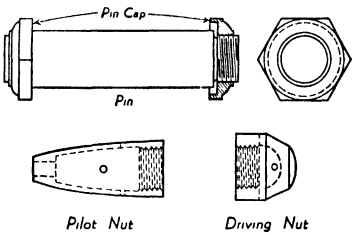
like or bun-like structures formed during the concomitant movement and congelation of the lava. Most pillow lavas are basalts. Frequently the "pillows" have a skin of rock glass called tachylyte. The evidence of the rapidity of the chilling suggests that pillow lavas owe their peculiar structure to having flowed into a body of water or as having originated as aquatic lava flows. (R.M.F.)

PILOCARPINE. Alkaloids.

PILOT FISH. Pisces, Teleostei. 1. A small marine fish, *Naucrates ductor,* which accompanies sharks and is sometimes supposed to guide and protect them. It is bluish with several dark vertical bars. 2. One of the **whitefishes** found in fresh water from the northern states to Alaska. (A.W.L.)

PILTDOWN MAN (Eoanthropus). Paleontology of man.

PIN. The structural pin is a solid steel cylinder, usually heat treated, which is used to connect steel members when freedom of angular movement at the joint is desired It is threaded at both ends to receive large pressed or cast steel pin **nuts**, which are used to secure the pin in its final position in the structure The pin-connected joint is usually assumed to be frictionless but there is always a certain amount of friction present The pin may be in direct contact with the member, as in the case of the **eye bar**, or it may pass through plates called pin plates which are attached to the members It is also used to transfer the loads from the bridge **truss** to the end **bearing** Pins are subjected to bearing, shearing, and bending **stresses.**



After the members of a pin-connected joint have been assembled in position so that the pin holes line up, the pin is driven through the holes This driving requires the use of a pilot nut and a driving nut, which are screwed on the ends of the pin The pilot nut guides the pin through the pin hole and the driving force is applied to the driving nut These nuts also protect the threads during the driving operation When the pin is in position the nuts are removed and the pin nuts screwed on (C W C)

PINACOCYTE. A flattened **cell** of the outer layer of the body wall of **sponges** These cells are able to change their shape (A W L)

PINACONE. Acetone.

PINEAL EYE One of two organs similar to an eye in structure which develop from the roof of the brain. The pineal organ lies behind the parietal organ when both are present, but the evidence of embryology and of their connections with the brain suggests that the two were primitively paired, the pineal organ belonging to the right side, the parietal to the left In amphibia it is the pineal organ, in reptiles the parietal, which is modified for light reception The pineal organ undergoes a glandular modification in many vertebrates, including the mammals, leading to the unproved suggestion of an endocrine function (A W L)

PINEAPPLE. *Ananas sativus* Bromeliaceae The pineapple is a native of northern South America Even in early times it had spread in cultivation to Peru and Mexico, now it is grown throughout tropical lands all over the world On the short unbranched stem are many thick pale green leaves with sharp-toothed margins. At the top of the stem is borne the **inflorescence**, a cone-like bunch of bluish flowers, each in the **axil** of a **bract** During ripening of the fruit all parts of the inflorescence, including the axis, bracts, **sepals**, **petals**, and **ovaries**, coalesce and become very fleshy, forming the familiar collective fruit The axis continues beyond this fruit as an elongate rosette of stiff-toothed leaves, which are generally marketed with the fruit Only rarely do seeds form in this fruit, so propagation is accomplished by cuttings or by means of suckers which are formed quite abundantly

The fruits are cut and sent to northern markets in a green state, coming into the United States mainly from Porto Rico and Cuba In Hawaii, where the pineapple is an important plant, immense quantities are canned and put on the market.

From the leaves of the pineapple is obtained a very strong but fine white flexible fiber which is unaffected by water and extremely durable From this fiber a delicate cloth may be woven. (R M W)

PINHOLE "IMAGE." If a small opening is made in one side of a darkened room or box, an inverted picture of objects outside appears upon the wall opposite the opening Such a picture differs from a true image in that it is not formed by light from a given point of the source diverging and being reconverged at the corresponding image-point, as by a lens, but is an effect of the rectilinear propagation of light The only spot on the screen reached by light from a given point of the source is that in direct line with the opening For this reason, pinhole images are of low intensity On the other hand, they are free from the distortions to which lens images are subject, and with sufficient exposure, very good photographs can be made by means of them The pinhole image also affords an excellent means of viewing eclipses of the sun (L D W)

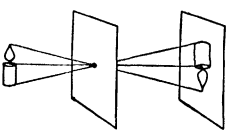


Diagram showing formation of pinhole image.

PINION. A pinion is the smaller of a pair of mating **gears** Usually it is the driving member (F T M)

PINK BOLLWORM Insecta, Lepidoptera A widely distributed enemy of cotton which probably originated in India or Africa The adult is a small gray-brown **moth**, *Pectinophora gossypiella*, and the **caterpillar** is one-half inch long and is pinkish above The **larvae** work in the flowers and bolls, causing imperfect development and destroying seeds and lint It also attacks other plants, including the hollyhock and okra

This species is found in the western part of the cotton-growing areas of the United States Vigorous measures have been taken to eliminate it, for no adequate methods of control have been discovered (A W L)

PINNATE. Leaf.

PINNIPEDIA. A division of the mammals containing the **seals**, **walruses**, and related forms Sometimes regarded as an order and sometimes as a suborder of the order **Carnivora** (A W L)

PINNULE. A small lateral branch of the arm of a feather-star (sea-lily, **crinoid**) The arms of these animals are sometimes divided into two or more radiating branches but whether branched or simple they bear small lateral branches which give them a feathery form, these are the pinnules (A W L)

PINO. The column of smoke and ashes emitted by an explosive **volcano**, usually in the beginning or in the early stage of an eruption The term is of Italian origin signifying the cauliflower-like shape of the cloud as observed during the eruptions of Vesuvius (R M F)

PIÑON NUTS. Conifers.

PINWORM. Nemathelminthes, Nematoda A small roundworm (**Nematoda**) which lives in the alimentary tract of man, chiefly in the large intestine The female is about two-fifths inch long and the male somewhat smaller Eggs are taken into the mouth in water or from the hands, or on raw vegetables. The entire life cycle takes place in the one host.

Pinworms are usually not harmful but they may cause

nervous symptoms and are said sometimes to lead to appendicitis (A.W.L.)

PIPE. Piping is constructed of cast iron, wrought iron and steel, brass, or copper The use of brass and copper pipe is limited by its cost to piping in which flexibility, appearance, or resistance to certain forms of corrosion are taken into account Brass and copper piping are used principally for oil lines Wrought iron is used under special conditions where its resistance to corrosion is expected to produce a longer working life and when the temperature-pressure service is not too rigorous Brass pipe should not be used above 300 pounds gage and 400° F, nor wrought iron pipe above 400 pounds gage and 750° F

The bulk of piping is the low-cost and strong wrought steel pipe Cast-iron pipe is ordinarily used for drainage, and for water and gas mains laid in the soil, as it is but little affected by soil corrosion It is also used for circulating water lines when the water is salty. The resistance of wrought steel pipe to corrosion is increased by a protective coating of zinc Such pipe is designated as "galvanized" Small water pipe is often galvanized but large pipes and gas, steam, air, or oil pipe are "black"

Wrought pipe is manufactured by welding long plates, called skelp, with butt or lap weld, or by piercing and drawing a seamless pipe from a billet Butt-welded pipe has small area of contact at the weld. Its inherent weakness limits its use to sizes smaller than 3-inch. Pipe is not lap welded in sizes smaller than 2-inch Large OD (outside diameter) pipe is made by hammer welding and by spiral riveting

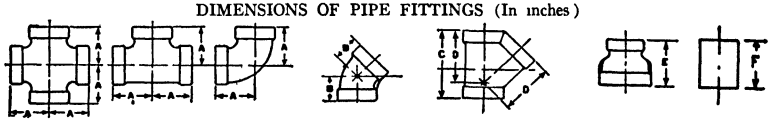
In order to meet the various service conditions economically, pipe is manufactured in several wall thickness classifications called "weights" Ordinary pipe is marketed under three weights, viz, standard, extra strong, and double extra strong The latter weight is used for high-pressure hydraulic work, but infrequently in steam power piping There are five working pressure classes, 250, 400, 600, 900, and 1350 pounds per square inch

Dimensions of standard or extra strong pipe are expressed in terms of the nominal inside diameter for sizes 12-inch and under, and the weight, i e, 2½-inch standard, 4-inch extra strong, etc When the pipe wall is thickened to provide additional strength, the increment is added to the inside so that, the outside diameter remaining constant, the same size of thread and fittings can be used for all weights. Above 12-inch nominal size the sizes are based on outside diameters, for instance, 16-inch OD by ⅜ inch Standard pipe is marketed in random lengths of 16–22 feet, extra strong in random lengths of 12–22 feet Seamless steel pipe in the smaller sizes can be obtained in very long lengths (25–35 feet) (P T M)

PIPE FITTINGS. A piping system, in fulfilling its function of providing a flow path for liquids or vapors, is rarely a straight run of pipe between two points Flows are joined, parted, started, stopped, and regulated in the piping system Only occasionally is it possible to take a "crow flight" path between end connections, the common run of pipe must follow configurations of equipment, walls, floors, beams, etc Fittings and valves, properly incorporated in the pipe system, enable it to meet these varied service conditions

In general, fittings consist of the pieces required to make turns, junctions, and reductions The straight size fittings are the 45° and 90° elbows, the tees, crosses, Y's, laterals, and reducers These fittings may also be had in special reducing sizes The fittings ordinarily have the same style of connections as the pipe line of which they form a part Fittings are made of brass for low and medium pressures in lines where appearance or non-corroding properties are needed, of cast iron for 125-pound and 250-pound WSP ("working steam pressure"), malleable iron for 150-pound WSP, and cast steel for high pressures and temperatures (P T M)

DIMENSIONS OF PIPE FITTINGS (In inches)



Cross Tee 90° Ell 45° Ell Lateral Reducer Coupling

Nominal Pipe Size	Cast Iron—125 Lb. WSP						Cast Iron—250 Lb WSP					Malleable Iron—150 Lb WSP					
	A	B	C*	D*	E*	F*	A	B	C*	D*	F*	A	B	C	D	E	F
¼	0 81	0 73	..	.	.	1 11/32	0 94	0 81				0 81	0 73	1 62	1 19	1 00	1 06
⅜	0 95	0 80				1 13/32	1 06	0 88	.		1 1/32	0 95	0 80	1 93	1 43	1 13	1 16
½	1 12	0 88	2 1/16	1 7/8		1 13/16	1 25	1 00	. .	.	1 7/8	1 12	0 88	2 32	1 71	1 25	1 34
¾	1 31	0 98	3	2 1/16		1 15/16	1 44	1 13			2 1/16	1 31	0 98	2 77	2 05	1 44	1 52
1	1 50	1 12	3 1/16	2 5/16		1 31/32	1 63	1 31			2 5/16	1 50	1 12	3 28	2 43	1 69	1 67
1¼	1 75	1 29	4 1/16	3 1/16	2 1/16	2 1/16	1 91	1 50	4 7/16	3 13/16	2 5/16	1 75	1 29	3 94	2 92	2 06	1 93
1½	1 94	1 43	4 7/16	3 11/16	2 1/16	2 5/16	2 13	1 69	5 1/16	4 1/2	2 7/16	1 94	1 43	4 38	3 28	2 31	2 15
2	1 25	1 68	5 1/16	4 1/2	2 5/16	2 5/16	2 50	2 00	6 1/16	5 5/16	3 1/16	2 25	1 68	5 17	3 93	2 81	2 53
2½	2 70	1 95	6 1/16	5 5/16	2 11/16	2 7/8	2 94	2 25	7 1/8	6 1/8	3 1/16	2 70	1 95	6 25	4 73	3 25	2 88
3	3 08	2 17	7 1/8	6 1/8	2 15/16	3 1/16	3 38	2 50	8 1/16	6 7/8	3 11/16	3 08	2 17	7 26	5 55	3 69	3 18
3½	3 42	2 39	8 1/16	6 7/8	3 1/16	3 1/16	3 75	2 63			4 1/16	3 42	2 39	8 10	6 24	4 00	3 43
4	3 79	2 61	9 1/16	7 7/8	3 7/8	3 1/16	4 13	2 81	10 5/16	8 1/2	4 1/4	3 79	2 61	8 98	6 97	4 38	3 69
5	4 50	3 05	11 1/16	9 1/16	3 1/16	4 1/16	4 88	3 19				4 50	3 05	10 77	8 43	5 12	4 22
6	5 13	3 46	13 1/16	10 1/16	4 1/16	4 1/16	5 63	3 50	15 1/16	12 1/16		5 13	3 46	12 47	9 81	5 86	4 75
8	6.56	4 28	16 13/16	13 1/16	5 1/16	4 5/16	7 00	4 31	18 1/16	14				.		7 25	5 75

* Not American Std

PIPE FRICTION. Piping carrying fluid will have a frictional surface with the fluid The extent to which friction is developed at this surface is a matter governing either the size of pipe which should be used, or the reduction by friction of pressure or velocity head in the pipe The size of a pipe is not determined alone by the weight or volume of the fluid being transported. For instance, there is no one pipe size that must be selected to carry 500 cubic feet of steam per minute At 5000 feet per minute velocity a pipe of 0 1 square foot cross-sectional area is required; at 10,000 feet per minute it is 0 05 square foot. As soon as the velocity as well as the volume is known, the pipe size is determined according to the familiar relation. (See next page)

Volume rate of flow = Velocity × Cross-sectional area

The most difficult quantity to determine in this equation is the velocity Of course, for short pipes it is easy enough to assume a velocity in accordance with actual practice This assumption is rarely one giving the most economical pipe size, but as the pipe is short the failure to strike an economic balance is of minor importance. The higher the velocity the smaller the pipe, but, at the same time, the greater the friction loss in the pipe The most economical pipe size is that for which the annual fixed cost plus the annual cost of friction head is a minimum

The following symbols are used in the formulas below

h = friction head in feet of the fluid
f = coefficient of friction
L = length of pipe in feet
v = velocity of flow in feet per second
g = 32 2
d = inside diameter of pipe in feet
D = inside diameter of pipe in inches
z = viscosity in centipoises
S = specific gravity referred to water as 1
γ = density in pounds per cubic foot
P = pressure in pounds per square foot
p = friction head in pounds per square inch

By assuming that the head lost in friction varies directly as the length of the pipe and as the square of the velocity of flow, and inversely as the hydraulic radius, the formula for feet head lost in friction is obtained

$$h = \frac{fLv^2}{2gR}$$

Practically all pipes are circular and $R = d/4$, d being the actual inside diameter of the pipe

$$h = \frac{4fLv^2}{2gd}$$

is the common formula for water pipes

The coefficient for old pipe is to be regarded as highly approximate due to the uncertain nature of the surface of pipe designated merely as "old pipe" The character of the wetted perimeter is liable to change much during the life of the pipe through tuberculation, corrosion, organic growth, scale, silt, etc

The coefficient f does not remain constant In order to fit it to the experimental hydraulic data, investigators in this field have found it necessary either to express the equation with fractional exponents on v and d or to express f as a function of v and d The equations given by Wilson, McAdams, and Setzler are

For fluid flow in copper, brass, lead pipe

$$f = .0181 + .0662\left(\frac{z}{DvS}\right)^{0.225}$$

For fluid flow in clean iron and steel pipe

$$f = .0035 + .0594\left(\frac{z}{DvS}\right)^{0.424}$$

These formulae and constants are based on turbulent flow, as opposed to viscous flow before the critical velocity is reached All ordinary water velocities are higher than the critical velocity and therefore represent turbulent flow—the more desirable of the two from the standpoint of friction drag

When a compressible fluid such as air or steam flows in a pipe with average velocity v it can be shown that the pressure loss due to friction is

$$P_1 - P_2 = \frac{4fLv\rho^2}{2gd},$$

from which can be derived

$$p = \frac{fLv\rho^2}{6gD}.$$

A formula for f in terms of the dimensionless group $\left(\frac{Dv^\rho}{z}\right)$ is

$$f = .0054 + .375\left(\frac{z}{Dv\rho}\right),$$

z for steam is

$$z = .0083 + 2 \times 10^{-5}t,$$

t being the steam temperature

The friction loss through steam fittings and valves can only be approximated (F T M)

PIPE JOINTS. Adjacent sections of pipe are connected together in various ways, but all connections can be grouped under these four headings.

1 Packed joints, such as leaded bell and spigot, or plain-end coupling Mainly used for low pressures, soil pipe, drainage, large outside-diameter pipe
2 Screwed joints, such as couplings and unions Generally used for sizes less than 4-inch, but large sizes are marketed
3 Flanged joints, with companion **flanges** either loose or screwed, shrunk, riveted, or welded to the pipe Flanged fittings are generally called for in the larger sizes of pipes, and for high pressure-high temperature work they have entirely superseded screwed connections
4 Welded joints **Welds** made by the fusion process (as opposed to hammer welds) using gas or metal arc welders The first cost of the welded line is an advantage in large pipe sizes (F T M)

PIPERIDINE. Pyridine and Related Compounds.

PIPING CROW. Aves, Passeriformes Australian birds (**Aves**) of several species related to the crows and jays but not true crows They are black and white, whence comes their other name, Australian magpie Unlike the true crows these birds are quite musical and can be taught to whistle tunes and to speak They are frequently kept as cage birds (A W L)

PIPISTRELLE. Bat.

PIPIT. Aves, Passeriformes. Small quietly colored birds (**Aves**) of numerous species, related to the wagtails and warblers They are widely distributed but most species occur in the Old World In North America the common pipit, *Anthus spinoletta*, nests in the north and at high altitudes in the western mountains, and the one other species, Sprague's pipit, *A sprague*i, is a bird of the plains (A W L)

PIRACY (STREAM CAPTURE). A term used by physiographers to designate the manner in which one stream or drainage system grows at the expense of the other For example, two streams, tributaries to the master stream flowing at the foot of an escarpment, finally tap the head waters of the streams tributary to the master stream on the plateau, diverting the drainage (R.M F)

PIRANHA, PIRAYA. Pisces, Teleostei *Serrasalmo* A fish (**Pisces**) of tropical American rivers which is noted for its ferocious attacks on living animals It has very sharp teeth and is said to be attracted over considerable distances by blood Although individuals are not large, so many swarm to a feast that a wounded animal in the water is said to be stripped of flesh very quickly The species is dreaded by man Similar fishes of African waters are known as dogs of the water (A W L)

PISCES. As used in astronomy, this is the name of a **constellation** (The fishes) (Map, page 306) Pisces is a large constellation which is of importance principally because it is the twelfth sign of the **zodiac**. There are

relatively few interesting objects in the constellation although the brightest star (Alpha) is a close double which may be resolved in instruments larger than a four-inch In spite of the fact that Pisces is the twelfth sign of the zodiac, nevertheless, the **vernal equinox** is located in this constellation at present This is because **precession** has caused the vernal equinox itself to move back an entire "sign" along the ecliptic since the time when the names were first assigned

In zoology, Pisces is a class of the phylum **Chordata** made up entirely of aquatic animals which breathe by **gills** The few species adapted to leave the water either do so for short periods or remain on the wet shores A few pass longer periods out of water but only in an inert state

Fishes are characterized by the following structures 1 The skin is kept moist by glandular secretions and in many species is covered with scales 2 The appendages are in the form of fins, used in swimming 3 The **gill slits** persist in the walls of the **pharynx** and serve as the seat of the respiratory gills 4 The heart has only two principal chambers an atrium or auricle and a ventricle

Fishes are widely distributed in the oceans and in fresh waters Many species are important as food Billions of pounds are taken each year for this purpose, millions coming from a single species such as the more important salmons and marine species like the herring and cod

Classification

Subclass Elasmobranchii Fishes with **cartilaginous** skeletons

Order Plagiostomi With sharp-pointed (placoid) scales and separate external openings of the gill slits The **sharks, dogfishes, rays, sawfishes, skates,** etc

Order Holocephali With crushing plates in place of sharp teeth External openings of the gill slits partly concealed by an **operculum** The **chimaeras**

Subclass Teleostomi Skeleton composed at least in part of bone Gill slits covered by an operculum

Order Crossopterygii The air bladder is a paired ventral sac connected with the pharynx and used for breathing air Many remains of extinct species

Order Chondrostei The **paddle-fishes, sturgeons,** and *Polypterus* The skeleton is composed largely of cartilage

Order Holostei The **gar-pikes** and **bowfin** The scales are covered with a hard material called ganoin and the skeleton is bony

Order Teleostei An immense order containing most of the existing fishes All of the familiar forms such as the **catfishes,** the **trouts** and **bass, salmon, herring, flounders,** and many others belong here The group is so varied in structure that there is a tendency to elevate the many families that it contains to the rank of orders When this is done the list is augmented by more than a score of orders in addition to those mentioned here

Subclass Dipnoi The **lung fishes.** These animals have slender pointed fins, crushing plates in place of teeth, and an air sac which serves as a lung The existing species are found in Africa, tropical South America, and Australia Some live in intermittent streams and pass the dry season coiled up in a cell formed in the dried mud of the stream bed, breathing air. (W K G, A W L)

PISCICULTURE. The breeding of fishes (**Pisces**), together with other methods of maintaining the supply of these animals in heavily fished waters.

Because of the great importance of fishes as food and the consequent enormous removal each season by commercial fisheries, many species would have been depleted long ago but for artificial propagation and protection In some cases, notably salmon and trout, it is possible to secure the eggs when they are ripe by gentle pressure on the body of the female This process is called stripping The germinal secretion of the male, called milt, is then mixed with the eggs to insure fertilization The eggs are kept under favorable conditions which insure a large percentage of hatching and the young fish are protected until they are able to shift for themselves before being released in open waters Hatcheries have been erected in many parts of the country for this work.

Some of the important food and game fishes cannot be handled in this way, but by permitting them to breed normally in protected waters it is possible to avoid much of the tremendous destruction which takes place under natural conditions Waters are stocked with young fishes of a size which guarantees a much higher percentage of survival than can be expected for newly hatched young

It is possible also to increase the number of fishes in natural waters at low expense by providing breeding stock from the hatcheries, although no protection can be given to the young in such cases other than the usual legal ban on fishing during the breeding season

Most states now have rigid laws against taking fish during the breeding season or by destructive methods such as unlimited use of nets and the use of explosives Unfortunately too many persons are ready to violate fishing laws, but these measures have undoubtedly been of great value

The United States Bureau of Fisheries and the fish and game commissions and bureaus of conservation of the various states are responsible for most of the work in pisciculture being carried on in the United States (A W L)

PISOLITE. Oölite.

PISTACHIO. *Pistacia vera* Anacardiaceae This small tree, with **deciduous pinnate** leaves, is native in southwestern Asia, from which region it has spread in cultivation to the Mediterranean countries The apetalous flowers are unisexual and borne in panicles and the plants are dioecious The fruit is a drupe, containing an elongate seed with a greenish kernel, having a very characteristic flavor The kernels are used in confections and ice cream and also eaten salted

Related to this true pistachio is *Pistacia Lentiscus*, a shrub or small tree of the Mediterranean region with evergreen, pinnately compound leaves From it is obtained a **resin,** mastic, which is often chewed by the natives of Turkey It is used in varnishes and, in medicine, as a mild stimulant Another species is *Pistacia Terebinthus*, a native of eastern Mediterranean countries, which yields Chian turpentine (R M W)

PISTIL. FLOWER.

PISTON. A piston forms the movable end of a **cylinder,** the volume of which varies Variable volume needed for expansion or compression of vapors and gases, or for displacement type pumps, is accomplished by the use of a cylinder in which slides a piston The space enclosed by the cylinder walls, cylinder head, and piston, forms the volume which can be varied by the motion of the piston Pistons are extremely valuable, for variable volume mechanisms, of which they form an essential part, are the heart of such important machines as **engines, compressors,** and **pumps**

Pistons may be classified as single-acting, double-acting, disk, or trunk type, also, of course, by their material Most steam engines are double-acting, having the piston joined to the **connecting rod** by a piston rod and crosshead The piston is disk-like in shape, being relatively thin, and having the piston rod rigidly attached to it The steam engine piston is often made of cast iron, with grooves for two or three rings on its periphery

The **steam engine** piston is different from the **internal combustion engine** piston because the latter works at much higher temperatures, and usually at larger pressures than the steam engine The internal combustion engine is usually single-acting, so that its piston is of the trunk type The bore of an internal combustion engine cylinder is smaller, on the average, than the steam engine cylinder A trunk type piston is one which has the shape of a short cylinder closed at one end, and open at the other The closed end forms the piston face, in contact with the working medium The remainder of it is the skirt of the piston, and is provided to align the piston properly in the cylinder, to support the wrist pin, and to provide bearing area on the cylinder wall against the side thrust arising from the angularity of the connecting rod Since the gasoline engine operates at a much higher rotative speed than the steam engine, more attention is given to reducing the weight of reciprocating parts, such as the piston, in order to secure a better running balance Many such pistons are made of aluminum alloy The typical gasoline engine piston has a length about equal to its diameter. It carries internal bosses for the wrist pin, and is ribbed near the top to give strength to the thin sections used Piston ring grooves are machined circumferentially near the piston face There are usually two or three of these grooves, the purpose of which is to contain the compression rings Below them is another groove, which may be of the same size, but sometimes is larger, in which is installed an oil scraper ring, whose function is to prevent excessive amounts of oil being pumped by the piston up to the compression space The wrist pin may oscillate in either the piston bosses, or the connecting rod, or may float in both.

Some pistons have specially shaped heads which are designed to carry out some idea related to the shape of the combustion chamber Some are dished, some are crowned, some are very irregular in shape, but in each case the shape chosen was one which seemed especially suitable in conjunction with the shape adopted for the end of the cylinder

Double-acting designs are occasionally found in internal combustion engine practice, and such pistons are hollow disks, through which cooling water is pumped The water enters and leaves through a hollow piston rod, to which is attached a swinging or telescoping water inlet tube (F T M)

PITCH. Musical Sounds, Resins; Bitumens, Anticline.

PITCHBLENDE. Uraninite.

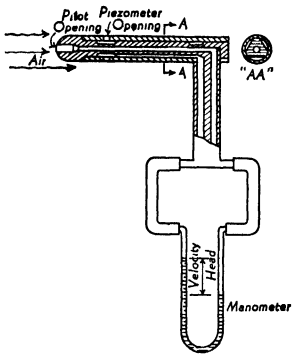
PITCHER PLANTS. Insectivorous plants.

PITCHSTONE. Pitchstone is a volcanic glass of a dull pitchy luster It contains about 5% of water, which distinguishes it from **obsidian**, of which it seems to be a variety

Pitchstone is found in a variety of colors, including grays, reds, greens, and browns, or it may be black (E S.C S)

PITHECANTHROPUS. Paleontology of man.

PITOT TUBE. This is a tube having an opening turned upstream in a fluid flow It receives the impact of the current against it, which, could it be completely converted into pressure head, would produce in the Pitot tube a pressure head of $\frac{V^2}{2g}$, superimposed on the existing static pressure of the fluid. When the pitot tube, which is the impact tube, is used in connection with a **piezometer tube**, the static pressure may be subtracted from the total pressure given by the Pitot tube, leaving a difference which is velocity head. This arrangement is frequently used for measuring the velocity of flow of water or air . For example, a Pitot head for measuring the velocity of air is shown in the illustration. The two leads from this head are carried to either leg of a U-tube manometer When a current of air flows past the head the liquid is displaced in the manometer by an amount which is proportional to the velocity squared When this manometer reading is converted into head of the fluid, i e , air, the velocity is $V = C\sqrt{2gh}$ C is the Pitot coefficient, obtained from a calibration test of the instrument (F T M)



Pitot static tube (Prandtl)

PITS. Because increase in the thickness of the walls of the **cells** of plants does not take place over the entire surface of the cell, many thin places, called pits, are left in the wall In cells in any given plant, pits have a very constant appearance, though they do vary greatly from plant to plant Pits are most abundant in the walls of **tracheids** and **vessels**, and are either entirely absent or of rare occurrence in the walls of **fibers** The thin places in the walls of two adjoining cells are found always to lie opposite to one another, though they may not have exactly the same size or shape In many cases the thickened wall of the cell forms an overhanging rim around the pit, which is then called a bordered pit, the surface-view showing a distinct border around the opening Pits which lack such a margin are called simple pits In bordered pits the thin membrane has a thickened central portion known as the torus, which is often pressed closely to the overhanging margin, and apparently acts as a valve Bordered pits are found in those cells which when mature are non-living, simple pits occur mainly in the walls of living cells

Bordered pits vary greatly in size and shape. Typically both the cavity and the opening of the pit are circular In much-thickened walls the opening of the pit may become slitlike instead of circular. Often the slits are very numerous and extend far beyond the margin of the actual cavity Pits may be found irregularly scattered over the entire surface of a cell, or they may occur in regular rows Frequently they are crowded so closely together as to appear **polygonal** in shape. The function of pits seems to be to facilitate the diffusion of liquids from cell to cell (R M W)

PITTA. Aves, Passeriformes *Pitta* Small, brightly colored birds (**Aves**) of the Old World, also called the ant thrushes, water thrushes, and ground thrushes They are only superficially like the true thrushes. (A W.L)

PITUITARY GLAND (THE HYPOPHYSIS). The pituitary gland is made up of two distinct parts or lobes, each having different functions in the body It is a round reddish mass of glandular tissue about one centimeter in size. It is situated at the base of

the brain in a depression of the sphenoid bone, called the *sella turcica*, above and behind the sphenoid sinuses of the nose.

The posterior lobe of the pituitary gland is of neural origin (derived and originating from brain tissue) The physiology of it is not completely understood, as isolated lesions of this lobe have not been seen. The secretion or **hormone** of this lobe is available for medical use and is called pituitary extract When injected hypodermically it causes smooth muscle to contract and inhibits the secretion of urine to some extent It is used to prevent abdominal distention after certain operations and in certain cases to increase labor pains or control post-labor hemorrhage It is also used in *diabetes insipidus* It is not effective when given by mouth

The anterior lobe originates embryonically from the epithelial lining of the pharynx This lobe may be divided into two main parts, the anterior and intermediate portions The function of the latter is not known The anterior portion has many functions, and several of its hormones have been isolated

Removal of the anterior lobe in young mammals causes growth to stop, bone changes to take place, the permanent teeth do not develop, and sexual development is inhibited Growth of hair, wound healing is impaired, and the basal metabolism is subnormal The blood sugar is reduced and may lead to death There are also atrophin changes in all the endocrine glands, showing that the pituitary is the master control of the endocrine glandular system

If certain extracts of the gland are injected into animals in sufficient quantities the opposite picture is seen. Giantism or a picture similar to acromegaly appears The bony skeleton and body weight increases, lactation may occur, enormous thirst and appetite occurs The blood sugar is above normal and hypertrophy of the genital organs and all the endocrine glands appears In immature animals ovulation and estrus make their appearance

Certain hormones have been isolated from the anterior lobe, some of which are made use of medically New hormones are being discovered, and on the other hand certain separate hormones are found to be a modification of one hormone

The following hormones have been described.

(1) A growth-producing hormone which is used in cases of undeveloped size It is given by injection

(2) A **gonad**-stimulating hormone which produces ovulation in immature or pregnant animals It also seems to inhibit growth It is similar in some respects to the hormone isolated from pregnancy urine which is available as "antuitrin-S," "prolan," "antophysin" The gonad-stimulating hormone may be further divided into (1) a follicle-stimulating factor which stimulates follicle formation in the ovaries, germ-cell multiplication in the testicle, (2) a luteinizing factor influencing corpus luteum formation in the ovary and interstitial cell stimulating in the testicle with increased formation of male hormone In immature animals testicular descent is hastened The formation of male hormone has the property of inhibiting pituitary function (as has the ovarian hormone), this formation acting normally to check overproduction of the gonad-stimulating hormone

(3) A hormone having influence on fat metabolism

(4) A parathyreotropic hormone The effect of this hormone on the parathyroid glands is not understood. The same may be said in regard to the hormone which has an effect on the pancreas and insulin formation

(5) A thyreotropic hormone which causes glandular hypertrophy of the thyroid gland with increase in its secretion

(6) A lactogenic hormone (prolactin) causing development of the breasts with secretion of milk.

(7) An adrenotropic hormone stimulating a portion, at least, of the adrenal gland

(8) A hormone that is antagonistic to the action of insulin (R S M)

PIT VIPER. Reptilia, Sauria A division of poisonous snakes characterized by the presence of a sharply defined pit between each eye and the adjacent nostril The numerous species occur only in Asia and the Americas The **copperhead**, water moccasin or **cottonmouth**, and **rattlesnakes** of North America are pit vipers Rattlesnakes also occur southward into South America, where the more dreaded species of pit vipers are the large **fer-de-lance** and **bushmaster** The former attains a length of seven feet and the latter twelve Their fangs are correspondingly long and their poison glands large, hence their bite is extremely dangerous The bushmaster is also called the surukuku Other pit vipers of South America are the jararaca and the labaria In Asia the group is represented by the halys vipers One small species is known as the carawila

The poison of the pit vipers acts largely on the blood (hemotarin) The prompt application of a tourniquet between the bite and the heart prevents its being carried freely into the general circulation The punctures made by the fangs should be cut across in two directions, deeply enough to cause free bleeding to their full depth Sucking the wounds is effective, but may be dangerous In any case of snake bite a physician should be secured promptly if possible and an antivenin serum should be administered (A W L)

PLACENTA. 1 A structure which attaches the unborn **embryo** or fetus to the uterine wall of the mother in the true **mammals.** It is formed of the **chorion** and the **allantois,** and the allantoic blood vessels provide communication between it and the circulatory system of the embryo In the simpler placentas the outer surface of the chorion is merely in close contact with the lining of the **uterus** and the structure is called a contact placenta or a semi-placenta Many mammals, including man, have a burrowing or true placenta In this form the chorion bears many roothke processes which invade the lining of the uterus and come into direct contact with the blood of the mother In no type of placenta do the fetal and maternal bloods mingle, although interchange takes place between them through the thin intervening tissues Many names have been applied to different forms of placentas, both normal and abnormal

The human placenta is a flat circular mass of tissue, which serves to establish communication between the mother and the child by means of the **umbilical cord** It is about six or seven inches in diameter, about one inch in thickness, and weighs about a pound During the third stage of labor, after the birth of the child, the placenta and membranes are passed (in the after-birth) If before the child is due, a separation of a portion of the placenta occurs, uterine hemorrhage results and miscarriage usually takes place The placenta is normally attached to the uterus away from the **cervix** or the opening of the uterus into the vagina When the placenta overlaps or covers this opening a condition known as *placenta previa* exists which may result in fatal hemorrhage with death of the child and mother.

2 Among the viviparous **arthropods** the young are attached to the walls of the genital passages for nourishment in some species The attaching structure is called a placenta It occurs in **onychophora, scorpions,** and a few **insects (flies)** The salpians also have an attachment of this kind (A W L, R S M)

PLAGIOCLASE. Feldspar.

PLAGUE. Plague has been known in the Eastern Mediterranean countries for 3000 years Pandemics occurred in the sixth and fourteenth centuries The latter was known as the Black Death, originated in Asia, and killed one-fourth of the population of Europe The present cycle began in Hong Kong in 1894 and spread throughout the world. Since then it has resulted in death to 10,000,000 in India alone

The disease is a rat infection transmitted to man by fleas which are infected by biting a rat. The fleas biting

human beings regurgitate infected blood into the body. The type of rat flea which will readily bite man is *Xenopsylla Cheopis* The incubation time is from two to five or more days The bubonic form is characterized by enlargement of the lymphatic glands which later become infected with the causative organism and break down with abscess formation The onset is sudden and is characterized by chill, headache, backache, high fever and rapid pulse Extreme prostration and lethargy develop rapidly with a greatly weakened heart and vomiting and delirium The swollen glands develop 24 to 36 hours after the onset of the disease Mortality is around 75% and death usually occurs on the third or fourth day Even in cases which seem to be recovering sudden heart failure may develop with immediate death

The pneumonic form is characterized by rapidly spreading **pneumonia** Here the onset is sudden, prostration extremely marked and the lungs fill up with frothy blood Death invariably results in one to four days This is the only form of plague which is transmitted from man to man without the intermediatory transmission of fleas The infection is carried by droplets coughed by the patient The strictest isolation and quarantine must be followed

Septicemic plague is a fulminating form of plague that develops so rapidly that death occurs before the signs of bubonic plague or pneumonic plague can develop It is invariably fatal Often a patient falls down and dies, having shown few or no premonitory symptoms Treatment is unsatisfactory Anti-plague serum helps only the bubonic type although not all observers agree as to its value

Preventive measures are of the utmost importance and consist of the killing of rats and prevention of transportation of rats or their fleas by ships, trains, or other means of transportation For those exposed to plague reliable observations have shown that Haffkine's plague vaccine markedly reduces the liability to the disease Even among those vaccinated, who do contract the disease, the mortality is one-tenth that of the unvaccinated (R S M)

PLAICE. Pisces, Teleostei A European **flatfish,** *Pleuronectes platessa,* related to the flounder but of exclusively marine distribution (A W L)

PLANCK CONSTANT. Planck's Law.

PLANCK'S EQUATION. An equation developed by Max Planck in 1900 to represent the **spectral energy distribution** of the radiation from a **black body** at a given temperature, in accordance with his then newly conceived **quantum theory** of radiation It expresses the emissive power of a black body within the infinitely small wave-length range, λ to $\lambda + d\lambda$, as follows

$$dE_\lambda = 2\pi c^2 h\lambda^{-5}[e^{ch/k\lambda T} - 1]^{-1}d\lambda$$

T is the absolute temperature of the black body, c is the **electromagnetic constant,** h is Planck's constant (See **Planck's Law**), and k is Boltzmann's constant (See **Ideal Gas Law**). The value of the coefficient $2\pi c^2 h$ is about $3\,607 \times 10^{-5}$ erg cm^2/sec , while the factor ch/k in the exponent is 1 432 cm deg An alternative form expresses the radiant energy density, within the same range, of the radiation in thermal equilibrium with a black body as equal to $8\pi ch\lambda^{-5}[e^{ch/k\lambda T} - 1]^{-1}d\lambda$ The law is found to agree accurately with experiment See **Wien's laws.** (L D W)

PLANCK'S LAW. The fundamental law of the **quantum theory,** expressing the essential concept that energy transfers associated with radiation such as light or x-rays are made up of definite quanta or increments of energy proportional to the frequency of the corresponding radiation This proportionality is usually expressed by the quantum formula $q = h\nu$, in which q is the value of the quantum in units of energy and ν is the frequency of the radiation

h, the constant of proportionality, is known as the elementary quantum of action or more commonly, "Planck's constant" Since q is energy and ν is frequency, h has the dimensions of energy $\times$ time, or **action.** Its value has been found to be about $6\,547 \times 10^{-27}$ erg-second Thus, if the wave length of a certain monochromatic green light is 5000 angstroms, its frequency is 6×10^{14} per second, and its energy is made up of quanta each equal to $6\,547 \times 10^{-27}$ erg-sec $\times$ 6×10^{14}/sec , or $3\,928 \times 10^{-12}$ erg

Why such a relation should exist between these natural units or quanta of radiant energy and the frequency of the radiation, is still an unsolved problem (L D W)

PLANE. A plane is a fundamental geometric concept, being one of the basic geometric elements used in the construction of geometric figures in space

The equation of any plane in **rectangular coordinates** x, y, z is of the first degree (i e , is a linear equation)

Every linear equation in rectangular coordinates x, y, z is represented by a plane in space

The normal form of the equation of a plane in rectangular coordinates is

$$x \cos\alpha + y \cos\beta + z \cos\gamma - p = 0,$$

where p is the perpendicular distance from the origin to the plane, and α, β, γ are the direction angles of that perpendicular

The intercept form of the equation of a plane is

$$\frac{x}{a} + \frac{y}{b} + \frac{z}{c} = 1,$$

where a, b, c are the intercepts of the plane on the axes

The equation of a plane through 3 given points may be written

$$\begin{vmatrix} x & y & z & 1 \\ x_1 & y_1 & z_1 & 1 \\ x_2 & y_2 & z_2 & 1 \\ x_3 & y_3 & z_3 & 1 \end{vmatrix} = 0$$

To reduce the general equation $Ax + By + Cz + D = 0$ of a plane to the normal form, divide each coefficient by $\pm\sqrt{A^2 + B^2 + C^2}$

The coefficients of x, y, z in the equation of a plane are proportional to the **direction cosines** of a line perpendicular to the plane

The angle θ between two planes $Ax + By + Cz + D = 0$ and $A'x + B'y + C'z + D' = 0$ is given by

$$\cos\theta = \frac{AA' + BB' + CC'}{\sqrt{A^2 + B^2 + C^2}\ \sqrt{A'^2 + B'^2 + C'^2}}$$

These two planes are parallel when and only when $A/A' = B/B' = C/C'$ (i e , when the corresponding coefficients of x, y, z are proportional)

These two planes are perpendicular when and only when $AA' + BB' + CC' = 0$

The intercepts of a plane are the distances cut off on each of the coordinate axes, they may be found by putting successively each pair of coordinates equal to 0 and solving the equation of the plane for the other coordinate

The traces of a plane are the straight lines in which the plane cuts the coordinate planes, they may be found by putting successively each coordinate equal to 0 in the equation of the plane

The perpendicular distance of a point $P_1(x_1, y_1, z_1)$ from a plane whose equation is $x \cos\alpha + y \cos\beta + z \cos\gamma - p = 0$ is given by

$$d = x_1 \cos\alpha + y_1 \cos\beta + z_1 \cos\gamma - p,$$

the perpendicular distance from the plane $Ax + By + Cz + D = 0$ is given by

$$d = \frac{Ax_1 + By_1 + Cz_1 + D}{\sqrt{A^2 + B^2 + C^2}}.$$

If $P_1 = 0$ and $P_2 = 0$ are the equations of two planes, the equation $P_1 + kP_2 = 0$ is a system of planes through the intersection line of the two given planes (L L S)

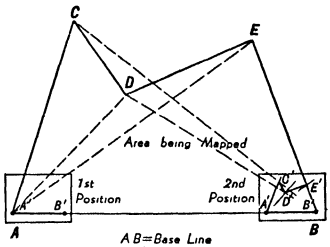
PLANER. The machine used to remove, by cutting action, the surface layer of material from a flat surfaced body is a planer. There are two kinds of planers,—

wood and metal working The wood planer has a set of knives composed of two to four blades per set, fastened at uniform intervals around the circumference of a rotating arbor, which is driven at high speed by means of a belt and pulley. Speeds of 3500 revolutions per minute or more are needed for smooth wood planing The board to be planed is caused to move along on a table over the knives so that a thin layer of the board will be planed off by the knives The high speed is necessary if the board is not to show a series of transverse knife impressions The board is moved past the knives and held firmly against them by rollers which are mechanically driven The operator, then, needs only to start the board into the rolls so that he is removed from the necessity of approaching the dangerous part of the planer Depth of cut is adjusted by building the supporting table so that the feed section is adjustable up and down

The metal working planer operates on a different principle altogether Whereas the entire width of the work is cut at one time in a wood planer, only a narrow shaving is taken off each time the work passes completely through the metal planer A large horizontal bed has ways upon which slides a reciprocating carriage. As the distance traversed by this carriage or table is quite large in a planer, a crank and connecting rod arrangement is not convenient to use Generally the table is equipped with a rack which is driven by a pinion The pinion is driven by belts and pulleys so arranged that when the table reaches the end of its travel, it operates a mechanism which shifts the belts, causing the pinion to rotate the other way and bring the carriage back This action is repeated at the other extremity of table travel The work is clamped to the table, and the cutting tool is held on a tool post which is brought down over the work from a bridge attached to the bed of the machine The tool holder has motion vertically and horizontally,—vertically to adjust the depth of cut, and horizontally to enable the entire surface of the work to be covered by a number of parallel cuts The horizontal motion is usually automatic, and the cut is taken in one direction only When the planer is in use the table is started and the cutting tool brought down over one edge of the work, and adjusted by hand until a cut of the right depth is being made, then the cross-feed is thrown in, and on each return of the table the tool is moved over slightly so that succeeding parallel cuts remove a certain amount of material uniformly from the surface of the work (F T M)

PLANE SAILING. This term is applied to the solution of various problems in the **sailings** in which the earth is considered as a plane surface The particular subject of plane sailing will be found discussed under the topic **Dead Reckoning.** (W K G)

PLANE TABLE. A plane table is a **surveying** instrument which is used for locating and mapping topographical features A drawing board, accurately made, and arranged so that it may be mounted on a tripod by an adjustable head which allows leveling of the board, is an essential feature of the plane table Spirit levels are attached to the table in mutually perpendicular directions The compass, the ruler, and a means for getting a line of sight, such as a telescope or open sights, complete the outfit A ruler combined with a telescope is called an **alidade** When the plane table is used for a survey, it is not necessary to take notes of angles or lengths of lines, since they are plotted, at the time of the survey, on the sheet of paper which covers the plane table Obviously the plane table is not suitable for use in bad weather When a survey is to be made with this instrument, the table is set up so that some convenient point on the paper is over a selected spot on the ground. The table is leveled and rotated horizontally until it is in **azimuth.** This is accomplished by means of the compass or by sighting back on a known point It is then clamped in this position and the ruler is brought to the point selected on the paper and swung about it so that the line of sight which parallels the ruler bears on a distant point whose location is desired A line is drawn in that direction, and after the distance to that point is measured, the length of line is plotted to some scale suitable to include the area being mapped on the surface of the plane table



Plane table method of survey

It is entirely possible to locate the points of a survey, with the exception of the two points specified in the above paragraph without measurement This method is known as the method of intersections, and requires only one distance to be actually measured In the method of intersections, the plane table is set over one point, and a line of sight taken on some other selected point, possibly a corner of the area The distance between those two points is measured, and the other point put in by scale on the plane table drawing The alidade is then swung about the initial point, and lines are drawn toward the several other corners which are to be located The plane table is then set up over the other terminus of the measured base line, and oriented by a compass or by aligning the initially measured line with the initial point by alidade The alidade is then swung about the second point and lines are drawn again toward the same other corners that are to be located The intersections will give the location of the points (F T M)

PLANETARY MOTIONS. The apparent motions of the **planets** on the **celestial sphere** have been observed, recorded and speculated about ever since mankind has existed on the earth A large part of the pseudo science of **astrology** is concerned with these motions, or, more particularly, with the various "aspects," or configurations, of the planets The motions as seen from the earth are complicated by the fact that the earth is moving about the sun in the same direction as the planets, but with a different rate

Apparent motions relative to the sun

In Figure 1, we have *S* representing the sun, *E* representing the earth (assumed fixed for the purpose of convenience), P'_1, P', P'_2, P'_3, P'_4 indicating various positions of a planet whose orbit lies between the earth and the sun (inferior planet), and P_1, P_2, P_3, P_4, positions of a planet whose orbit is outside of that of the earth (superior planet) The angle between the sun and the planet (e g, *SEP'* or *SEP*) is defined as the elongation of the planet For an inferior planet the elongation may have any value from o to

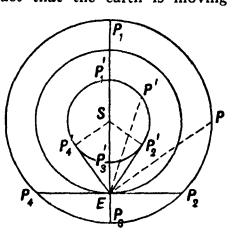


Figure 1 Motions of planets as seen from earth relative to the sun

SEP'₃ or SEP'₄ while for a superior planet the elongation varies either east or west from 0 to 180°. With elongation 0 we have the planet in the aspect of conjunction.

Inferior planet It will be noted that the elongation is 0 both at P'_1 and also at P'_5 and hence there are two conjunctions for an inferior planet To distinguish between them P'_1 is known as superior conjunction and P'_5, inferior conjunction An inferior planet moves more rapidly in its orbit than does the earth and accordingly from superior conjunction the planet moves out with increasing eastern elongation (evening object) to the point P'_2 (greatest eastern elongation) It then moves in with decreasing elongation, passes the sun and becomes a morning object at inferior conjunction (P'_5) and moves out with increasing western elongation to P'_4 (greatest western elongation) and thence back to superior conjunction again Hence these planets apparently oscillate back and forth across the direction of the sun They do not ordinarily pass either between the earth and the sun or directly behind the sun because of the fact that their orbits are not in the plane of the **ecliptic** (See **Transit of Venus**).

Superior Planets It must be remembered that these planets are moving more slowly in their orbits than is the earth These planets apparently move from conjunction at P_1 slowly out to the west of the sun (morning objects) to P_2 where the western elongation is 90° and the aspect is western quadrature From this point the increase in western elongation increases rapidly to 180° at P_3 (aspect opposition) from which point the elongation becomes east (evening object) and decreases rapidly to 90° eastern elongation at P_4 (eastern quadrature) The decrease in eastern elongation then slows down as the planet moves slowly back to conjunction again.

Apparent motions of the planets relative to the stars:

In Figure 2, we have S representing the position of the sun, E representing the (assumed circular) orbit of

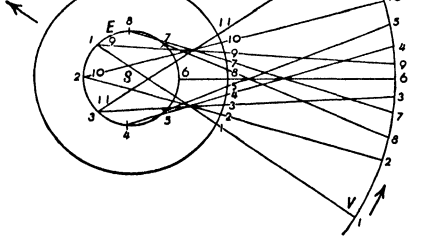


Figure 2 Motion of planet as seen from the earth relative to the stars

the earth, with successive positions marked, P the orbit of a planet with successive positions marked with numbers corresponding in date with the marked positions for the earth, and an outer circle representing directions on the celestial sphere, V being the direction of the vernal **equinox**, A the direction of the autumnal equinox and the direction of increasing **longitude** (or **right ascension**) indicated by arrows

The successive positions of the planet as seen from the earth relative to the stars, are obtained by drawing lines, representing the lines of sight from successive positions of the earth through corresponding positions of the planet By examining the successive directions, as indicated by numbers on the outer circle, it will be evident that the general trend of the planetary motion is in the direction of increasing right ascension Such motion in increasing right ascension is known as direct motion. It will be noticed, however, that in the vicinity of opposition of the planet, the motion reverses for a period (numbers 6, 7, and 8) and the planet moves in the direction of decreasing right ascension Such motion, in the direction of decreasing right ascension, is known as retrograde motion

Since the diagram is plotted in the plane of the ecliptic with the planet also assumed in this plane, the reversal in direction appears only in longitude However, there will also be changes in direction of motion both in celestial **latitude** and **declination**, giving the appearance on the celestial sphere of loops in the motion of the planet These loops were observed by the early astronomers and it was to account for those on the assumption of the geoconcentric universe that the epicycles of the **Ptolemaic system** became necessary

The general subject of planetary motions referred to the sun alone will be found discussed under the general topic of orbits. (W K G.)

PLANETS. The word planet, which comes from a Greek root meaning "**wanderer**," was used prior to the fifteenth century to designate those celestial objects (other than **meteors** and **comets**) which were observed to be in motion relative to the stars Prior to the fifteenth century, seven objects were listed as planets **Sun, Moon, Mercury, Venus, Mars, Jupiter**, and **Saturn** With the advent of the **Copernican** heliocentric hypothesis for the structure of the **universe**, the sun and moon were removed from the list and the earth added Since the application of the telescope to astronomy three large planets have been added (**Uranus, Neptune**, and **Pluto**) and over a thousand small planets or **asteriods**. The term as it is used at present applies to any opaque object which is shining by reflected sunlight and travels about the sun in an **orbit**.

In spite of the fact that many of the planets are larger than the earth, their distance is so great that they appear to the naked eye as bright stars The only certain method for distinguishing a planet from a star without the use of a telescope is to watch it carefully for a considerable period, frequently several days are required, and if the object is a true planet, it will move relative to the stars For a quick method of identification, it may be said that usually a planet does not appear to twinkle as do the stars, but this rule is not infallible With a telescope a planet may be immediately distinguished from a star (with the exception of the planet Pluto or the asteroids) because of the fact that a planet will show an appreciable disk while the stars appear as points of light no matter how much modification is used

The planets are classified in two general ways Mercury, Venus and Earth are frequently referred to as the inferior planets, while the others are called the superior planets Another system of classification considers Mercury, Venus, Earth, and Mars as the minor or terrestrial planets, while Jupiter, Saturn, Uranus, Neptune, and Pluto are called the major planets

In this article we shall limit ourselves to the material contained in the accompanying tables. Elsewhere in this work will be found discussions of planetary **motions**, descriptions of the individual objects, and an outline of the various theories of planetary evolution under the discussion of the **solar system**. The **satellites** will also be considered elsewhere

In planetary table I will be found the characteristics of the individual planets which have to do with distances and motions of the planets themselves The various terms used for column headings will be found defined elsewhere in this work either under their individual terms or under the general subject of **orbit**.

Planetary table II contains data relative to the physical conditions of the planets themselves The mean diameter in seconds of arc, given in the third column, is the average diameter as seen from the earth. Since the distances of the planets from the earth, particularly in

PLANETARY TABLE I ORBITAL CHARACTERISTICS

Planet	Mean Distance from the Sun		Eccentricity	Inclination to Ecliptic, Degrees	Angular Momentum	Periods	
	Millions of Miles	Astr Units				Sidereal in Years	Synodic in Days
Mercury	36 0	0 387	0 2056	7 0036	0 02	0 241	115 88
Venus .	67 2	0 723	0 0068	3 3940	0 07	0 615	583 92
Earth	92 9	1 000	0 0167	0 0000	1 00	1 000	.
Mars	141 5	1 524	0 0933	1 8501	0 13	1 881	779 94
Jupiter	483 3	5 203	0 0484	1 3067	722	11 862	398 88
Saturn	886 1	9 539	0 0558	2 4909	293	29 458	378 09
Uranus	1783	19 182	0 0471	0 7729	64	84 015	369 66
Neptune	2793	30 057	0 0086	1 7758	. 94	164 788	367 49
Pluto .	3671	39 518	0 2486	17 1468	1 2 (?)	248 430	366 73

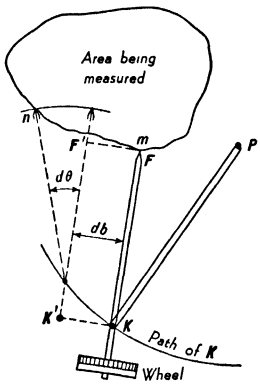
PLANETARY TABLE II PHYSICAL CHARACTERISTICS

Planet	Mean Diameter		Temp in ° K	On Scale of Earth = 1			Rotation Period
	In Miles	Apparent in Seconds of Arc		Mass	Mean Density	Surface Gravity	
Mercury	3,100	5 45	690	0 037	0 68	0 26	88 (dy) (?)
Venus	7,700	30 40	290	0 826	0 94	0 90	(?)
Earth	7,920		287	1 000	1 00	1 00	24 00 (hr)
Mars	4,215	8 94	285	0 108	0 71	0 38	24 60 (hr)
Jupiter	85,700	. 22 65	135	318 4	0 24	2 65	9 9 (hr)
Saturn	71,500	9 25	120	95 2	0 12	1 14	10 2 (hr)
Uranus	32,000	1 88	Below 90	14 6	0 25	0 96	10 7 (hr)
Neptune	31,000	1 26	Below 90	17 3	0 24	1 00	15 8 (hr)
Pluto	5,000 (?)	(?)	Below 90	0 2 (?)	0 8 (?)	(?)	(?)

the case of Venus and Mars, vary through wide limits, the angular diameter at any particular instant may be very different from the value given The fourth column gives the average temperature of the objects on the Kelvin scale The values given are those determined by means of radiometric observations In the case of Mercury the value for the sunlit side is given, in the case of Venus the average of the dark and bright sides is used, and for Mars the value obtained for the warmest portion is taken. Further information regarding planetary temperatures will be found in the articles dealing with the individual objects The mean densities are calculated from the masses and measured diameters It should be noted that the measured diameter is that of the planet plus atmosphere and probably in the cases of the outer planets the layer of atmosphere is very thick Possibly this accounts for the low value of the density in comparison with that of the earth. By surface gravity is meant the **gravitational** attraction on unit mass at the surface of the planet. For example, on Jupiter a mass of 10 gms would have a **weight** of 26 5 gms All values tabulated for the planet Pluto are very uncertain. (W K G.)

PLANIMETER. The polar planimeter, which is credited to Amsler, is an instrument for the measurement of irregular plane areas While the area of a regular plane figure may be found by the application of rules for averaging, methods of subdivision, etc , such methods are tedious compared to the ease and accuracy with which the planimeter measures irregular areas The general form of the polar planimeter is shown in the accompanying figure There are two arms pivoted together at the point *K*. The arm *PK* is free to rotate about the needle point *P*, and is held in place at that point by a weight. The other arm *KF* carries a tracing point at *F*.

This is guided around the border of the area to be measured The arm *KF* also carries a wheel whose axis must be parallel to *KF* The rim of this wheel is in contact



Theory of the Planimeter

with the paper so that any motion of the arm except that in the direction *KF* will cause the wheel to rotate A graduated scale with **vernier** attachment measures the travel of the circumference of the measuring wheel To use the planimeter, the tracing point is set at some initial point on the circumference of the area, and the reading of the record wheel is next noted The tracing point is carefully guided around the border of the area clockwise until it has returned to the starting point A final reading is taken and subtraction of the two readings gives a number which is either the area directly in square inches, or bears a relationship to it as follows

$$\text{area} = \text{reading} \times \text{a constant.}$$

In some planimeters there is only one constant, but in others the length of the tracing arm may be varied by a micrometer adjustment This feature is useful when the planimeter is to be used on areas drawn to scale By employing the proper setting (i e, the setting constant = scale of area), the area may be obtained directly from the wheel reading

The explanation of the planimeter rests on a mathematical basis of the integral calculus, since it is primarily an instrument performing a graphical **integration.** It will be shown that the dimensions which are involved in the measurement of area are length of the tracing arm and the movement of the wheel The length *PK* has no effect as long as *K* moves in the arc of a circle In common use of the planimeter this is true, but large areas sometimes necessitate placing the pole (needle point) inside so that the arm *PK* describes a complete circle In this case the area is not read directly from the record wheel It is the area of the zero circle, plus or minus the wheel reading The zero circle is that traced by the point *F* when the plane of the measuring wheel, extended, passes through *P* The area of the zero circle, if the graduated scale gives the area directly, is the difference between the readings obtained by traversing the outline of any given area, first with the pole inside and then with the pole outside the area If the scale does not give the area directly the difference between the readings must be multiplied by a constant to obtain the true value of the zero circle

The figure above explains the theory of the planimeter Suppose the tracing point *F* is moved from *m* to *n* along the curve bordering the area. The area swept over by *KF* can be considered to be made up of a translation dB and of a rotation $d\theta$. The area of translation is the length (L) of the tracing arm *KF*, multiplied by db Note also, db is the distance rolled by the wheel The center *K* must then be returned to the arc by a motion along the line *K'F'* This generates no area, and causes no wheel rotation The area generated in rotation is $\frac{1}{2}L^2 d\theta$ The area generated, then, is

$$A = L\int db + \tfrac{1}{2}L^2\int d\theta$$

When the point *F* has been carried completely around the closed line, the net area swept through by *KF* is equal to the area enclosed by that line By returning point *F* to its original position, the integral of $d\theta$ becomes zero, and area equals $L\int db$. The $\int db$ is the net distance rolled by the wheel, and is read directly therefrom. Thus it is seen that the area measured by planimeter equals the length $FK \times$ the net distance rolled by the wheel. (F T M)

PLANKTON. The portion of the aquatic **fauna** composed of animals which merely float and drift and those whose active locomotion is not directional Most of the animals of the plankton are small or minute The terms limnoplankton and haliplankton are sometimes applied to fresh-water and marine animals, respectively, and other subdivisions have received special names Floating organisms in the air have been called the aerial plankton, a category which includes no permanently planktonic forms although some organisms may be carried by air currents in some stages of their development

The plankton includes many of the smaller invertebrates, such as **protozoans, coelenterates, worms,** and lower **chordates** (A W L)

PLANTAIN EATER. Aves, Cuculiformes An African bird (**Aves**) of an extensive group also called the touracos and louris They are brightly colored birds and with the exception of the giant plantain eater, which is almost three feet long, are of moderate size (A W L.)

PLANTAINS. *Plantago* sp Plantaginaceae There are some 200 widely distributed species of plantains, many of which are ubiquitous weeds Some species are stemless plants, the **petioled** leaves forming a rosette which covers a considerable area of ground, from which it excludes other desirable plants These are the species which cause unsightly patches in lawns

Plantago major is one of these, with broad ovate leaves on long petioles *Plantago lanceolata* has **lanceolate** erect leaves The flowers are borne in elongated **spikes** the pistil maturing before the **stamens.** Plantains are wind-pollinated plants, although insects occasionally visit them for their pollen The fruit is a **capsule,** the upper half of which comes off when mature, through the development of a circumferential line of **dehiscence** The seeds of plantains are often fed to caged birds In some species the seeds imbibe water and become mucilaginous One species, *Plantago Psyllium,* native in southern Europe, is sometimes used in medicine under the name Psyllium seed (R M W)

PLANT CUTTER. Aves, Passeriformes Birds (**Aves**) of several species found only in Temperate South America They have a short thick beak with finely serrate edges Related to the chatterers. (A.W.L.)

PLANT LOUSE. **Aphid.**

PLANULA. A **larval** form of the **coelenterates.** It is covered with a ciliated (**cilia**) ectodermal layer and is filled at first with a solid mass of endoderm, which later splits to form the enteric cavity. A free-swimming stage. (A W L.)

PLASMA. (See also **Blood,** and **Chalcedony.**) In physics, plasma refers to any portion of an electric discharge, in a gas at low pressure, which is almost elec-

trically neutral because the positive and the negative ions exist there in such proportions as to represent nearly equal quantities of electricity. (L D W)

PLASMODESMA. Plasmodesmata are minute threads of **protoplasm** passing through minute tubes in the walls of adjoining cells These threads are so minute that special methods of **histological** preparation are usually needed to make them visible They are larger and more easily seen in the walls of cells of the **endosperm**, and in cells of **gymnosperms** and ferns It is possible that they may be found connecting the photoplasts of all living cells in plants, but are too minute to be seen. Their function is not known. (R M W)

PLASMODROMA. A subdivision of the one-celled animals characterized by the presence of a single kind of **nucleus.** The phylum **Protozoa** contains two such subdivisions, the subphyla **Cilophora** and **Plasmodroma** This subphylum is divided into three classes and many orders The classification is briefly summarized below.

Class **Mastigophora.** Animals with one or more **flagella.** Many species have chlorophyll and are intermediate between plants and animals
- Subclass Phytomastigina Mostly colored species, with chlorophyll
  - Order **Chrysomonadida.** Minute species of yellow to brown color, rarely bluish or green
  - Order **Cryptomonadida.** With a cytopharynx Body flattened
  - Order **Dinoflagellida.** Body enclosed in a cellulose covering of two parts.
  - Order **Phytomonadida.** Color green No cytopharynx
  - Order **Euglenoidida.** Cytopharynx present Color green Stored food in the form of **carbohydrates.**
  - Order **Chloromonadida** Cytopharynx present Color green Stored food in the form of oils
- Subclass Zoomastigina Without chlorophyll Usually with a single vesicular nucleus
  - Order **Pantostomatida.** Animals with both **pseudopodia** and flagella
  - Order **Protomonadida.** Small animals with one to three flagella
  - Order **Polymastigida.** Minute forms with two to eight flagella and one to many nuclei Mostly parasitic in the digestive tract of animals
  - Order **Hypermastigida.** With more than eight flagella Parasitic in the intestine of insects

Class **Sarcodina.** Without a **pellicle** and therefore without constant body form Pseudopodia are formed for locomotion and to secure food
- Subclass **Rhizopoda.** Species which form temporary pseudopodia of various forms
  - Order **Proteomyxa.** Without hard parts Pseudopodia slender, sometimes branching and anastomosing
  - Order **Mycetozoa.** The slime molds, formerly regarded as plants Active stage a plasmodium consisting of a large mass of protoplasm with many nuclei
  - Order **Amoebaea.** Without hard parts Pseudopodia thick protuberances
  - Order **Testacea.** With an enclosing shell or test containing a single chamber Chitinous
  - Order **Foraminifera.** With an enclosing test of many chambers Calcareous
- Subclass Actinopoda With straight slender radiating pseudopodia which are semipermanent
  - Order **Heliozoa** Chiefly fresh-water species Body usually spherical, without a central capsule enclosing the inner portion
  - Order **Radiolaria** Marine forms Usually spherical, with the central portion enclosed in a membranous central capsule

Class Sporozoa. Parasitic species without flagella or cilia and with pseudopodia only in the immature stages
- Subclass Telosporidia Spores without a polar filament Spore containing more than one sporozoite or without a resistant capsule The orders are characterized by peculiarities of the reproductive stages
  - Order **Coccidia.** Parasitic chiefly in the lining of the digestive tract of vertebrates and higher invertebates, and in the associated glands
  - Order **Haemosporidia.** Part of the life cycle occurs in the blood of vertebrates and part in the alimentary tract of a blood-sucking invertebrate. The **malarial** parasites and others
  - Order **Gregarinida.** Parasitic chiefly in arthropods and annelids
- Subclass Cnidosporidia Spore with a coiled polar filament
  - Order **Myxosporidia.** Mostly parasites of fishes
  - Order **Actinomyxidia.** Parasitic in aquatic **annelids.**
  - Order **Microsporidia.** Typically parasitic in cells of **arthropods** and fishes
  - Order **Helicosporidia.** A single peculiar species parasitic in insects
- Subclass Acnidosporidia Spores without polar filament, with a single sporozoite
  - Order **Sarcosporidia.** Parasitic in the muscles of mammals and to some extent of birds and reptiles
  - Order **Haplosporidia.** Parasitic in invertebrates and lower vertebrates. (A W L)

PLASMOTOMY. A reproductive process of certain one-celled animals By this process a multinucleate form of species parasitic in fishes (**Plasmodroma,** Myxosporidia) subdivides into two or more parts, each with several nuclei (A W L)

PLASTER OF PARIS. Calcium sulfate.

PLASTICITY However defined by physicists and geophysicists, the effects of plasticity are of interest to the geologist (**stratigrapher**) principally in relation to the development of intraformational structures in **sediments** of the silt or clay grade, and are therefore indicative of the peculiar condition under which the sediments were deposited, deformed or reworked previous to **lithification.** (R M F)

PLASTICS · Plastic materials are of two types, namely, (1) bodies which are rigid at ordinary temperatures and pressures, and, when subjected to increased temperature or pressure, become softened so as to permit bending and forming, e g, glass, (2) bodies which in the process of working soften sufficiently—generally but not always when they are subjected to increased temperature or pressure—so that they can be made to fill molds of forms, e g, moist clay, moist Portland cement, rubber The term plastics is loosely used to denote the classes of organic materials represented by "celluloid," "bakelite," "vinylite," "galalith" and rubber These are used in a great variety of ways, and several are not confined in their uses to the field of plastics but have extensive use—in the form of resins in a solvent—as lacquers (See **Pigments.**)

A convenient classification is as follows· (1) Rubber See **Rubber.** (2) Nitrocellulose plastics, example celluloid (3) Shellac plastics (4) **Phenol-formaldehyde** resins, example "bakelite" (5) Casein-**formaldehyde,** plastics, example "galalith" (6) Vinyl polymerides, example "vinylite"

Nitrocellulose plastics are made by taking 70 to 80 parts by weight of nitrocellulose (11 percent nitrogen), mixing with non-volatile solvents and plasticizers, e g, castor oil, camphor, butyl phthalate, diethylphthalate, tricresyl phosphate, at 75 to 90° C, 20 to 30 parts by weight of camphor, and with 0 to 14 parts by weight of dyes, pigments, fillers A volatile solvent, e g, ethyl alcohol, is added, the material is shaped, and the volatile

solvent evaporated Residual volatile solvent remains to the extent of 1 to 5 parts by weight The working range for molding is 85 to 120° C. The product, commonly "celluloid," is inflammable and therefore hazardous upon heating The flash point test shows 160 to 200° C. The process was perfected and manufacture begun in the United States by J W and I S Hyatt in 1869

Shellac plastics are made by mixing shellac or a substitute, e g , dammar, rosin, asphalt, pitch, with a filler Wood pulp, asbestos and a wide range of materials are used as fillers The mixture is molded into shape by pressure at a suitable temperature, or a solvent is used which, after shaping is volatilized

Phenol-formaldehyde plastics and resins are made by mixing **phenol** and **formaldehyde** solution (37–40% HCHO) with **ammonia as a catalyzer.** The mixture is heated to 80–90° C When the mass has formed a resin, the water is boiled off The product is immediately drawn off and allowed to cool in thin layers, or a solvent, e g , ethyl alcohol, acetone, is added to stop further reaction by dilution Another method is to mix phenol and formaldehyde without adding ammonia, and subject the mixture to a temperature of 140–160° C in a digestor Heating slowly to the higher temperature in a period of about 3 hours is necessary to avoid the rapid reaction Water is allowed to pass off by opening a valve on the digestor The thin resinous product is drawn off and allowed to cool When the properly prepared resin is mixed with modifying agents, such as nitrocellulose, resins, casein, and the desired fillers, at 110 to 140° C under pressure for one hour, a hard molded product is obtained Products insoluble in most solvents, and infusible are for use as plastics, and other products soluble in certain solvents for use in lacquers

Casein-formaldehyde plastics are made by shaping casein in molds under pressure for several hours, allowing to stand several days, and then hardening by immersion in a solution of formaldehyde and glycerol (4 parts by weight HCHO to 1 part $C_3H_5(OH)_3$) The articles are dried at room temperature

Vinyl plastics and resins are made by polymerization of vinyl compounds, for example, vinyl chloride (CH_2 CHCl, monochloroethylene)

Cellulose acetate, and urea-formaldehyde plastics are similar materials of growing importance

Some additional specific data on plastics are presented below.

Material	Tensile Strength Pounds per Square Inch	Softening Temperature ° C	Electrical Behavior Dielectric Strength Volts per mil (0 001 inch)
Hard vulcanized rubber	1,200–2,000	90	300–1,100
Cellulose nitrate	4,000–10,000	75	250–780
Shellac plastics	900–2,000	80	100–400
Phenol - formaldehyde plastics	5,000–10,000	150–250	200–700
Casein-formaldehyde		85	125
Vinyl plastics	7,000–9,000	75	350–400
Cellulose acetate	5,000	50–75	720
Urea-formaldehyde	5,000–6,000		300–400
Glass			300–1,500
Porcelain	650–2,300	600–1,000	1,000
Portland cement	2,500	550	40–150

(R K S)

PLASTIDS. Pigments in plants are often located in special bodies called plastids There are many kinds of plastids leucoplastids, those which contain no pigment and which are therefore colorless, chloroplastids, those which are green (by far the commonest kind); and chromoplastids, those of colors other than green.

Chloroplastids have been the subject for considerable study, and much debate In the **algae** the shapes of these bodies are many, in a large number of cases the plastid is a thick cup-shaped body occupying the greater part of the volume of the cell, in other algae the plastids have a central mass from which radiating plates or arms extend outward to the cell-wall, spiral, net-shaped and ring-shaped plastids are not uncommon in this group of plants. In some algae and in nearly all higher plants, the chloroplastids are small subspherical or lens-shaped bodies, varying in number from one to many in a single cell Always the chloroplastids are found embedded in the **cytoplasm** of the **cell.** In many plants the continuous movement of the cytoplasm in the cell carries the plastids along with it, in others these bodies have a fixed position In certain algae and in many cells in higher plants, as for example in the palisade layer of leaves, the plastids may change their position so that they will receive the most favorable amount of light If the light intensity is low they will present their flat surface to it, while if the light intensity is high, the plastid rotates so that it is placed edge-wise to the light The minute structure of the plastid has received some study The results are conflicting All agree, however, that **chlorophyll** is found in the chloroplastid and that starch (See **Carbohydrates**) accumulates within it as a result of **photosynthesis.** (R M W)

PLASTOGAMY. The union of individuals by which the **plasmodium** of the slime molds is formed The **cytoplasm** becomes confluent but the **nuclei** remain distinct In some cases the mass formed is large enough to be conspicuous to the naked eye. (A.W L)

PLATE GIRDER. Girder.

PLATE, STRUCTURAL. Structural plate is a large, flat body of **steel** which is produced by the working of ingots, billets, or slabs in a rolling mill There are two types of these plates, one known as sheared plate, the other as universal mill plate The sheared plate is used for square or rectangular shapes, the universal mill product for long strips, like those needed for plate girders The sheared plate is rolled in a mill having horizontal rollers through which the plate is passed back and forth while the rollers are successively brought closer to each other During this process the slab or ingot is rolled to a flat plate Mills having horizontal rollers only are built to roll extremely large plates, some of which are over 100 inches wide The selvage left during rolling is rough and irregular, and the plates must be sheared to standard marketable sizes or customers' specifications by power shears Between rolling and shearing operations the plates are straightened, but shearing takes place when the plates are hot, so shrinkage must be allowed for when laying out lines to which the plates are sheared For this reason, and also for the reason that the shears can not be manipulated with a great deal of precision, sheared plates must have a large tolerance allowance However, sheared plates are the only plates available in wide widths

Universal plate is made on universal mills which have vertical as well as horizontal rolls, the function of the vertical rolls being to edge the plate Universal plates can be obtained in widths up to 48 inches Plates of great length are produced with rolled edges, and these are always used for the construction of girders The allowable tolerances are much smaller, and the purchaser does not need to machine the rolled edge Structural plate is rolled to several standard thicknesses, beginning at ¼ inch, and advancing by small increments to 2 inches

Another usage of this word describes the structural members with which the tops of walls of buildings are finished off. For example, in the ordinary dwelling built with masonry walls, anchor bolts are built into the ma-

sonry at the top of the wall. A substantial wooden timber is bored to receive these bolts and placed on the wall with the bolt projecting through it The bolts are then capped with nuts which are tightened against washers bearing on the plate By spacing these anchor bolts at close intervals, the plate is securely anchored to the wall, and forms a base to which rafters or other wooden timbers may be nailed In wooden wall construction the plate is the horizontal member which is attached to the tops of the studs (F T M)

PLATINUM. Symbol: Pt. Atomic number: 78. Atomic weight: 195 23 Density: 21 37 Hardness: 4 3. Melting point: 1773 5° C. (Isotopes page 239)

Compact platinum is a grayish-white metal, softer than silver, and hardened by the presence of other metals, iridium being frequently used to accomplish this result Platinum is resistant to attack by air or water at any temperature, by **hydrofluoric acid, hydrochloric acid,** nitric acid, dilute **sulfuric acid;** but is attacked by **aqua regia** forming chloroplatinic (platinichloric) acid (H_2PtCl_6), by ignition with **sodium** hydroxide, nitrate, peroxide, or cyanide Probably discovered by Scaliger in the 16th century, and named from its similarity to silver in appearance (*platina* (Spanish), small silver).

Platinum is used in alloys for jewelry (white gold contains small percentages of platinum alloyed with gold), pen points (alloyed with iridium), parts of scientific apparatus, especially electrical contacts, surgical tools, standard weights and measures; and containers, such as crucibles and dishes The change of electrical resistance of a pure platinum wire coil upon the passage of a constant current is used to measure high temperatures A platinum and platinum-**rhodium** thermocouple is also used for the same purpose

Finely divided platinum is an important catalyzer for the reaction **sulfur** dioxide gas plus oxygen of air at 450° C forming **sulfur** trioxide, in the manufacture of **sulfuric acid** by the so-called contact process The platinum catalyzer must be specially prepared for this purpose A smooth platinum surface as fine wire gauze, is used as a catalyzer for the reaction **ammonia** gas plus oxygen of air at 600° C, forming nitric oxide which is ultimately recovered as **nitric acid.**

Platinum occurs native but containing other elements, especially **osmium,** iridium and similar metals, **gold,** and iron. Found in the Ural Mountains of Russia, and less abundantly in South Africa, Canada, and the United States By treating with aqua regia, platinum and similar metals are dissolved After filtration, the filtrate is treated with calcium hydroxide and again filtered From the resulting filtrate crude platinum is recovered by evaporation to dryness, and ignition

Chlorides Platinous chloride ($PtCl_2$); platinic chloride ($PtCl_4$), reddish-brown, hygroscopic, crystalline material By evaporation of platinic chloride solution with hydrochloric acid, chloroplatinic acid ($H_2PtCl_6\ 6H_2O$), reddish-brown crystals, is obtained, which yields upon ignition at 100° C, chloroplatinic acid ($H_2PtCl_6\ 2H_2O$) as commonly marketed, and, upon ignition in **hydrogen chloride** gas, platinic chloride

Chloroplatinates. Potassium chloroplatinate (K_2PtCl_6), and ammonium chloroplatinate ($(NH_4)_2PtCl_6$) are insoluble in water, and in a mixture of alcohol and ether; sodium chloroplatinate (Na_2PtCl_6) is soluble in the same solvents. This is applied in the separation of potassium in chemical analysis

Oxides: Platinous oxide (PtO), gray to dark violet; platinic oxide (PtO_2), black.

Sulfides Platinous sulfide (PtS), black; platinic sulfide (PtS_2), black.

Platinum salts combine with **ammonia** forming interesting compounds known as platinous and platinic **ammines.** (R K S.)

PLATYHELMINTHES. The **flatworms,** a major division of the animal kingdom containing the most primitive of the **Metazoa.** The phylum includes both free-living and parasitic species. Among the latter are the **flukes** and tapeworms, some of which are serious parasites of man

The phylum is characterized by the following details of structure. 1. The body is bilaterally symmetrical and flattened 2 The ectoderm is ciliated in free-living forms but forms a **cuticle** in the parasitic species. 3 The mesoderm forms a compact tissue between the various organs, known as a parenchyma 4. The alimentary tract, when present, has a single opening 5. The nervous system is a network in which a brain and longitudinal nerve cords are developed 6 The excretory system consists of large hollow cells with a group of **cilia** extending into the cavity, known as flame cells, connected with tubes

There are three classes of flatworms:

Class **Turbellaria.** Free-living species **Planaria.**

Class **Trematoda.** The **flukes.** Parasitic in various parts of the animal body

Class **Cestoda.** The tapeworms Parasitic as adults in the alimentary tract of animals (A W L.)

PLATYOSAURUS. Fossil Reptiles.

PLATYPUS. Duckbill.

PLAYA. A thin sheet-like deposit of fine **clastic** and chemical muds with sometimes important and valuable crystalline mineral precipitates Playas are formed within desert basins due to intermittent interior drainage, which, during cloudbursts, forms intermittent lakes in which the sediments are deposited A region remarkable for playas is the Great Basin of the western United States, which covers all of Nevada and Utah Commercially important mineral salts derived from playa deposits are: **gypsum, sodium** carbonate, the soluble **chlorides,** and **borates.** (R M F)

PLECOPTERA. The stone flies. An order of insects with aquatic early stages The mouth is formed for biting but is usually poorly developed in the adult. They have four wings which fold flat over the back when at rest Sometimes abundant in the vicinity of water. (A W L)

PLEIADES. The Pleiades is a very famous group of bright stars in the **constellation of Taurus.** Probably no one group of stars in the entire sky has received so much notice in classical literature and mythology as has the Pleiades The Great Pyramid, which was undoubtedly designed for astronomical purposes, is so oriented that in 2170 B C, when the Pleiades were on the meridian at midnight on the first day of spring, they could be seen through the south passageway. References to this group of stars are to be found in both the Old and New Testaments One of the seven stars at present is distinctly fainter than the other six and there are many myths regarding this so-called "lost pleiad" In fact, the myths occur in so many different ancient literatures that there is a well established theory that at one time all seven of the stars were of approximately the same brightness

The Pleiades is an open **star cluster** with the various members all moving through space together. Long exposure photographs of this group indicate that the space surrounding the stars is filled with a luminous **nebulosity.** (W K G)

PLEISTOCENE. The "great ice age," and first period of the **Quaternary** in the geologic time-scale The term was proposed by Lyell in 1836 This period, as postulated by the first advance of the continental ice sheets in western Europe and northern North America, is supposed to have begun approximately two million years ago Marine deposits occur in southern California Both in North America and Europe there was considerable volcanic activity as evidenced by ash beds and basaltic

lava flows. The early Pleistocene terrestrial sediments suggest increased humidity in the formerly arid regions. The terrestrial deposits as a whole are classified according to whether they were deposited within or without the glaciated areas. Great areas of **loess** were deposited

Map of North America showing the maximum extent of glaciers during the Pleistocene Ice Age. The locations and general directions of movement of the great ice sheets are indicated, and regions of local mountain glaciers are shown in black. (Modified after U. S. Geological Survey.)

at the margins of the melting continental glaciers, and the cycles of refrigeration produced not only great ice fields in northern Europe and northern North America, but also caused sympathetic glaciation in the mountainous regions further to the south. The **fossil** plants suggest distinct climatic zones. Both in Europe and North America it has been shown that there were four glacial cycles, or advances and retreats of the continental ice sheets, each with their typical sediments and accompanying floras and faunas. During the Pleistocene there was a great reduction in the number of the larger mammals, except in Asia and Africa. The characteristic types in North America were *Elephas* (**elephant**), as well as the mastodon, *Cervalces* (giant "moose"), a number of *Equidae* (true **horses**), *Smilodon* (last of the great saber-tooth tigers), and *Megalonyx* (giant ground sloth). In South America occur the peculiar Pampean fauna, descended from the earlier indigeneous Pliocene forms, including large *Glyptodons*, *Megatheria* (giant ground sloths), and *Hypidium* (Pampas horse). The interglacial stages were remarkable for the replacement of northern by southern types of plants and animals, including the progenitors of modern man. The pleistocene is said by some geologists to end with the beginning of the Recent period. Others suggest that the Recent is merely an interglacial epoch preceding the next epoch of continental glaciation. (R.M.F.)

PLENUM. Pressures slightly above atmospheric are known as plenums. Such pressures usually occur in air or gas systems as the result of the action of **fans** or **blowers.** The plenum is measured in small units of pressure, such as ounces per square inch, or in inches head of a liquid on a differential manometer. (F.T.M.)

PLEOCHROIC HALOES. The term applied to the colored zones concentric to a **radioactive** mineral, such as **zircon**, included in another mineral, such as **biotite.** (R.M.F.)

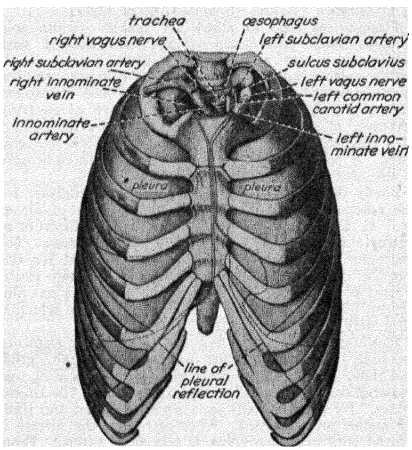
PLEOPOD. A form of the **biramous appendage** of **crustaceans.** The pleopods occur on the more anterior abdominal segments and are fringed appendages known usually as swimmerets. (A.W.L.)

PLEROCECRUS. A form of the bladder worm **larva** of tapeworms (**Cestoda**) which resembles the scolex of the adult. (A.W.L.)

PLEROCERCOID. A form of the bladder worm **larva** of tapeworms (**Cestoda**). In contrast with the simpler bladderworms which resemble the scolex of the adult, the plerocercoid contains other parts of the body in addition to a scolex. (A.W.L.)

PLESIOSAUR. Fossil Reptiles.

PLEURA. A thin, shiny layer of membrane which covers each **lung.** At the root of the lung this membrane is reflected onto the inside of the chest wall covering it and the **diaphragm.** Between these two layers



Dissection of a subject hardened by formalin injection to show the relations of the two pleural sacs, as viewed from the front. (Cunningham, *Textbook of Anatomy*, Oxford Press.)

of pleura is a potential space called the pleural space. In this space the pressure is less than atmospheric pressure. Through this mechanism the lungs are enabled to fill up with air. As the chest and diaphragm expand the pressure of the outer air forces the lungs to fill the cavity fully. (R.S.M.)

PLEURISY. Infection of the **pleura** or lining membrane of the lung and chest wall.

Dry pleurisy may be primary following a cold or respiratory infection or secondary, complicating **pneumonia, tuberculosis,** or other infection of the lung.

Pleurisy with effusion. (Pleurisy with fluid in the chest.) This is commonly caused by tuberculosis, and undiagnosed tuberculosis is usually present in the lungs. It may also occur in **rheumatic fever, cancer** of the lung, **nephritis, cirrhosis** of the liver, pneumonia, and injuries to the chest. In some cases, especially in pleurisy accompanying pneumonia or lung abscess, the fluid may become septic and pus develops. This condition is known as **empyema** and requires surgical drainage. (R.S.M.)

PLEUROBRANCHIAE. Gills arising from the sides of the **thorax** in certain **crustaceans.** (A.W.L.)

PLEURODONT. Dentition.

PLEURON. Skeletal system.

PLEUROPODITE. A basal joint of the **biramous appendages** of certain **crustaceans.** It precedes the usually basal coxopodite and is also called the precoxa. (A.W.L.)

PLEXUS. A network. 1. In many animals the processes of **nerve cells** join to form a plexus or nerve net. This is the characteristic form of nervous system in the **coelenterates** and persists with modifications in the flatworms. The nerves of the radially symmetrical **echinoderms** also take on this form. A plexus underlies the ectoderm of these animals and deeper in the body other nerve fibers form plexuses of limited extent. In the vertebrates nerves branch and rejoin in some parts of the body. The brachial plexus, made up of the spinal nerves which enter the arm, and the solar plexus above the stomach are examples. Almost a hundred such plexuses have been named in the human body. 2. A network of blood vessels. The choroid plexuses of the **brain** are the most commonly mentioned examples of this group. They are the very thin and highly vascular roof plates of the most anterior and the most posterior cavities of the brain, which expand into the interior of the cavities. Other vascular plexuses are found elsewhere in the body. (A.W.L.)

PLIOCENE. The last major subdivision of the **Tertiary** in the geologic time-scale. Term proposed by Charles Lyell in 1832 after the type locality in the Paris Basin. The Pliocene Period began approximately 8,000,000 years ago and lasted for about 6,000,000 years. In the United States the principal marine deposits occur on the Pacific Coast, but the outline of the continental margins was approximately what it is at the present day. There was continued mountain building during the period, and the interior continental terrestrial deposits were relatively thin and unimportant. There was considerable volcanic activity in the Rocky Mountain region, with great extrusions of **rhyolitic** lavas in the Yellowstone Park. The fossil plants are of the modern type, and more abundant in Europe than in North America. Also the marine invertebrates are practically identical with the modern forms. Among the mammals were a number of forms quite similar to those of the **Pleistocene** and recent, including all types of carnivores, horses, browsing camels, antelopes, and mastodons. For a description of the mineral resources of this period see the Tertiary. (R.M.F.)

PLIOPITHECUS. Paleontology of man.

PLOVER. Aves, Charadriiformes. Wading birds (**Aves**) with moderately long legs and a moderate beak. Although usually found near water, many species frequent dry ground. The **killdeer** is the most common of the several North American species. The golden plover, *Pluvialis dominica,* is remarkable for its long migrations between arctic breeding grounds and its winter home in Patagonia. The Bartramian sandpiper is sometimes called the upland plover. True plovers constitute the family Charadriidae. (A.W.L.)

Killdeer. *Oxyechus vociferus.* Grayish above, white below, two black bands across the breast.

PLUM. Rose Family.

PLUMBAGO. Graphite.

PLUMBUM. Lead.

PLUM CURCULIO. Insecta, Coleoptera. A **weevil,** *Conotrachelus nenuphar,* which damages plums and other stone fruits, apples, pears, and quinces in the eastern half of the United States. The insects hibernate in fencerows and rubbish in orchards and pupate in the ground, hence the destruction of their hiding places and thorough cultivation of the soil in late July and early August are useful measures of control. Spraying just after the petals drop and again after ten days with **lead** arsenate (2 pounds to 100 gallons of water) is effective. For control of the pest on peaches special methods are necessary which differ in various peach-growing regions. (A.W.L.)

PLUME MOTH. Insecta, Lepidoptera. A small **moth** whose wings are deeply split to form two to six slender fringed lobes. In the family Pterophoridae most species have the front wings split for about one-third of their length to form two short lobes and the hind wings deeply divided into three lobes. One genus has the wings entire. Members of the Orneodidae have six slender plumes to each wing. (A.W.L.)

PLUMULE. Seed.

PLUNGE (Geological term). For the use of this term in geology, see **Anticline.**

PLUTEUS. A **larval** form of brittle stars and sea urchins (**Echinoidea**). It is bilateral, with a tubular alimentary tract. The body bears several projecting lobes and locomotion is accomplished by **cilia** arranged in a tortuous band. (A.W.L.)

PLUTO. (c.f. tables of planetary data, page 865.) The planet Pluto, the outermost known member of the **solar system,** was discovered early in 1930 at the Lowell Observatory. The discovery of the planet was announced on March 30, 1930, the anniversary both of Percival Lowell's birth and also of the discovery of **Uranus.** The discovery marked the culmination of a search for a planet outside of the **orbit** of **Neptune** which had been carried on for many years at the observatory of Dr. Percival Lowell at Flagstaff, Arizona. The circumstances which led to the belief that such a planet existed are similar to those which led to the discovery of Neptune. After the **orbit** of Neptune was computed and the motion carried back through the years, it was found that the planet had been observed several times previous to its announcement as a planet, the early observers having recorded it as a star. These early observations were of great value in making an accurate determination of the orbit, and, when all **perturbations** due to known objects had been computed and applied, certain unexplainable differences between observed and computed positions appeared. On the basis of these perturbations Lowell made the necessary laborious computations to determine the positions of a possible planet that might be causing the attractions and predicted Pluto. There is considerable doubt in the minds of many astronomers as to whether Pluto is actually the planet producing the perturbations in the orbit of Neptune or whether the perturbations may not actually be due to accidental errors in the observations of Neptune itself. Whether Pluto is actually the predicted planet itself or not, nevertheless, it is certain that the computations of Dr. Lowell stimulated the search, and that the planet was found as a result of this search.

The name Pluto was selected for the new planet and the first two letters of the name, combined in monogram form ♇, are used as the symbol for the planet. Since these two letters are not only the first two letters

of the name of the planet, but also are the initials of Percival Lowell, they are particularly fortunate

The orbit of Pluto is the most eccentric of all of the orbits of the major planets, and the inclination to the plane of the ecliptic is also the largest The mean distance of the planet from the sun is slightly less than 40 **astronomical units** Due to the large value of the eccentricity (0 25) the planet is more than 50 astronomical units from the sun at aphelion and within 30 at perihelion The latter figure is less than the distance of Neptune from the sun, so at times the planets Pluto and Neptune pass each other However, the large inclination of the orbit of Pluto makes a collision virtually impossible, the closest approach of the two planets being about 240,000,000 miles

Comparatively little is known regarding the physical characteristics of this remote member of the sun's family It appears as a very faint star of about the fifteenth **magnitude**, with a distinctly yellowish color which is in contrast to the greenish appearance of its nearer neighbors in the solar system In size and mass the planet is apparently much more like the planets Mars and the Earth, than like its closer companions, Uranus and Neptune (W K G)

PLUTONIC. Plutonic is a general term applied to **igneous rocks** of deep-seated origin as distinguished from volcanic lavas which cool and congeal under the air, or under water The word is derived from the Roman god Pluto, who ruled the underworld (R M F)

PNEUMOSTOME. 1 The opening leading into the chamber containing the respiratory organs of **scorpions** and **spiders** 2 A small opening on the right side of a snail between the head and the edge of the mantle It leads into the mantle cavity of the air-breathing forms. Aquatic forms have a much more extensive opening (A W L)

PNEUMATOLYSIS. Pneumatolysis is the process of alteration of existing rocks and mineral deposits, or the formation of new ones, by means of gases or vapors emanating from the magma (E S C S)

PNEUMONIA. One of the most serious of the infectious diseases It is a massive inflammation in one or both lungs, usually produced by one of the strains of *Pneumococcus* It can also be produced by such organisms as the *Tubercle bacillus*, *Streptococcus* or *Staphylococcus*, or even the typhoid bacillus, etc

Pneumonia occurs in one of two forms, (1) lobar or primary form, where one or more lobes are diffusely involved, or (2) bronchial, which is usually a complication of some other infection—and is a patchy involvement of portions of the entire lung

The disease itself is characterized by chills, high fever, pain in the side, cough, and expectoration of rusty sputum Termination may occur by **crisis** or by **lysis** The complications may be varied, such as **pleurisy with effusion, empyema, pericarditis**, lung abscess, **gangrene** of lung, **parotitis**, middle ear infection, or delayed resolution

The most marked susceptibility to pneumonia occurs among the very young and the very old It is commonest among men, among the poor, the undernourished, the negro race, run-down individuals, those exposed to sudden drops of temperature, and those who have had previous attacks

Certain types of pneumonia are now treated by **serum**, and the advent of the oxygen tent or chamber has been of great benefit in many cases. (R S M)

PNEUMOTHORAX. The introduction of air or other gas into the **pleural cavity**, causing a part or the whole of the **lung** on that side to collapse so that the vesicles of the lung become airless and the lung remains quiet This occurs following a wound through the chest wall or a rupture of the lung surface through a disease process near the surface such as tuberculosis.

Artificial pneumothorax is the injection of air or **nitrogen** gas into the pleural cavity as a therapeutic measure It is most frequently used in pulmonary **tuberculosis** to put a diseased lung at rest so that healing may occur. (R S M)

POCHARD. Aves, Anseriformes A name applied in the Old World to **ducks** of several species related to the scaup ducks, the redhead, and the canvas-back of North America (A W L)

PODICAL PLATE. Two triangular plates flanking the **anus** in certain **insects** They lie just behind the tenth abdominal segment and are regarded as the halves of the ventral sclerite of the eleventh segment. They have also been called paraprocts (A W L)

PODIUM. Tube foot.

PODOBRANCHIA. A form of **gill** found in some of the **crustaceans** It is named from its attachment to the basal segments of the thoracic legs. (A W L)

POEBROTHERIUM. Oligocene.

POIKILITIC. Ophitic.

POIKILOTHERMY. A condition in which the temperature of the animal body fluctuates according to that of its surroundings It may be higher or lower, but is always directly conditioned by external temperatures **Homoiothermy**, in contrast, is the maintenance of a more or less constant body temperature, regardless of the surroundings, and is found only in birds and mammals Thus a vast majority of animals are poikilothermal

Poikilothermy has the disadvantage of limiting the activity of the animal to temperatures sufficient for the normal rate of metabolic processes When it is too cold the animal becomes incapable of movement and its other processes are slowed As a result poikilotherms must hibernate during the winter as a rule and must avoid the colder regions where their period of active life would be too greatly curtailed

Animals of this kind are commonly called cold-blooded (A W L)

POINT OF INFLECTION ON A PLANE CURVE Concavity and Convexity of a Plane Curve.

POINTES EN FEUILLE DE LAURIER. Paleontology of man.

POISEUILLE'S LAW. Viscosity.

POISON CLAW. A jointed appendage of the first body segment of **centipedes** These appendages are not used in locomotion but are sharp-pointed and work together like a pair of jaws They bear poison glands and are used in capturing and killing prey. (A W L)

POISONS. Compounds of **mercury (-ic), lead, copper, zinc, arsenic, antimony, selenium, barium, thallium, fluorine**, are notably poisonous Soluble metallic **cyanides**, isocyanic acid esters, **cyanogen, hydrogen cyanide**, some **glucosides, alkaloids**, many **nitrogen** and **sulfur** containing organic substances, yellow **phosphorus**, and **chromates** are extremely poisonous The poisonous nature of many chemicals, some of which are common and necessary, encountered in laboratory and factory, constitutes a serious hazard to life and health Careful provision for this hazard should be made Some poisons, notably **phenol, hydrofluoric acid, sodium** hydroxide, **bromine**, yellow **phosphorus, nitric acid** con-

centrated, **sulfuric acid** concentrated, are also very corrosive to the flesh

Among the gases which are extremely hazardous are especially **carbon monoxide**—odorless, and present in all gases of *incomplete* combustion of fuels, whether of coal, oil, or motor fuels—**hydrogen sulfide, nitrogen tetroxide, chlorine, bromine, hydrogen cyanide, cyanogen, cyanogen chloride** Some poisonous gases are used as fumigants of rooms, foods, and in other ways Gases thus used include hydrogen cyanide, cyanogen chloride, **sulfur** dioxide, **carbon disulfide** vapor—inflammable, ethylene oxide, **formaldehyde.** Their removal when used for fumigation and disinfection, before use of the space or materials, is a matter to be carefully confirmed.

Of liquid poisons, carbon disulfide is one commonly used, also phenol and cresols.

Many solids, either as fine powder or solution, are used as insecticides, germicides, fungicides, weed-killers, rodent-killers Examples are **copper** sulfate—with calcium hydroxide as Bordeaux mixture—copper **arsenite,** copper-acetoarsenite (Paris green), sodium arsenite, calcium arsenate, lead arsenate, sulfur, calcium sulfide (lime-sulfur), **calcium** hypochlorite, **sodium** hydochlorite, thallous sulfate, mercuric chloride, barium carbonate, sodium fluoride, nicotine, para-dichlorobenzene, pyrethrum, sodium chlorate—easily ignited in the presence of organic material such as clothing

In many situations the only substances sufficiently toxic for use against lower organisms are also toxic to man, and the hazard arising from their use cannot be too strongly emphasized

The maximum safe concentration of the following as gases or vapors in air is stated to be

1	Arsine	0 001%
2	Benzene ..	0 0005
3.	Bromine	0 0001
4	Carbon disulfide	0 0001
5	Carbon dioxide	2 0–3 0
6.	Carbon monoxide	0 04
7	Carbon tetrachloride	0 001
8	Carbonyl chloride	0 C001
9	Chlorine	0 0001
10	Chloroform	0 001
11	Dichlorodiethyl sulfide	0 002
12	Hydrogen chloride	0 005
13	Hydrogen cyanide	0 002–0 004
14	Hydrogen sulfide	0 01–0 02
15	Iodine	0 00005–0 0001
16	Mercury	Less than 0 0001
17	Nitrogen dioxide	0 003
18	Nitrobenzene	0 00002

19. Phosgene (see **Carbonyl chloride**). (R K S)

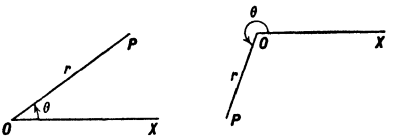
POISSON'S EQUATION. Laplace's Equation.

POISSON'S RATIO. If a rod of elastic material is stretched lengthwise with sufficient pull it can be elongated The unit elongation (elongation per unit of length) is the strain, and may be denoted by s At the same time the lateral dimension will contract The ratio of the unit lateral contraction to the axial strain, which is a constant for a given material within the elastic limit, is known as Poisson's ratio For materials in which there is no "grain" to **elasticity,** the value of Poisson's ratio was demonstrated by that celebrated mathematician to be 0 25, and actual cases bear out his deductions closely Calling Poisson's ratio M, the unit lateral contraction equals $M \times s$, hence lateral dimensions diminish by a percentage equal to 100 Ms. (F T M)

POLAR COMPOUNDS. Valence.

POLAR COORDINATES IN A PLANE. A point in a plane may be determined in position by two numbers called coordinates. One simple method for fixing the position is by means of polar coordinates.

Let O be a fixed reference point, called the pole (or origin), and let OX be a fixed reference line through O, called the polar axis (or initial line).



The position of any point P in the plane is determined by the distance OP and by any one of the directed angles having its initial side along OX and its terminal side along OP

We agree to consider the directed distance OP as positive when measured along the terminal side of angle XOP, otherwise negative, and to regard the angle XOP as positive when it is generated by counter-clockwise rotation of OP from the initial position OX and negative when the rotation is clockwise

The polar coordinates of the point P are the directed distance OP and the directed angle XOP The directed distance OP is called the radius vector of P and is usually denoted by r or ρ, the directed angle XOP is called the vectorial angle of P and is usually denoted by θ A point whose polar coordinates are r and θ is denoted by the symbol (r,θ)

Every pair of polar coordinates is represented by a single point, but conversely, every point has an infinite number of polar coordinates, since any one of a set of **co-terminal angles** may be used as the vectorial angle and also various combinations of positive and negative coordinates may be used

Polar coordinate paper is paper ruled into a network of lines by concentric circles and radial lines through the center of the circles, and is useful for plotting points given by polar coordinates

The distance between the points whose polar coordinates are (r_1, θ_1) and (r_2, θ_2) is given by

$$d^2 = r_1^2 + r_2^2 - 2r_1r_2 \cos(\theta_1 - \theta_2)$$

The relations between **rectangular coordinates** and polar coordinates in a plane are given by the equations

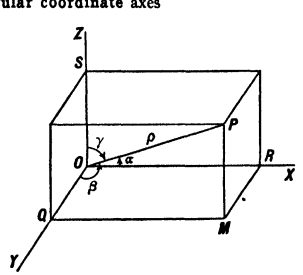
$$x = r \cos\theta, \quad y = r \sin\theta,$$

and

$$r = \pm\sqrt{x^2 + y^2}, \quad \theta = \arctan(y/x),$$

if the pole coincides with the origin and the polar axis coincides with the positive X-axis (L L S)

POLAR COORDINATES IN SPACE. Let P be any point in space, referred in position to a system of **rectangular coordinate** axes



The angles α, β, γ which the line OP makes with the X-, Y-, and Z-axes respectively are called the direction angles of the line OP, their cosines are called the direction cosines of OP

The distance $\rho = OP$ and the three direction angles α, β, γ of OP are sometimes called the polar coordinates of point P

The relation between the rectangular and polar coordinates of a point in space are given by the formulas $x = \rho \cos \alpha$, $y = \rho \cos \beta$, $z = \rho \cos \gamma$, $\rho^2 = x^2 + y^2 + z^2$ (L L S)

POLARIS. Polaris (α **Ursae Minoris**) is the principal star of the **constellation** and, as a matter of fact, about the only claim to recognition which the "little dipper" has This star has been the closest star to the pole of rotation of the celestial sphere for the past five millenniums and has been used by navigators throughout written history The antiquity of the use of this star is attested to by the fact that it is found represented on the earliest known Assyrian tablets At present, Polaris is slightly over one degree from the pole of rotation and hence revolves about the pole in a small circle about two degrees in diameter Twice, and only twice, during every twenty-four hours Polaris accurately defines the true north **azimuth**

At present, the star is universally used by navigators and surveyors for the purpose of determining true azimuth and also astronomic **latitude** Tables have been computed and are to be found in the **Ephemerides** of the various governments for the purpose of reducing the actual position of the star at any particular instant to the actual position of the pole of rotation (W K G)

POLARISCOPE. An instrument for ascertaining the properties of **polarized light** or for studying the effects of various agencies upon light of known polarization It commonly consists of a "polarizer" for rendering common light plane-polarized in any desired azimuth, and an "analyzer" for identifying the character of polarized light, between these is usually a mounting for objects whose effect upon the light from the polarizer it may be desired to test For example, the polarizer may be a **Nicol prism** from which the light emerges vibrating, say, in a horizontal plane, the analyzer may be another, similar Nicol, and between them may be mounted a tube with glass ends in which are placed various liquids to be tested for their rotatory effect A polariscope of this type for sugar solutions is a **saccharimeter.** Or the object to be tested may be a doubly refracting crystal plate or a metallic reflector, rendering the plane-polarized light elliptically polarized, and the analyzer a Babinet **compensator** or similar device for identifying such light Some polariscopes use a "half-shade analyzer," for example, a half-wave plate (equal to two quarter-wave plates) covering half the field, the two halves of which look equally bright through a Nicol only when the analyzer is turned into a certain position with reference to the azimuth of the plane-polarized light entering it In the simplest polariscopes the polarizer and the analyzer are reflecting plates of opaque glass set at the proper polarizing angle (L D W)

POLARITY. In biology, a fundamental differentiation of cells according to functional potentialities Polarity is commonly and often conspicuously expressed in egg cells by a differentiation from an animal pole at one end to a vegetal pole at the other The animal pole is the region of greatest **metabolic** activity Yolk tends to accumulate at the vegetal pole, resulting in extreme cases in a marked concentration of this material in the one part of the cell Such eggs are called telolecithal

Polarity is also expressed in other **cells** of the body Gland cells, for example, have the end toward the free surface of the **epithelium** in which they lie specialized for the accumulation and discharge of the special secretion, while the base of the cell is related to the underying basement membrane The phenomenon is also closely associated with the **axial gradients of the animal body** (See also **Magnetism**) (A W L)

POLARIZATION. Cell, and Electrochemistry; and Polarized Light.

POLARIZATION PHOTOMETER. In the main forms of **bench photometer**, the illuminations or luminous flux densities from the two sources to be compared are made equal by regulating the relative distances. In photometers of the polarization type, the same object is accomplished by introducing a pair of Nicol prisms into the beam from the brighter source and turning one of these polarizers until the beam is cut down to equality with that from the other source The ratio in which the flux density has been reduced, and hence the luminous intensity ratio of the two sources, is readily calculated from **Malus' law**, and the polarizer circle may thus be calibrated to give the ratio directly

The polarization principle may also be applied to **stellar photometry** for the determination of **stellar magnitudes** In one type of polarization photometer an "artificial star" is produced in the same manner as is described under **wedge photometer** and a pair of Nicol prisms is introduced into the path of light from this star The method of use of this instrument is similar to that described for the wedge photometer, the difference being that the angles at which the Nicol prisms are set instead of wedge settings are converted into stellar magnitude difference In the Pickering type of polarization photometer two telescopic objectives are combined in one tube, so that the images formed by each fall side by side In front of each objective a plane mirror is placed, one being adjusted so that an image of Polaris is formed in the field of view, and the other adjustable so that the image of any star, close to the meridian, may be brought into the field of view close to the image of Polaris In the light path from Polaris the pair of Nicol prisms is placed, and the angles at which they are set relative to each other may be calibrated to give the magnitude difference between Polaris and the star under examination There are many modifications of this same general principle which have been devised by observers for their particular problems (L D W, W K G)

POLARIZED LIGHT Whenever ordinary light is reflected from a glass plate, a varnished table-top, or other polished **dielectric** surface, we find upon suitable examination that a much larger part of the reflected beam is vibrating at right angles to the plane of reflection than in that plane, whereas originally it gave no evidence of any preferential direction of vibration A little experimenting shows that at a certain angle of incidence (the "polarizing angle," different for different dielectrics), the component vibrating in the plane of reflection is practically extinguished, all vibration being confined to the plane at right angles to this The light is then plane-polarized The effect is more conveniently produced by a **Nicol prism** or by one of the recently invented polarizing films, which polarize by transmission with less loss of light

When the light passes through two such polarizers in succession, as in a **polariscope**, the fraction of it finally emerging depends upon the angle between the transmission planes of the polarizers, and varies all the way from nearly 100% to zero (See **Malus' law**) The same effect may be produced by two reflections at glass plates turned to reflect in different planes but at the same (polarizing) angle It seems probable that when the polarizing films above mentioned have been further perfected and cheapened, this intensity-reducing effect will be turned to account in solving the problem of automobile headlight glare

Metallic reflectors do not produce plane-polarization, but when plane-polarized light falls on a polished metal, its vibration is in general changed from a rectilinear to an elliptic one, and the light is said to be elliptically polarized (See **Compensator**)

When plane-polarized light traverses a crystal ex-

hibiting **double refraction**, such as calcite, at right angles to its axis, it is transformed into elliptically polarized, or even circularly polarized, light

If plane-polarized light is passed through quartz along its axis, or in any direction through one of the many optically active liquids such as turpentine or sugar solution, it undergoes optical rotation, i e, its vibration plane is twisted around through an angle which steadily increases with the distance traversed in the substance Different substances have very different rotatory power, and some rotate one way and some the other The **saccharimeter** is especially adapted to the study of this effect in liquids Somewhat similar is the **magneto-optical rotation** produced under suitable conditions by a magnetic field (L D W)

POLARIZING ANGLE. Polarized Light; Brewster's Law.

POLECAT. Mammalia, Carnivora Long-bodied animals with short legs, related to the weasels and minks They are known for their disagreeable odor, a characteristic which is responsible for the occasional erroneous application of the name to skunks

The European polecat, also known as the foumart or foul marten and as the fitchet, fitcher, or fitcheu, is the source of the fur known on the market as fitch Three other species occur in Europe and Asia, and one, the black-footed polecat, commonly called the black-footed **ferret**, is found in the plains region of North America The **Cape polecat** of South Africa is more closely related to the skunks than to the true polecats (A W L)

POLES AND POLARS OF CONICS. For the **ellipse** $b^2x^2 + a^2y^2 = a^2b^2$, the equation of the **tangent** at the point (x_1, y_1) is $b^2x_1x + a^2y_1y = a^2b^2$ But if

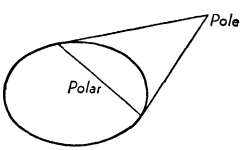


Fig 1

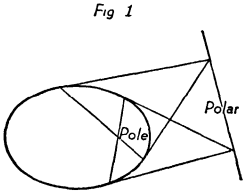


Fig 2

(x_1, y_1) is not a point on the ellipse, the preceding equation represents a straight line called the polar of the point $P_1(x_1,y_1)$ with respect to the ellipse, and P_1 is called the pole of the polar line If the pole P_1 is outside of the ellipse (Figure 1), the polar of P_1 may be obtained by drawing the two tangents from P_1 to the ellipse, and drawing the chord of contact If the point P_1 is inside the ellipse (Figure 2), the polar of P_1 may be obtained by drawing two chords through P_1, drawing the pair of tangents to the ellipse at the ends of each chord, and joining their intersections

The poles and polars of the other **conic sections** are defined in a similar way

An important property of poles and polars of conics is If a point P_2 lies on the polar line of P_1, then P_1 lies on the polar line of P_2. (L L S)

POLIAN VESICLE. Water vascular system.

POLIOMYELITIS (Acute Anterior Poliomyelitis, Infantile Paralysis) An acute systemic infectious disease producing lesions in the brain and spinal cord While isolated cases may occur, it is commonly seen in epidemic form The infective **virus** is transmitted through the respiratory passages, in all probability.

The disease is an old one, but was first accurately described in 1774 The causative organism of the disease has not been isolated, but it is believed to be a virus that attacks only those individuals who have a special susceptibility or no immunity to the disease It is possible to isolate a filtrate from the tissues of the spinal cord and brain of patients who have died of the disease, which will cause infantile paralysis in monkeys

The disease usually has two phases The first, a toxic systemic disorder, marked by fever, respiratory and intestinal symptoms, as vomiting and diarrhea Signs of mild irritation of the central nervous system are frequently present Following the acute stage all symptoms may subside for one to two days, only to return, accompanied by **paralysis** of various groups of muscles in the body This is the second phase Often the first phase is so slight that it is not noticed, and paralysis seems to strike out of a clear sky. The variety and extent of the paralysis is tremendous The degree of recovery from this paralysis is remarkable, however, when proper measures are used to treat it

The advantage of giving serum from convalescent or cured patients remains to be proved However, it can do no harm and may do good, although it does no good after paralysis once sets in

Treatment of the paralysis differs during the initial acute stage and the final permanent paralysis During the initial stage active measures such as massage, movement, electricity, have done untold harm. Later on, active measures are necessary (R S M)

POLLACK. Pisces, Teleostei A marine fish (**Pisces**) related to the haddock and cod One species, *Gadus pollachius*, found in European waters, is also called the whiting-pollack, and another which is taken on both sides of the Atlantic is sometimes called the coal fish. (A W L)

POLLAN. Pisces, Teleostei A species of **whitefish** found in Irish lakes, *Coregonus pollan* (A W L)

POLLEN TUBE. Flower.

POLLINATION. Pollination is the act of transference of pollen grains to the **stigmatic** surface of a flower, where the pollen grain will germinate, forming a slender pollen tube, the development of which leads to the process of **fertilization**

That the ancients should know anything of the act of pollination is scarcely to be expected, yet they had at least an inkling as to the necessity of the process, since they knew that male flowers of dates must be brought to the female flowers if a crop of fruit was to follow Picture engravings on Egyptian monuments show this quite clearly Later the need for caprification in **figs** was recognized

But scientific understanding of the significance of the process and the ways in which it was accomplished was delayed until the studies of Joseph Kolreuter in the second half of the eighteenth century and of Christian Sprengel, who followed soon after From the keen observations of these two men came the first real knowledge of pollination Later Charles Darwin (1809–1882) made careful observations on pollination, observing the existence of two or more flower types in a single species and pointing out the way in which they might effectively cause cross-pollination, which he believed to be of great importance in maintaining the vigor of a race He also attentively studied the process of pollination in **orchids**, observing many of the elaborate developments

found in these flowers to insure successful cross-pollination In the United States, Asa Gray (1810–1888) extended observations to American plants, including many native orchids In Brazil Fritz Muller (1822–1897) made many interesting additions to the knowledge of the mechanisms and agencies involved in pollination While these names are those of men whose observations were extensive, many others have also studied the various ways in which flowers are modified seemingly by foresight as to the needs of the process

Flowers may be self-pollinated or cross-pollinated In self-pollinated flowers, pollen from the **anthers** is transferred directly to the **stigma** of the same flower, while in cross-pollination pollen is carried to the stigmas of other flowers, often not on the same plant That pollen may easily be deposited on stigmas of the same flower does not mean necessarily that self-pollination shall occur, for in many cases pollen under such a condition fails to develop or develops so slowly that foreign pollen from other flowers soon grows beyond it and brings about fertilization When pollen from the same flower or plant fails to bring about fertilization, the plant is said to be self-sterile, many varieties of cultivated fruit are of this sort This explains why it is necessary to plant other varieties of apple among trees of the MacIntosh variety; the pollen of the latter variety is self-sterile

Self-pollination must be a fact in certain flowers of the type known as cleistogamous—flowers which never open to allow pollen to be shed into the air or transferred by any means from flower to flower In such flowers, which are found in many plants, as in several species of violet, the pollen grains may germinate while still in the anther, the pollen tubes growing out to the stigma, and then on to bring about fertilization In other cleistogamous flowers the pollen is shed from the anthers and falls directly onto the stigma, and there develops. Self-pollination also occurs, though not of necessity, in many perfect flowers In many cases the stigma is directly beneath the ripened anthers, so that pollen shaken from the anther is likely to fall onto the stigma In some plants the stigma is always beneath the mature anther, while in other plants movement occurs so that as the part grows older the stigma bends over to a position beneath the anther In such a case, if cross-pollination has not already occurred, self-pollination may be effected In other flowers it is the stamen which exhibits movements, curving or bending in such manner that pollination shall be accomplished In still other plants the filaments gradually elongate so that the anthers are carried upward to the stigma

Cross-pollination is insured by several means In many plants, the stamens mature and shed their pollen long before the stigmas are receptive, while in other plants, the stigmas are mature before the pollen of the same flower has ripened Either case necessarily insures cross-pollination Equally certain is the occurrence of cross-pollination in those plants which bear unisexual flowers on different plants, or if on the same plant male flowers mature some time before the female, as is the case of the Alder, where the inconspicuous pistillate (See **Pistil**) flowers are mature two to four days before the pendulous **catkins** of staminate (See **Stamen**) flowers begin shedding their pollen

Another method which tends to effect cross-pollination is the occurrence of flowers of two, or three, or even four different kinds The purple swamp loosestrife, *Lythrum Salicaria*, shows one such case Some of the flowers of its spike have anthers borne on long filaments and contain pollen grains of relatively large size, other flowers have stamens with short filaments and contain small pollen grains, while a third flower type is intermediate in habit, the filaments being between the others in length and the pollen grains of intermediate size In flowers like these, if insect-pollinated, every likelihood is that pollen of one flower type will be carried to stigmas which show the same gradations in length, so that pollen from stamens with long filaments will be deposited on such parts of the insect's body as will be touched by long-styled pistils; and since these long-styled pistils are not found in flowers having long filaments, cross-pollination will probably occur Flowers having such differences in style length are called heterostylous flowers

Many plants, notably those in the **Carrot** and **Composite Families**, often bring about cross-pollination in another way The flowers grow in compact groups, either **umbels** or heads As the floral organs, stamens and pistils, mature, they grow out in a way that brings about contact between nearby flowers, the stigmas of one flower touching the anthers of another That this does often occur is seen in the **Composite Family**, where in many instances the styles curl back at maturity so that the stigmatic surface is brought directly against the pollen masses

While the transference of pollen from anther to stigma usually occurs, many cases are known in which development of the **ovules** occurs without the presence of any pollen Development of the ovule in such cases is said to be by parthenogenesis In some of these it may be that the vegetative cells around the ovule play a significant part in the process

The agents which are instrumental in carrying pollen from one flower to another are principally air-currents and insects Plants pollinated by air-currents, or wind, are said to be anemophilous, those by insects are entomophilous In addition to these two main agencies there are several minor ones, in a few plants, water is the agent carrying pollen from flower to flower A few flowers are considered to be pollinated by snails, others by birds and some even by bats Man himself may effect pollination by selecting plants or flowers of special value to him and transferring pollen from one to the other, taking special precautions to prevent the presence of foreign unwanted pollen, this is artificial pollination to produce special strains of plants Commonly it is accomplished by gathering mature pollen from any desired flowers, shaking it into a small container With a small camel's hair brush this pollen is then placed on the stigmas of another selected flower, often the second flower is emasculated, that is, the stamens are removed before maturing, to prevent any possible self-pollination Flowers to be pollinated are usually kept enclosed in bags to prevent the presence of any unwanted pollen until fertilization has been effected

As a rule wind-pollinated flowers are inconspicuous, and of small size color, odor, and nectar, all associated with insect-pollinated flowers, are largely lacking Pollen is produced in immense quantities, since much will be lost by adverse winds The pollen grains are smooth-surfaced, dry and dust-like, and so float buoyantly in the air In many plants of this group the stigmas are much-branched, feathery objects, offering a considerable area of sticky surface to catch any pollen that falls on it To further the ready discharge of pollen, which ordinarily occurs only when the atmosphere is dry, the flowers are often borne in pendulous catkins, or on slender flexible **pedicels**, or have stamens the anthers of which are versatile, that is, attached at the middle and easily moved by any slight disturbance Examples of wind-pollinated plants are found in the **Gymnosperms**, all of which are so pollinated, in most grasses, in many hardwood trees, such as birches, alders, **oaks**, and beeches, and in the common **cat-tail** of the marshes

Water-pollinated plants are not numerous. That a plant grows in water is not an indication that its flowers shall be pollinated by water Indeed, only a very few water-plants are so pollinated In some cases, as in the marine **eel-grass**, *Zostera marina*, pollination occurs under water, the heavy pollen grains being carried by the water and by chance reaching the stigmatic surface The fresh-water plant, *Naias*, is similarly pollinated under water, its pollen grains having a specific gravity of 1. In other water plants, pollination occurs at the surface

of the water. Examples of this type are found in the fresh-water eel-grass, *Vallisneria spiralis*, and in the marine *Ruppia maritima* When the staminate flowers of eel-grass are mature, they break from their rather short stem and, being buoyant because of air-chambers, float to the surface of the water There the spathes surrounding the flowers open, exposing the stamens within These float about on the surface of the water, driven by air currents, as well as borne by water currents. The pistillate flower is solitary at the end of a long spiral stalk, when this flower is mature the stalk straightens so that the flower floats on the surface of the water, its three stigmas spreading wide and over-reaching the three-parted perianth Chance drifting of the staminate flowers brings them near the stigmas which may then be pollinated by contact with the anthers After pollination and subsequent fertilization, the stalk of the pistillate flower coils into a tight spiral, drawing the developing ovary deep into the water, where it matures

Plants with flowers pollinated by animals are extremely numerous, and with many variations seemingly calculated to assure cross-pollination A few tropical plants are said to be pollinated by bats. The flowers have very fleshy petals, open during the evening hours, and are apparently sought by bats, which eat the petals, or perhaps seek any insects which may occur in the flowers Quite possibly, in going from flower to flower, bats do bring about a transfer of pollen Pollination by such animals is undoubtedly restricted to a very small number of plants

Similarly birds, especially humming-birds and honey-suckers, are held to be the agents pollinating several tropical plants In these the question arises as to whether the birds are seeking the numerous insects which are to be found in the flowers or after the nectar which is found in the flowers The flowers visited by birds are rather large, brilliantly colored, often scarlet Unquestionably humming-birds do visit flowers, both in the tropics and in temperate regions Pollination may well result from their visits

A few flowers are said to be pollinated by snails or slugs Plants so pollinated have dense masses of flowers borne on a fleshy stock This mass of sterile tissue attracts these animals, which crawl over it in the search for food, and so are said to carry pollen from flower to flower Many observers doubt that such animals ever bring about pollination

All, however, recognize that insects are very important in the pollination of many flowers In many cases the flowers show remarkable adaptations fitting them to be pollinated by certain insects The insects which effect pollination are for the most part bees, flies, beetles, and moths and butterflies

As certain features characterize wind-pollinated flowers, so also insect-pollinated flowers exhibit several common features In them the pollen grains are usually somewhat adhesive, often sticking together into considerable masses The surface of each grain is variously sculptured, with knobs, spines, or other protuberances definitely increasing the ability of the grain to stick to the insect body As in wind-pollinated flowers, so here the pollen would be seriously impaired by water, from which it must be protected during periods when pollination would not occur Many are the ways in which protection is obtained In some plants the entire flower bends down at night, while in many others the petals close together over the stamens, often a passing cloud is sufficient stimulus to cause closing, which takes place with surprising speed In many plants the flowers are located beneath the leaves, as in the common Jewel-weed or Touch-me-not (*Impatiens biflora*), in the common Iris, each stamen is located beneath the broad-petaloid stigma Often the anther itself is so constructed as to afford considerable protection, the pollen frequently being shed through narrow slits which close tightly during periods of excessive moisture; or small pores may allow the pollen to escape when advantageous but protect it from water otherwise

A most obvious characteristic of insect-pollinated flowers is color, which may be found in a single flower with large conspicuous petals, or may result from the massing together of many small flowers, as in the **Composite Family** While it is generally assumed that bright color is an aid to pollination because it attracts insects, it should be recognized that insect vision is not necessarily like that of human beings. To see any reason for the existence of color in flowers, if not to attract insects, is a difficult problem Often the color of a flower changes with age, many becoming gradually deeper toned, as in the common Lady's Slipper, while others as gradually fade out Flowers opening at night are almost all white or very light-colored

The odors of flowers are also assumed to attract insects Every fragrant flower has an odor which is quite distinctive The odors of flowers are of many types, from the foul rankness of the Skunk Cabbage and Carrion Flower to the delightful perfume of Verbena, Gardenia, the Roses, and many Lilies In many cases the odor of the flower is very delicate, being scarcely detectible to many people, in others it is of such penetrating strength as to become objectionable Often the odor is evident only during certain periods, some flowers being scentless by day but fragrant during the night, while others emit their odors only in broad daylight All these differences in odors seem designed to attract special insects which will accomplish pollination The foul odor of carrion calls carrion-flies, and the sweet fragrance of night-blooming flowers attracts moths. After pollination the odor of the flower generally ceases, attraction of insects being no longer of any value

Many insects undoubtedly visit flowers for the purpose of obtaining nectar, a sweet watery secretion formed in special glands called nectaries These nectaries are variously located in the flower, usually deep down at the base of the corolla, so that any insect obtaining it must either have a mouth part of sufficient length to reach the nectar or be strong enough to push its way into the flower, passing any obstructions which may serve to protect the nectar from thieving insects Obstructions are found of several sorts A very common means of excluding such crawling insects as ants, which in all probability would not be efficient pollinators, is by the presence of a barricade of hairs, especially in the throats of flowers having a tubular corolla Long-tongued bees are able to push through these hairs enough to reach the nectar, while at the same time they are thoroughly powdered with pollen which may be removed later in another flower The existence of a sticky secretion over the outside of the flower or on the stem of the plant is an effective barrier to many crawling insects, as is also a waxy coating Especially noteworthy are those flowers in which the nectar is located at the base of a long narrow tube or spur, often the nectar is present in quantities large enough to form a considerable volume In such cases there is usually an insect with mouth part just long enough to reach through the tube into the nectar supply, which is sucked up greedily This becomes the more remarkable when one considers that in some flowers the nectar is at the bottom of a tube which may be three or four inches long, and in the case of one tropical Orchid a nectar-secreting sac over a foot long exists, in such cases insects, usually moths or butterflies, with correspondingly long sucking tubes are found Often short-tongued insects succeed in obtaining the nectar illegitimately by biting a hole in the wall of the nectar-containing part of the flower, and obtaining the nectar thereby It is interesting to note, in connection with this problem of nectar-secreting flowers and insects, that the introduction of clover into Australia was not a success until honey-bees were also introduced The native Australian bees were too short-tongued to reach the nectar and so pollination was not effected As a consequence the clover crop soon died out, no seed

being formed to perpetuate it With the introduction of suitable bees the plant grew readily and seeded abundantly

It is interesting to note that in addition to the existence of colors, odors, and nectar, the structure of the flower and its position on the plant seem designed to facilitate the work of the insect in transferring the pollen Many flowers are broad and flat, affording convenient support to the insect as it crawls about over the flower. Others, especially those which are visited by long-tongued moths, are borne in such a position as seems most suited to permit the insect to insert its tongue and obtain the nectar The pollen is collected in quantities by many species of bees, who use it as a food for the developing young

Several plants have developed a most striking relationship with insects While the majority of flowers are not visited indiscriminately by all insects but only by certain species or genera, in these special cases the restriction is extreme, both the flower and the insect seeming to be modified especially to serve one another One such case is seen in the edible **fig,** pollinated only by a small insect, *Blastophaga grossorum,* which lays its eggs in the ovaries of certain flowers of the fig Another example of this insect-flower association occurs in a species of Yucca The creamy-white flowers of this plant are borne in large panicles They open during the evening and are visited by a small moth, *Pronuba Yuccasella,* which seeks the abundant pollen of the flower Of this pollen the moth makes a tiny ball which it carries away to another Yucca flower In the ovary of this flower the female moth lays her eggs, while on the stigmatic surface it deposits its ball of pollen The developing ovules serve as food for the growing larvae of the insect However, many ovules grow to maturity to form viable seeds, which perpetuate the plant and so continue the food supply of the moth, which seems to be the sole agent capable of transferring the sticky pollen of the Yucca from plant to plant Many other cases are known where pollination of the flower depends on the visit of certain insects, which do not, however, themselves depend on the flower for existence (R M W)

POLLUCITE. The mineral pollucite is rather rare It contains caesium, aluminum, silicon, and oxygen, its chemical composition being approximately $H_2O\ _2Cs_2O\ _2Al_2O_3\ _9SiO_2$ It is **isometric,** usually in cubic crystals or crystalline masses, conchoidal fracture, brittle, hardness 6 5, specific gravity 2 9, luster, vitreous on fresh surfaces, colorless and transparent Found on the Island of Elba and in the **pegmatites** of Maine Pollucite and **petalite** were found in the **granites** of Elba and at first named pollux and castorite for the two famous brothers of Roman mythology, Castor and Pollux Pollucite is derived from the Latin genitive *Pollucis* (E S C S)

POLLUX. Pollux (β **Geminorum**) is the brighter of the "heavenly twins" The two stars are always considered together in ancient writings and in astrology, and, as a matter of fact, are not mentioned individually in literature, but always as the **constellation** of Gemini This constellation is of very ancient lineage and is referred to throughout all classical literature They were always considered of good omen by all peoples and always referred to as twins **Astrologically,** the constellation was most favorably regarded portending genius, goodness, and liberality (W K G)

POLONIUM. Symbol· RaF (or Po) A radioactive element of the uranium-radium series See **Radioactive Changes** (R K S)

POLYCHAETA. **Chaetopoda.**

POLYCLADIDA. **Turbellaria.**

POLYCONIC PROJECTION In this type of projection the surface of the earth is developed on a series of cones tangent to the surface of the earth at certain selected parallels of **latitude** and along some selected **meridian** When a cone is developed as a plane surface the base, or any circle on the cone parallel to the base, will appear as a circle with the apex of the cone as center In the case of the development of the earth on many cones the different apexes of the cones are on the axis of the earth, produced by the necessary amount so that the tangent from the selected latitude will intersect it Accordingly in the polyconic projection parallels of latitude will be developed as circles of different radii and the sections due to latitude zones of finite width will be tangent to each other only along the central meridian As we go out from the central meridian the divergence between the successive parallels becomes greater and greater and, in order that the chart shall be continuous, stretching and distortion must be introduced

On the completed chart parallels of latitude will appear as sections of approximate circles, and meridians will be curves converging on the pole of rotation of the earth The central meridian of the chart will be a straight line perpendicular to the parallels of latitude The great advantage of the polyconic projection is that there is no distortion of shape or size along the central meridian and the distortion does not become at all serious until a considerable distance from this central meridian is reached Furthermore, the same scale of distance can be used all over the chart unless it extends to extreme distances from the central meridian On this type of chart the geodesic line (shortest distance between two points on the surface of the earth) will be projected as practically a straight line, but the **rhumb line** will appear as a curve Hence such a chart is not in general used for laying down long courses, but is used for details along a coast line (W K G)

POLYEMBRYONY. The development of more than one individual from a single fertilized egg cell In this process the egg breaks up during its early development into several to many component parts, each of which becomes a complete animal It takes place in the phylum **Bryozoa** in connection with the formation of colonies and has been reported in some of the parasitic insects (**Hymenoptera**) Since the host animal defends itself against the efforts of the female parasite to deposit her eggs in its body, the development of many young from each egg successfully placed is an obvious advantage The process is akin to an asexual reproduction (A W L)

POLYMASTIGIDA **Mastigophora.**

POLYMERIZATION **Association and Polymerization.**

POLYMORPHISM. The occurrence of individuals of distinctly different structure or appearance within a species In many cases two such forms occur and the species is said to be dimorphic rather than polymorphic

Polymorphism depends upon many different conditions in various groups of animals The various forms may be adapted for different places in a life cycle, for special parts in a colonial or social organization, or for special stages in a **metamorphosis** They may also result from the incidence of different environmental conditions due to seasons or to unusual climatic conditions

The alternation of **polyp** and **medusa** in a reproductive cycle in some species of **coelenterates** is a conspicuous example, as also is the appearance of such varied polyps as the gasterozooids and dactylozooids in colonial species A differentiation of individuals according to special duties is evident in the castes of social insects Many insects also vary according to the season or according to geographical range, as in the case of the wet and dry season forms of various tropical butterflies.

Seasonal form, geographical race, variety, and subspecies are terms applied to forms of this kind The influence of unusual conditions sometimes affects an occasional individual, producing an aberration In chemistry, the term polymorphism is applied to compounds which exhibit **allotrophy.** Thus a substance that can occur in two crystalline forms like calcium carbonate is said to be dimorphous, one that can exist in three crystalline forms like thallous nitrate is said to be trimorphous, etc The term polymorphous, as stated above, is general for them all (A W L)

POLYNOMIAL EQUATIONS A polynomial equation of degree n in one variable or unknown is an equation of the form

$$a_0x^n + a_1x^{n-1} + a_2x^{n-2} + \quad + a_{n-1}x + a_n = 0 \ (a_0 \neq 0),$$

where n is a positive integer and the coefficients a_0, a_1, . , a_n are independent of x It is also frequently called a rational integral equation

Polynomial equations are classified into various types according to degree, as **linear equations, quadratic equations, cubic equations, quartic** (or biquadratic) **equations,** quintic equations, etc

Every **linear equation** and every **quadratic equation** in one unknown can be solved in terms of algebraic expressions involving the coefficients **Cubic equations** (of third degree) and **quartic equations** (of fourth degree) can also be solved by explicit formulas for the roots in terms of algebraic expressions involving the coefficients It has been proved, by Abel, however, that a polynomial equation in one unknown of degree higher than 4 cannot be solved in the general case algebraically, that is, for the roots in terms of algebraic expressions involving the coefficients

In special cases, polynomial equations may be solved by the method of **factoring**

Approximate values of the real **roots** of polynomial equations may be found by a graphical solution, by constructing the **graph** of the equation and finding the **abscissas** of the intersections of the graph with the X-axis

If a **polynomial function** $P(x)$ contains $x - r$ as a factor exactly k times and no more, so that $(x-r)^k$ is an exact divisor of $P(x)$ but $(x-r)^{k+1}$ is not, then r is called a multiple root of the equation $P(x) = 0$, or we say that r is a root of multiplicity k or a root of order k A root of order one is called a simple root

The so-called "fundamental theorem of algebra" is: Every polynomial equation in one unknown has at least one root (which may be real or complex)

It follows from this that every polynomial equation of degree n in one unknown has n and only n roots, provided a multiple root of order k is counted as k roots

If r is a simple root of a polynomial equation $P(x) = 0$, (i e , if $x - r$ is a factor of $P(x)$ once and only once) it is not a root of the equation $P'(x) = 0$, where $P'(x)$ denotes the **derivative** of $P(x)$ If r is a multiple root of order $m > 1$ of $P(x) = 0$, it is a root of order $m - 1$ of $P'(x) = 0$

If a root of a polynomial equation is known, the corresponding factor may be divided out of the polynomial, leaving a new equation of lower degree, called the depressed equation

The location of the real roots of a polynomial equation may be investigated by means of **Descartes' rule** This rule gives more or less definite information about the nature of the roots of a polynomial equation

The location of the real roots of a polynomial equation may be determined by the following theorem If $P(x)$ is a polynomial with real coefficients, and if $P(a)$ and $P(b)$ have opposite signs, the equation $P(x) = 0$ has at least one and in fact an odd number of real roots between a and b; if $P(a)$ and $P(b)$ have like signs, the equation $P(x) = 0$ either has no roots between a and b, or it has an even number of roots between a and b

In locating the real roots of the equation, the following result is also of use If in substituting in a polynomial $P(x)$ a positive value r by **synthetic division,** all the partial sums are positive, then r is greater than any real root of the equation $P(x) = 0$

In the process of finding the rational and irrational roots of a numerical polynomial equation, certain **transformations of the equation** are useful

The determination of the rational roots of a polynomial equation is generally based on the following theorem.

If a polynomial equation, with the coefficient of the highest power of the variable unity, and all the other coefficients integers, has any rational roots, those roots must be integers, and must be divisors of the constant term, if the constant term is not 0

To find the rational roots of a polynomial equation with first coefficient unity and all other coefficients integers, it is only necessary to test whether the integral factors of the constant term satisfy the equation, usually using synthetic division

If the coefficient of the highest power of the variable is not 1 or if the coefficients are not integers, we may divide all terms by the coefficient of the highest degree term, and then remove any fractions in the other coefficients by transforming the equation by multiplying the roots by the appropriate factor, and thus reduce the equation to the form of the preceding method

If a quadratic surd $a + \sqrt{b}$, where a and b are rational but $\sqrt{b}$ is irrational, is a root of a polynomial equation $P(x) = 0$ with rational coefficients, the conjugate surd $a - \sqrt{b}$ is also a root of the equation

For the calculation of the approximate values of the irrational roots of a polynomial equation, there are available **Horner's method, Newton's method,** interpolation methods, and combinations of these These methods will give the approximate values of the roots to any desired degree of accuracy

If a complex number $a + bi$ is a root of a polynomial equation $P(x) = 0$ of degree $n \geq 2$ with real coefficients, the conjugate complex number $a - bi$ is also a root of the equation $P(x) = 0$

In other words, complex roots of polynomial equations occur in conjugate pairs

Approximate values of the roots of a polynomial equation may also be calculated by use of Graeffe's root-squaring method, this method is particularly useful in finding the complex roots of high-degree equations

The relation between the roots and coefficients of any polynomial equation are given as follows If $r_1, r_2, \ldots, r_n$ are the roots of the equation

$$x^n + a_1x^{n-1} + a_2x^{n-2} + \quad \cdot \quad + a_{n-1}x + a_n = 0,$$

then

$$\begin{aligned} -a_1 &= r_1 + r_2 + \quad + r_n, \\ a_2 &= r_1r_2 + r_1r_3 + \quad + r_{n-1}r_n, \\ -a_3 &= r_1r_2r_3 + r_1r_2r_4 + \quad \cdot \quad + r_{n-2}r_{n-1}r_n, \\ &\cdots\cdots\cdots\cdots\cdots \\ (-1)^n a_n &= r_1r_2 \cdots r_n \end{aligned} \qquad \text{(L L S)}$$

POLYNOMIAL FUNCTION. A rational integral function (or polynomial function) is a **rational function** in which the variable never appears in the denominator of a fraction. It can be expressed in the form

$$P(x) = a_0x^n + a_1x^{n-1} + \cdots + a_{n-1}x + a_n,$$

where x is the variable, n is a positive integer, and the coefficients a_0, a_1, . , a_n are constants (independent of x), in this case, the function is said to be of the n^{th} degree

Polynomial functions are classified into types according to the degree, into **linear functions, quadratic functions, cubic functions, quartic** (or biquadratic) **functions,** etc. (L L S.)

POLYNOMIALS. A polynomial in general is an **algebraic expression** consisting of two or more terms connected by plus or minus signs

A polynomial in one variable is an expression of the form

$$a_0x^n + a_1x^{n-1} + a_2x^{n-2} + \cdots + a_{n-1}x + a_n,$$

where the coefficients a_0, a_1, . . ., a_n are **constants** (independent of x), x is the **variable** and n is a positive integer, which is called the degree of the polynomial The degree of the polynomial is the highest power of the variable that occurs in the expression A polynomial in a variable x is frequently denoted by a symbol as $P(x)$

A polynomial in several variables x, y, z, . . is an algebraic expression of the form of an algebraic sum of terms of the type $cx^my^nz^p$, where c is a constant coefficient and each of the **exponents** m, n, p, . . is either a positive integer or zero The degree of such a polynomial term in the variables x, y, z, . . is the sum $m+n+p+$ . . of the exponents of these variables The degree of the polynomial is the degree of its term of highest degree (L L S)

POLYOPISTHOCOTYLINEA. Trematoda.

POLYP. In zoology, a polyp is one of the two types of individual found in many species of **coelenterates.** The two are the polyp or hydroid and the **medusa.** Polyps are approximately cylindrical, elongated on the axis of the body One end is usually attached and the other bears the mouth, surrounded by a circlet of tentacles The wall is relatively thin, due to the thinness of the mesogloea In the class **Hydrozoa** polyps are often very simple, like the common little fresh-water species of the genus Hydra Actinozoan polyps, including the **corals** and **sea anemones,** are much more complex, due to the development of a tubular stomodaeum leading inward from the mouth and a series of radial partitions called mesenteries Many of the mesenteries project into the enteric cavity but some extend from the body wall to the central stomodaeum

In medicine, a polyp is smooth-coated tumor from a mucous surface It is attached to the surface by a narrow elongated **pedicle.** They are commonly found in the nose, bladder, rectum and large intestine They may also occur elsewhere in the body (A W L, R S M)

POLYPEPTIDES. Aminoacids, Polypeptides, and Proteins.

POLYPHYLETIC. A group of organisms derived from more than one ancestral stock is said to be polyphyletic (R M W)

POLYPHYLY. An evolutionary hypothesis which assumes that animals have originated by several lines of descent from as many ancestral forms, rather than from a single primordial form by gradual divergence Special creation is the extreme of polyphyly but the hypothesis is not in discord with organic **evolution.** Although a great majority of organic forms seem traceable to a common ancestry there are a few peculiarities among the simpler living things which may indicate origin from independent lines Among them are the cell structure of the **bacteria,** which lack a centralized **nucleus,** and the peculiar **metabolism** of some of the autotrophic species, such as iron and sulphur bacteria. Since modern evolution assumes the origin of life in the beginning from inorganic matter, there is no inherent obstacle to the assumption that living matter in that simple state may have been established independently in more than one place on the surface of the earth (A W L)

POLYPLACOPHORA. Amphineura.

POLYSACCHARIDES. Carbohydrates.

POLYTROPIC PROCESSES. The expansion or compression of a constant weight of gas may assume a variety of forms, depending on the extent to which heat is added to or rejected from the gas during the process, and also on the work done There are, theoretically, an infinite number of ways possible in which a gas may expand from an initial pressure p_1, and volume v_1 to a final volume v_2 All these expansions may be grouped generically as polytropic expansions, and all could be represented graphically on the PV plane by the family of curves $pv^n = C$ n may have any possible value whatever, and having been selected numerically it defines the type of expansion. From the infinite number of possible polytropic expansions, it is worth while to isolate four which deserve special attention. When one of the four physical characteristics, to wit — **pressure, temperature, entropy,** or **volume,** remains a constant, expansions of more than ordinary interest are denoted, since they are frequently employed in a practical way, in situations which can be subjected to **thermodynamic** analysis The value of the exponent n of the polytropic family for each of these is:

Isobaric	. $n = 0$,
Isothermal	$n = 1$,
Adiabatic	$n = \gamma$ (γ = ratio of specific heat at constant pressure to test at constant volume)
Isometric.	.. $n =$ Infinity

These thermodynamic processes, as they occur in useful machines, are not often of the exact polytropic form desired For example, an adiabatic process which is exemplified, at least theoretically, by expansion of the burned gases after the explosive combustion in the gasoline engine, is modified slightly by the interchange of heat between gases and cylinder wall, whereas a true adiabatic has no heat either added or rejected in this way The particular polytropic curve which would suit these conditions of expansion would depart somewhat from the adiabatic form

During a polytropic process conditions of the working medium are constantly varying, and analysis may be aimed at determining one of the following the work done, the heat added, the variation of temperature, and the change of entropy Some information may be obtained merely by comparing the value of the exponent n with certain other data For example, if n lies between 0 and 1, the temperature rises during an expansion and falls during a compression, when n is greater than 1, the temperature falls during expansion, and rises during compression Also, when n is less than γ, heat must be added to obtain an expansion, whereas when it is greater than γ, heat must be expelled From the above it will be noted that there is a certain range of polytropic expansion in which, although heat is added, the temperature falls This may seem to some to be paradoxical, but it is readily explained During these expansions work is being done by the gas at a rate greater than that at which heat is being added, with the result that the deficiency must be made up from within the gas The only way that this may be accomplished is for the gas to cool and give up some of its internal energy

The equations for work done and for heat added in the case of the general polytropic expansions are

$$W = \frac{p_1v_1 - p_2v_2}{n-1}.$$

$$Q = (p_1v_1 - p_2v_2)\left(\frac{1}{n-1} - \frac{1}{\gamma-1}\right).$$

Both of these are expressed in foot-pounds. Sometimes a substitution of a definite value of n in one or the other of these equations leads to an indeterminate, for example, with the isothermal,

$$W = \frac{p_1v_1 - p_2v_2}{1-1}.$$

But since the equation of the isothermal for an ideal gas is

$$pv = C,$$
$$p_1v_1 = p_2v_2,$$

and the work equation becomes indeterminate:

$$W = \frac{0}{0}.$$

By approaching the isothermal from a different angle, however, the equation

$$W = pv \log_e \frac{v_2}{v_1}$$

may be deduced for work done (F T M)

POLYZOA. Bryozoa.

POMACE FLY. Drosophila.

POME. Fruit.

POMEGRANATE. *Punica granatum* Punicaceae The pomegranate is a shrub or small tree which is native to southeastern Europe and southwestern Asia It has been cultivated since early times, and is now grown extensively in tropical and subtropical regions in both hemispheres The plant has opposite entire leaves which are elliptical to oblong in shape The flowers are borne either singly or in small clusters in the axils of the leaves They are perfect and have a bright red **corolla** of 5–8 **petals,** and many **stamens.** The **fruit** is a many-seeded berry The outer coat of each seed is soft and fleshy and red in color Pomegranates are used in making jellies and jams (R M W)

PONS. Brain.

PONTOON. Cottontail.

PONY. Mammalia, Perissodactyla A **horse** of various small hardy and agile breeds indigenous to certain islands of the Old World The Shetland pony is most familiar, from its use for children in the United States Other breeds occur in the Orkneys and Iceland, northern Europe and Great Britain (A W L)

POOR-WILL. Aves, Caprimulgiformes. A small North American **goatsucker,** *Phalaenoptilus nuttali* The species lives in the western half of the United States and Canada (A W L)

POPPY. *Papaver somniferum* Papaveraceae The poppy from which opium is obtained is an annual herb having a smooth branching stem 2–3 feet tall, large dull green smooth leaves and solitary single flowers, varying from white to purple in color and rather showy The flower consists of two **sepals,** which soon fall off when the flower opens, four **petals,** many **stamens** and a single **pistil** with a one-celled **ovary.** The fruit is a **capsule,** 1–2 inches in diameter, containing many small seeds, which escape through a ring of pores which form around the top of the capsule, beneath the persistent **stigma.**

To obtain opium, the unripe capsules are incised with a knife From these cuts the milky juice oozes and dries to form a plastic gummy substance, which is scraped off and molded into a ball This is crude opium, which contains fragments of the plant tissues and considerable dirt About 10% of the opium is the alkaloid morphine. When first prepared opium is brownish and easily molded It gradually dies to a hard brittle substance, easily ground to a powder. Besides morphine it contains many other alkaloids

The opium poppy was known and used by the ancients. It is a native plant in southwestern Asia, but has spread in cultivation over much of Asia as well as parts of Europe and elsewhere In the Orient opium is much used in smoking, a habit-forming pastime which quickly ruins its follower. To produce opium profitably much cheap labor is necessary, therefore the principal producing countries are in Asia

Opium and its derivative, morphine, are extremely valuable medicinally, being used to relieve pain and to induce sleep

Poppy seeds, which contain no harmful substances, are frequently used in bread and cakes From them is expressed an expensive oil used in cooking and in making artist's paints (R M W)

PORBEAGLE. Pisces, Plagiostomi A **shark,** *Lamna cornubica,* found in the warmer parts of the Atlantic, occasionally farther north and in the Pacific Its length is eight to ten feet Also called the mackerel shark, although this name belongs to another larger species (A W L)

PORCELLANITE. Metamorphosed **marls** and **shales** which look like porcelain (R M F)

PORCUPINE. Mammalia, Rodentia An animal with many modified hairs resembling quills in form These hairs are sharp-tipped rigid spires with finely barbed tips which penetrate flesh very readily and serve as an almost impregnable defense

North America has two species of porcupines, one ranging over the eastern half of the continent as far south as Virginia and the other, *Erethizon epixanthum,* in the far west, from Alaska to Mexico The common eastern species, *E dorsatum,* is also called the hedgehog Both species are partial to the leaves, twigs and bark of evergreen trees as food

The tree porcupines differ in having long prehensile tails They are found in Mexico and South America Still other species live in Eurasia, Africa, and the Oriental Region (A W L)

PORGY. Pisces, Teleostei A fish (**Pisces**) of the family Sparidae, in particular a valuable food fish found along the Atlantic coast from Cape Cod to South Carolina This species is also called the scup, or scuppaug Among the other species of the family are the red snapper, and sheepshead, both among our best marine food fishes The name is also spelled porgie and porgee. (A W L)

PORIFERA. The sponges A **phylum** of animals of low organization, related to some of the one-celled **protozoans** and much more primitive than any other multicellular group Because of their loosely integrated structure the sponges are regarded as one of three major types of animal organization, designated by the term Parazoa This group lies between the Protozoa, also a single phylum, and the Metazoa, containing all of the other multicellular phyla

Sponges develop only two germ layers, the ectoderm and endoderm, but many different cells lie in the mesogloea between the two The body wall is perforated by many canals leading to a central cavity, the **paragaster.** Some part of these passages is lined with collared **flagellate** cells which produce currents of water flowing inward through the pores and out of a larger opening of the paragaster called the osculum The body wall contains several kinds of specialized cells The scleroblasts form hard supporting structures of various forms and materials, called spicules **Phagocytes** ingest, digest, and transport food **Porocytes** become perforated to form canals The outer surface is covered with flattened cells called pinacoecytes

Three kinds of sponges are recognized, according to the plan of the canal system· 1 Ascon sponges have canals leading entirely through the body wall and collared cells (choanocytes) in the lining of the paragaster 2 Sycon sponges have radial canals lined with choanocytes and opening into the paragaster Between them inhalant canals lead inward from the outside but do not reach the paragaster The two types of canals are connected by minute pores called prosopyles through which

water must pass to reach the interior. 3. In the rhagon or leucon sponges the canal systems are more intricately branched and the choanocytes are located in small chambers.

Commercial sponges are the skeletal remains of species whose bodies are supported by fibers of a peculiar material, spongin. The organic matter is removed by maceration and washing.

The phylum is divided into three classes:

Class Calcarea. Sponges whose bodies contain calcareous spicules only. The **choanocytes** are large and all three types of canal systems are represented.

Class Hexactinellida. **Spicules** six rayed and siliceous. Choanocytes small. Canal system of a simple rhagon type. The glass sponges.

Class Demospongiae. Spicules siliceous but not six-rayed or an association of siliceous (**silicon**) material and spongin. Rhagon type of canal system. The sponges of commerce are included here. The subfamily Spongillinae includes the only species of sponges found in fresh water. See also **Invertebrate Paleontology.** (A.W.L.)

POROCYTE. A kind of cell found in sponges. They become perforated to form minute pores through which water passes to enter the body of the sponge. (A.W.L.)

POROUS PLUG EXPERIMENT. Joule-Thomson Effect.

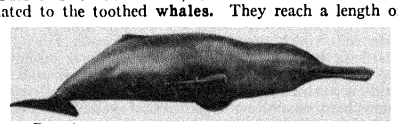
PORPHYRINS. Pyrrole and Related Compounds.

PORPHYRITE. A term applied to **hypabyssal igneous** rocks, such as **dykes, sills** and **laccoliths** of andesitic composition and pronounced porphyritic texture. (R.M.F.)

PORPHYROBLAST. A term proposed by Becke, in 1900, for pseudo-**porphyritic** crystals formed by thermodynamic **metamorphism.** (R.M.F.)

PORPHYRY. Porphyry is a textural term applied to **igneous rocks** in which one or more of the mineral constituents present exists as well crystallized individuals in a ground mass that is relatively of much finer grain. The derivation of the word presents an interesting study. The gasteropods of the genus Murex were much used for obtaining a purple dye, the Greek name for both the animal and the dye is the same. A certain Egyptian rock which was once much used for building and ornamental purposes displays very prominent crystals in a purplish groundmass and so the same Greek word was applied to it, then later came to mean all rocks of this general appearance. Modern use now restricts the term porphyry to the description of texture alone as in the case of the Egyptian rock. (E.S.C.S.)

PORPOISE. Mammalia, Odontoceti. Small animals related to the toothed **whales.** They reach a length of



Porpoise. (Courtesy of *American Museum of Natural History.*)

about five feet. The muzzle is bluntly rounded and most species have a dorsal fin. Porpoises are found chiefly in the northern oceans although one species ranges from Japan to southern Africa and enters the rivers of China and India. (A.W.L.)

PORT. The word port refers to the opening or means of entry into a certain region. In engineering, the port is that connecting passage or opening by means of which a fluid flow is admitted to such a region as that furnished by a cylinder. The gasoline engine (**Otto engine**), the **Diesel engine,** and the **steam engine,** as well as the **air compressor,** have openings arranged in the cylinder so that the contents may enter and leave properly. In the steam engine, the single port may sometimes serve for both admission and exhaust of the steam. This port leads from the valve chest into the end of the cylinder. The valve will alternately connect the cylinder with either the high pressure steam or the exhaust region, and the steam flows first in through the port, then out. Some steam engines are double-ported, having separate ports for admission and release of steam. This is an aid to reducing a loss known as **initial condensation.** The **internal combustion engine** usually has two ports, one the inlet, the other the exhaust, since the internal combustion type valve is not suitable for single valve practice. In the gasoline engine, the typical port is a circular opening cored into the cylinder block, terminating at one end in the valve seat, and at the other in the manifold. Usually the valve stem passes through this port for a short distance. If an exhaust port, it must be well water-jacketed or flanged, so that heat may be conducted away rapidly enough to prevent damage to the metal. Smoothness of stream flow through the ports, and minimum friction loss are desirable in obtaining the maximum possible inflow to the cylinder, or exhaust from it. The size of a port is fixed by the cylinder bore and piston speed, and the ports should bear a relationship to piston area which has been found to be satisfactory in actual practice. (F.T.M.)

PORTLAND CEMENT. Cement, Portland.

PORTUGUESE MAN-OF-WAR. Coelenterata, Hydrozoa. A beautiful but dangerous colonial **hydrozoan,** *Physalia.* It consists of a large hollow float, the pneumatophore, from which many delicate filaments hang into the water. These filaments are tentacles of a form of individual called a dactylozooid. The stinging cells in them kill the prey and their muscular contractions draw it up within reach of the gastrozooids which digest it. The poison of these animals is virulent and the colony is large enough to be dangerous even to human beings. (A.W.L.)

POSITION ANGLE. The term position angle is used in astronomy to denote the angle between the great circle joining any two celestial objects, and the **hour circle** through one of the objects. In measuring **double stars** the position angle is the angle between the great circle joining the two stars and the **hour circle** through the brighter of the pair, the angle being measured from the north to the east through 360°. (W.K.G.)

POSITIVE RAYS. Canal Rays.

POSITIVE-RAY ANALYSIS. Mass Spectrograph.

POSITRON. An elementary charged particle, sometimes called the "positive electron" because its mass is apparently of the electronic order and its charge is positive. Positrons were first observed by C. D. Anderson by means of their ionization tracks in the air of a **cloud chamber.** They were thought to arise from the impacts of **cosmic rays** of very high energy upon atoms. Anderson later showed that particles of the same type are emitted when gamma rays of very high frequency are intercepted by a plate of metal. For this purpose the gamma-ray quanta must have energies exceeding a million electron-volts. Blackett and Occhialini have set forth the remarkable theory that in such an encounter the quantum itself, originally neutral, is transformed into a positron and an electron, part of its energy being converted into the masses of these particles (See **Energy** and **Relativity**), and the rest appearing as their kinetic energy. (L.D.W.)

POT HOLE. Under favorable conditions where streams flow over the bed rock, swirling eddies will wash sand,

gravel or pebbles around and around in the same place with the result that cylindrical holes called pot holes, are worn, often to a considerable depth These pot holes may be from a few inches to several feet in diameter and rarely as much as forty to fifty feet deep Similar features found on the sea shore, the result of wave action, are called sea-mills Pot holes also have been formed by water from crevasses and ice cliffs of glaciers (R M F)

POTAMOGALE. Mammalia, Insectivora *Potamogale* An amphibious animal of western Africa It has a slender body and short legs like the mink and otter, and is further characterized by the compressed tail and valves to close the nostrils (A W L)

POTASH. Term applied to **potassium** compounds. Potash, potassium carbonate, caustic potash, potassium hydroxide Percentage of potash expressed in analyses of chemicals is for potassium oxide (K_2O). (R K S)

POTASSIUM. Symbol K (kalium). Atomic number 19 Atomic weight 39 096 Density. 0 87 Hardness 0 5 Melting point 62.3° C Boiling point. 760° C Isotopes 39 (93 4%), 40 (0 01%), 41 (6 6%)

Potassium is a silver-white metal, can be readily molded, and cut by a knife, oxidizes instantly on exposure to air, and reacts violently with water yielding potassium hydroxide and **hydrogen** gas, which burns spontaneously in air with a violet flame due to volatilized potassium element, is preserved under kerosene, burns in air at a red heat with a violet flame Discovered by Davy in 1807

Potassium occurs as potassium chloride or sulfate in certain salt deposits (**carnallite**, potassium magnesium chloride ($KCl\ MgCl_2\ 6H_2O$), **kainite**, potassium magnesium chloride sulfate ($K_2SO_4\ MgSO_4\ MgCl_2\ 6H_2O$)), mainly in Stassfurt, Germany, Alsace-Lorraine, Spain, Poland, California, New Mexico, in common rocks (average of the solid shell of the earth, 2 6%) and the minerals, **feldspar, greensand, alunite, leucite;** present in vegetation (average 1 7%) remaining in the ash when burned

Potassium metal is obtained by **electrolysis** of fused potassium hydroxide or chloride fluoride mixture in a specially designed cell

Acetate potassium acetate ($KC_2H_3O_2$), white solid, soluble, formed by reaction of potassium carbonate and **acetic acid**, and then evaporating

Alum potash alums are those alums, such as **aluminum** potassium sulfate ($Al_2(SO_4)_3\ K_2SO_4\ 24H_2O$), chromium potassium alum ($Cr_2(SO_4)_3\ K_2SO_4\ 24H_2O$) where potassium sulfate is crystallized with the heavy metal sulfate

Bromate potassium bromate ($KBrO_3$), white solid, soluble, melting point 434° C, upon heating oxygen is evolved and the residue is potassium bromide, formed by electrolysis of potassium bromide solution under proper conditions. Used as a source of bromate and bromic acid

Bromide potassium bromide (KBr), white solid, soluble, formed by reaction of potassium hydroxide and **bromine,** and then evaporating and heating to decompose bromate Use (1) in photography, in engraving and lithographing, (2) in medicine as a sedative.

Carbonate potassium carbonate, potash, pearl ash (K_2CO_3), white solid, soluble, formed (1) in the ash when plant materials are burned, (2) by reaction of potassium hydroxide solution and the requisite amount of **carbon dioxide.** Used (1) in making special glasses, (2) in the making of soft soap, (3) in the preparation of other potassium salts (a) in solution, (b) upon fusion; potassium hydrogen carbonate, potassium bicarbonate, potassium acid carbonate ($KHCO_3$), white solid, soluble.

Chlorate· potassium chlorate, chlorate of potash ($KClO_3$), white solid, soluble, melting point about 350° C., powerful oxidizing agent, and consequently a fire hazard with dry organic materials, such as clothes, and with **sulfur;** upon heating oxygen is liberated and the residue is potassium chloride, formed by electrolysis of potassium chloride solution under proper conditions Used (1) in matches, (2) in pyrotechnics, (3) as disinfectant, (4) as a source of oxygen upon heating (Hazardous! Use of potassium perchlorate is recommended instead)

Chloride potassium chloride, chloride of potash, muriate of potash (KCl), white solid, soluble, melting point 790° C, boiling point 1500° C Common constituent of potassium salt minerals Volatilized when potassium bearing silicates, such as **feldspar, leucite,** are heated with **calcium** chloride to a high temperature, as in a cement kiln Used (1) as an important potassium fertilizer, (2) as a source of other potassium compounds

Chloroplatinate potassium chloroplatinate (K_2PtCl_6), yellow solid, insoluble, formed by reaction of soluble potassium salt solution and chloroplatinic acid Used in the quantitative determination of potassium

Chromate potassium chromate (K_2CrO_4), yellow solid, soluble, formed by reaction of potassium carbonate and **chromite** at a high temperature in a current of air, and then extracting with water and evaporating the solution Used (1) as a source of chromate, (2) in leather tanning, (3) in textile dyeing, (4) in inks.

Cobaltinitrite dipotassium sodium cobaltinitrite ($K_2NaCo(NO_2)_6\ H_2O$), golden yellow precipitate, formed by reaction of **sodium** cobaltinitrite solution in **acetic acid** with soluble potassium salt solution Used in the detection of potassium

Cyanate potassium cyanate (KCNO), white solid, soluble, formed along with lead metal by reaction of potassium cyanide and **lead** monoxide solids upon heating Source of cyanate

Cyanide potassium cyanide, cyanide of potash (KCN), white solid, soluble, very poisonous, formed by reaction of calcium **cyanamide** and potassium chloride at high temperature Used as a source of cyanide and for hydrocyanic acid, but usually replaced by the cheaper sodium cyanide

Dichromate potassium dichromate, chromate of potash ($K_2Cr_2O_7$), red solid, soluble, powerful oxidizing agent, formed by acidifying potassium chromate solution and then evaporating Used (1) in matches and pyrotechnics, (2) in leather tanning and in the textile industry, (3) as a source of chromate

Ferricyanide potassium ferricyanide, red prussiate of potash ($K_3Fe(CN)_6$), red solid, soluble, formed by reaction of potassium **ferrocyanide** solution and **chlorine,** and then evaporating

Ferrocyanide potassium ferrocyanide, yellow prussiate of potash ($K_4Fe(CN)_6$), yellow solid, soluble, formed by treating "spent oxide" of coal gas works with **calcium** hydroxide to extract ferrous cyanide as soluble calcium ferrocyanide and then treating with potassium carbonate, filtering and evaporating the filtrate Used (1) as a source of ferrocyanide, but usually replaced by the cheaper sodium ferrocyanide, (2) in blue print paper, (3) in tanning, (4) in tempering steel.

Fluoride potassium fluoride (KF), white solid, soluble, formed by reaction of potassium carbonate and **hydrofluoric acid,** and then evaporating Used in the etching of glass, potassium hydrogen fluoride, potassium bifluoride, potassium acid fluoride (KHF_2), white solid, soluble, formed by reaction of potassium carbonate and excess hydrofluoric acid, and then evaporating

Glycerophosphate potassium glycerophosphate ($(KO)_2PO(C_3H_7O_3)$), pale yellow liquid, formed by warming **glycerol** and **metaphosphoric acid,** and then neutralized with potassium carbonate Used in medicine

Hydroxide. potassium hydroxide, caustic potash, potassium hydrate (KOH), white solid, soluble, melting point 380° C, formed (1) by reaction of potassium carbonate and **calcium** hydroxide in water, and then separation of the solution and evaporation, (2) by electrolysis of potassium chloride under the proper conditions, and

evaporation. Used in the preparation of **potassium salts** (a) in solution, (b) upon fusion

Hypophosphite potassium hypophosphite (KH_2PO_2), white solid, soluble, formed (1) by reaction of **hypophosphorous** acid and potassium carbonate solution, and then evaporating, (2) by reaction of potassium hydroxide solution and **phosphorus** on heating (poisonous phosphine gas evolved)

Iodate: potassium iodate (KIO_3), white solid, soluble, melting point 560° C, formed (1) by electrolysis of potassium iodide under proper conditions, (2) by reaction of **iodine** and potassium hydroxide solution, and the fractional crystallization of iodate from iodide Used as a source of iodate and iodic acid

Manganate potassium manganate (K_2MnO_4), green solid, soluble, permanent in alkali, formed by heating to high temperature **manganese** dioxide and potassium carbonate, and then extracting with water, and evaporating the solution The first step in the preparation of potassium manganate and permanganate from pyrolusite

Nitrate potassium nitrate, saltpeter, niter (KNO_3), white solid, soluble, melting point 333° C, formed by fractional crystallization of **sodium** nitrate and potassium chloride solutions Used (1) in matches, explosives, pyrotechnics, (2) in the pickling of meat

Nitrite potassium nitrite (KNO_2), yellowish-white solid, soluble, formed (1) by reaction of nitric oxide plus **nitrogen** tetroxide and potassium carbonate or hydroxide, and then evaporating, (2) by heating potassium nitrate and **lead** to a high temperature and then extracting the soluble portion (lead monoxide insoluble) with water, and evaporating Used as a reagent (**diazotizing**) in organic chemistry

Oxalate potassium oxalate ($K_2C_2O_4$), white solid, soluble, formed by reaction of potassium carbonate or hydroxide and **oxalic acid**, and then evaporating Used as a source of oxalate, potassium hydrogen oxalate, potassium binoxalate, potassium acid oxalate (KHC_2O_4), white solid, soluble, potassium tetroxalate ($KHC_2O_4 \cdot H_2C_2O_4\ 2H_2O$), white solid, moderately soluble

Oxide potassium oxide, potassium monoxide (K_2O), white solid, reactive with water to form potassium hydroxide, formed by reaction of potassium and **oxygen** at reduced pressure, and removal of excess metal by distillation in vacuum, potassium peroxide, potassium tetroxide (K_2O_4), yellow solid, soluble in water with evolution of oxygen, formed by heating potassium at 200° C in a current of oxygen

Perchlorate potassium perchlorate ($KClO_4$), white solid, very slightly soluble, melting point 610° C, but above 400° C decomposes with evolution of oxygen gas and formation of potassium chloride residue, formed (1) by electrolysis of potassium chlorate under proper conditions, (2) by heating potassium chlorate at 480° C and then fractional crystallization Used (1) as a convenient and safe (preferred to use of potassium chlorate) method of preparing oxygen by heating, (2) in the determination of potassium in soluble salt solution

Periodate. potassium periodate (KIO_4), white solid, very slightly soluble, melting point 582° C, formed by electrolysis of potassium iodate under proper conditions

Permanganate potassium permanganate, permanganate of potash ($KMnO_4$), purple solid, soluble, formed by oxidation of acidified potassium manganate solution with **chlorine**, and then evaporating Used (1) as disinfectant and bactericide, (2) in medicine, (3) as an important oxidizing agent in many chemical reactions.

Persulfate potassium persulfate ($K_2S_2O_8$), white solid, slightly soluble, formed by **electrolysis** of potassium sulfate under proper conditions Used (1) as a bleaching and oxidizing agent, (2) as an antiseptic

Phosphates· tripotassium phosphate (K_3PO_4); dipotassium hydrogen phosphate (K_2HPO_4), potassium dihydrogen phosphate (KH_2PO_4); potassium pyrophosphate ($K_4P_2O_7\ 3H_2O$); potassium metaphosphate (KPO_3); white solids, similar in properties and formation to the corresponding and more common **sodium** phosphates,

Phosphites: dipotassium hydrogen phosphite (K_2HPO_3), potassium dihydrogen phosphite (KH_2PO_3); white solids, similar in properties and formation to the corresponding **sodium** phosphites

Silicate potassium silicate (K_2SiO_3), colorless (when pure) glass, soluble, melting point 976° C, formed by reaction of **silicon** oxide and potassium carbonate at high temperature, similar in properties and uses to the more common sodium silicate

Sulfates potassium sulfate, sulfate of potash (K_2SO_4), white solid, soluble Common constituent of potassium salt minerals Used (1) as an important potassium fertilizer, (2) in the preparation of potassium or potash **alums**; potassium hydrogen sulfate ($KHSO_4$), white solid, soluble, potassium pyrosulfate ($K_2S_2O_7$), white solid, soluble, formed by heating potassium hydrogen sulfate to complete loss of water

Sulfides potassium sulfide (K_2S), yellowish to reddish solid, soluble, formed by heating potassium sulfate and **carbon** to a high temperature, potassium hydrogen sulfide, potassium bisulfide, potassium acid sulfide (KHS), formed in solution by reaction of **sodium** hydroxide or carbonate solution and excess **hydrogen sulfide.**

Sulfite potassium sulfite ($K_2SO_3\ 2H_2O$), potassium hydrogen sulfite ($KHSO_3$), white solids, similar in properties and formation to the corresponding **sodium** sulfites.

Tartrates· potassium tartrate ($K_2C_4H_4O_6\frac{1}{2}H_2O$), white solid, soluble, formed by reaction of potassium carbonate solution and **tartaric acid**, and then evaporating, potassium hydrogen tartrate, potassium bitartrate, potassium acid tartrate, "cream of tartar" ($KHC_4H_4O_6$), white solid, slightly soluble Obtained from "argols," a by-product of wine fermentation (argols consist of 50%–85% potassium hydrogen carbonate and 6%–12% calcium tartrate). Used (1) in **baking powder** as a source of acid, (2) as a source or tartrate, (3) sometimes by formation potassium or tartrate, potassium sodium tartrate, Rochelle salt ($NaKC_4H_4O_6\ 4H_2O$), white solid, soluble Used (1) in medicine, (2) as a source of tartrate

Thiocarbonate potassium thiocarbonate (K_2CS_3), yellow solid, soluble, formed by reaction of potassium sulfide and **carbon disulfide.**

Thiocyanate potassium thiocyanate, potassium sulfocyanide, potassium rhodanide (KCNS), white solid, soluble, melting point about 170° C, formed by fusing potassium cyanide and **sulfur**, and then crystallizing Used as a source of thiocyanate

All potassium containing substances impart a characteristic violet color to the bunsen flame, but small amounts are easily masked by the presence of sodium and its yellow flame (R K S)

POTATO FAMILY. Solanaceae This is a relatively small family of some 1700 species, in about 80 genera The members include herbs, shrubs, and a few trees, most of the last being found in the tropics The family has many important food and medicinal plants Not a few of its members contain poisonous **alkaloids**, as solanin, capsaicin, **belladonna**, nicotine, and **atropine.**

Members of this family have leaves which are usually alternate and variously shaped, often lobed or dissected or **pinnately** compound The variability frequently occurs in the leaves of a single plant The flowers occur either singly or in **cymes**, and are regular with an inferior five-lobed **calyx**, a five-lobed **corolla** of various shapes; often large and conspicuously colored, five **stamens** and a **pistil** composed of two united **carpels**, a long **style** and a single terminal **stigma.** The **ovary** contains many **ovules.** The fruit is either a **berry** (potato and tomato) or a **capsule** (tobacco)

The most important member of this family is the Potato, *Solanum tuberosum*, commonly called the Irish potato, common potato, White Potato, or English potato, to distinguish it from the sweet potato The plant is a branched herb, the branches tending to spread out more or less, and growing two to four feet in height.

The green stems are annual, but the tubers, which are modified stems, give to the plant a perennial nature. The leaves are pinnately compound and rather irregular. The flowers are from one to one and a half inches in diameter, white, often with blue or purple tones or stripes, and with a tubular corolla. The fruit is a globular berry containing many small seeds embedded in a green pulp Common names given these potato berries are potato balls, potato apples or seed balls When mature, they are either green or brown, often they contain few seeds, but since they are rarely used in propagating the potato, this is of little consequence They are used experimentally in the production of new varieties Once a desirable variety is found, it is perpetuated vegetatively by means of the tubers. These tubers are formed at the tips of modified underground branches, or **stolons,** which radiate outward from the basal portion of the stem and to the casual observer resemble roots The length of these stolons varies from a few inches to a foot or more, depending somewhat on the variety. Stolon formation and tuber development start soon after the tops appear above ground, and are apparently advanced by darkness and low temperatures The tubers continue to grow throughout the growing life of the plant A mature tuber has the structure of a stem, but very much modified Externally, one may recognize nodes and internodes, the nodes being determined by the eyes, depressions in the surface of the potato, each depression or eye containing a tiny bud Internally the tuber is largely **parenchymatous** tissue with the cells filled with starch-grains Near the surface of the potato, cross sections show a faint dark line which is the **vascular** tissue, very much reduced Potato tubers vary greatly in shape, as well as in size, the better varieties are oblong or oval, with smooth skin and rather shallow eyes In color, tubers range from brown through yellow to red, according to variety The length of time required to mature a tuber also varies greatly, some early varieties reaching maturity in about two months, while late varieties require five or six months

The tubers are the principal means of propagation For this purpose a tuber is cut into irregular pieces, each of which contains two or three eyes To prevent disease the cut pieces are treated with sulfur and allowed to dry slightly, after which they are planted. Sprouting starts at once, indeed frequently occurs while the potato is still in the storage bin If the bin is dark the sprouts formed will be long, slender and white Sprouts formed in light are short, stout and dark green

In addition to being an important article of food to inhabitants of the temperate regions of the world, the potato has many other uses **Starch** is made from them, cull or small potatoes being much used for this purpose To make starch the raw potatoes are cleaned, soaked in water for several hours, then washed thoroughly and reduced to a pulp This pulp is strained to remove any fibrous material The strained liquor is allowed to stand, the starch settling to the bottom This starch layer is drawn off and purified by running slowly down an inclined table where the starch grains once more settle to the bottom They are then collected and dried thoroughly, then broken up into marketable size

Another use for potatoes is as a source from which to make **alcohol.** However, the product is rather expensive compared with alcohol from other sources Finally, potatoes are much used as food for domestic animals, especially swine, being fed either raw or cooked or, at times, dried

The potato is a native plant of cool upland regions of South America, where it has been long cultivated by the natives, who use the tubers for food From America it was carried to the southern part of Europe, where at first it was grown largely as a curiosity From Europe the plant was brought back to America and introduced into what is now the United States, thus explaining its name of English or Irish Potato It is now extensively grown in regions having a cool climate, Maine being particularly noted for its potato crop

In all green parts of the potato a poisonous alkaloid, solanin, occurs. This substance may also occur in the tubers, particularly if the latter are exposed to light long enough to become green in color

Another important food plant of this family is the tomato, *Solanum lycopersicum,* and related species This is a native of South America, in which continent the tomato is still found wild. The tomato is a coarse branching annual herb which becomes perennial in favorable climates It is an important food which in recent years has become immensely popular Large quantities are consumed raw or canned Tomato juice is an important article of diet From the seeds an oil may be obtained, which is used in making soaps

The tomato was carried to Europe by the early Spanish explorers and became an important food plant in southern European countries In England and also in the United States it was widely grown as a garden vegetable known as "Love Apple," which however was not eaten, but was held by many to be rankly poisonous

A third member of the family providing food to man is the egg plant, *Solanum melongena,* a coarse, somewhat woody, branching herb native to India. The plant has a rough stem, two or three feet tall, large sinuate-lobed ovate leaves and purplish flowers The fruit is a berry, very large in some varieties It is eaten either baked or sliced and fried

Serving rather as a condiment than a food, but still used as a food stuff in some of its varieties, is the **pepper,** *Capsicum annuum,* another native plant of tropical America Peppers are either annual or biennial plants, with branching stems one to three feet tall, smooth shining leaves and white flowers There are many varieties, which bear fruits of a variety of sizes and shapes, as well as degrees of pungency Some varieties are known as sweet peppers, and are used in salads or stuffed and baked, others are hot peppers The pungent taste is due to the drug capsaicin, which in hot peppers occurs throughout the fruit, but in sweet peppers is largely restricted to the immediate region of the seeds, since only the fleshy **pericarp** is eaten, the seed being removed, this pungent substance is lost

Peppers are used in many ways other than as food Small hot peppers are a frequent component of mixed pickles, and also are used in salads The whole fruit of some varieties is ground up to a powder, and becomes Cayenne pepper, an extremely hot substance Small smooth fruits of var *conoides* are preserved whole in brine or vinegar, and known as Tabasco sauce or Tabasco peppers Red peppers are used medicinally Many varieties of pepper are grown as ornamental plants, the brilliant fruit offering a startling contrast to the dark green leaves

More widely grown for its ornamental properties is the Petunia, derived from South American plants

Many members of the Potato Family are important drug plants Here belong *Atropa belladonna,* yielding **atropine,** and *Datura Stramonium,* the Thorn Apple, called also Jimson Weed or Jamestown Weed The latter is a tall, rather coarse, branching annual having broad leaves with sinuate margins and large trumpet-shaped white flowers, borne singly in the axils of the leaves (a related species, *D Tatula,* has purple flowers) The fruit is a prickly capsule In all parts of the plant, but especially in the seed, are found several drugs The most abundant is **hyoscyamine,** with small amounts of atropine and scopolamin present The powdered leaves and seeds are used medicinally, chiefly in treating asthma

Less important medicinally are several plants such as *Hyoscyamus niger, Solanum Dulcamara,* the Bittersweet, and *Solanum niger,* the garden Nightshade, all held to be poisonous plants if eaten by man or domestic animals, although this fact is disputed by many

Another member of this family, ranking along with the potato in importance, is the tobacco plant, *Nicotiana Tabacum*, also a native plant of tropical America It is an annual plant growing three to six feet or more in height, and stout The leaves are alternate, simple and rather large and, like the stem, covered with sticky hairs The rather large flowers are borne in terminal racemes and have a funnel-shaped corolla which is yellow, white, pink or purple in different species and varieties The fruit is a capsule containing many small seeds The entire plant contains a poisonous alkaloid, nicotine

While tobacco plants are sometimes grown as ornamentals, the principal use is made of the large leaves, which are smoked or chewed Different demands have led to the development of several types of tobacco One of these is the cigar type, in which the leaves are large, thin and have a fine texture with a relatively small amount of vascular tissue This type of leaf is often obtained by growing the plants in the shade of sheets of cloth Another type of tobacco has the leaves thicker and with many veins giving a rather coarse structure The leaves of these coarser sorts are used in making pipe tobacco, chewing tobacco, cigarettes, etc In all tobaccos considerable differences are produced by cultivation and the nature of the soil on which the plants are grown

In preparing tobacco for use, the leaves are removed from the plant and dried, either by natural air currents in open ventilated sheds, a process requiring six to eight weeks, or by artificial heat, which is naturally much quicker The leaves are then packed tightly in wooden containers and left for several months During this time fermentation occurs, and important changes take place which lead to the formation of the pleasing aromas of prepared tobaccos During fermentation the leaves may be repacked several times The cured leaves are either rolled into cigars or blended, ground up, and used in smoking tobaccos and cigarettes Mixed with various substances and pressed into cakes it becomes chewing tobacco Ground fine it becomes snuff

Tobacco is now extensively grown, not only in tropical regions but also in temperate climates Its users are very numerous, including a large proportion of the human race The United States alone grows considerably over a billion pounds each year

Many other plants have been used in much the same way as tobacco One of these, *Lobelia inflata*, a small herb of the Bellflower family (Companulaceae) is known as Indian Tobacco It is an inconspicuous plant of no particular value (R M W)

POTENTIAL. This term is used to denote a number of different quantities used in physics, all characterized by their connection with potential energy (hence the name) The most familiar is **electric potential.** One of the simplest is gravitational potential or mass potential The mass potential at any point is measured by the energy necessary to carry a unit mass from that point to a region of space infinitely removed from all matter Its value is the integral of $G\frac{dm}{r}$, in which G is the **gravitation constant,** dm is any mass element, and r is its distance from the point in question, the integration being extended throughout all existing matter So far as we know, it always has the same sign, that is, gravitation is always an attraction, and the energy must therefore always be added to the unit mass in the process described, whereas electric potential may be either positive or negative The magnetic potential at any point is measured by the energy necessary to carry a unit north pole from infinity to that point, or mathematically, it is the line integral of the magnetic intensity between that point and infinity The "Newtonian potential function" is a mathematical expression occurring as a factor in all these potentials See **Laplace's Equation.**

A characteristic of the mass potential, the electric potential, and the magnetic potential, is that in each case the first derivative of the potential with respect to any direction, as x, at any point in space, is equal in magnitude to the component of the intensity in that direction at the point in question

The foregoing potentials all involve inverse square forces, if the field obeys the inverse first power law, the potential involves the logarithm of the distance, and is called the "logarithmic potential"

By analogy, we have also a so-called "thermodynamic potential," which, in reference to a substance in any state, represents the work which has been required to bring unit mass of the substance to the state in question from some arbitrarily defined, initial state. (L D W.)

POTENTIAL DROP, LAW OF. Electric Circuits; Electric Currents.

POTENTIAL ENERGY. Whenever energy takes a form not directly associated with motion, it is called potential energy Energy is apparently able to go into a state of "hibernation" and to remain dormant, sometimes for long periods We are taught, for example, that there are somehow locked up in coal or petroleum deposits vast stores of energy traceable to the solar radiation of past geological ages The evidence of such energy is the work which can be derived from burning the fuel in a suitable engine, or more directly, the **heat** produced by its combustion, which we recognize as a form of **kinetic energy** But a closer analysis shows that, since combustion is a union of carbon and other elements of the fuel with oxygen, and since the process effected by the sun's rays in the growth of carboniferous plants was largely the separation of oxygen from those elements in carbon dioxide and other compounds, there is really no more reason for localizing the energy in the fuel deposit than in the oxygen of the air A weight lifted from the earth is able to do work in descending, and we say that it has potential energy But lifting a weight is merely the work of separating two mutually attracting masses, one of which is the earth, so that the energy may as well be said to belong to the earth as to the lifted weight These illustrations suffice to show that the "location" of potential energy is quite ambiguous

A notable characteristic of potential energy is its tendency to transform itself into kinetic energy at every opportunity, and to continue the process until a state of stable equilibrium is reached This is the well known **least energy principle** In many physical processes, such as the swinging of a pendulum or the oscillation of electricity in a conductor, the transformation takes place back and forth from potential to kinetic and *vice versa*, but in each cycle the total potential energy becomes a little less and the total kinetic energy a little greater (including the heat generated in friction) Ultimately all the energy except a certain minimum corresponding to stable equilibrium takes the form of radiation and is lost It has thus suffered "degradation" and final "dissipation" (L D W)

POTENTIOMETER An instrument used for the measurement or comparison of small potential differences or electromotive forces, based upon the "law of potential drop" (See **Electric Circuits**) One of the simplest potentiometer circuits is shown in the accompanying diagram Current from a battery B is sent through a resistance MN and is adjustable by means of a rheostat A From one extremity M of this resistance is taken off a branch cir-

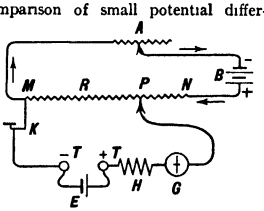


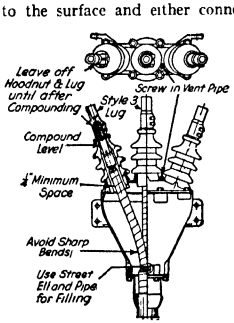
Diagram of potentiometer circuit

cuit containing the potentiometer terminals $+T$, $-T$, between which E, one of the electromotive forces to be compared, is connected This circuit rejoins the main circuit at a point P which is adjustable so that the partial resistance MP or R can be varied, while MN as a whole remains constant The + and — leads from E must be connected as shown, and the electromotive force of B must exceed E The position of P is now adjusted until the galvanometer G shows no current, indicating that the potential drop from P to M just balances the electromotive force E If two different electromotive forces E_1, E_2, are thus connected and balanced in succession, and if the corresponding values of the resistance MP are R_1, R_2, then since the current through MN is unaltered, the law of potential drop gives

$$\frac{E_1}{E_2} = \frac{R_1}{R_2}$$

In particular, one of the electromotive forces may be a **standard cell** of accurately known voltage, the other is thereby determined In such case the standard cell should be safeguarded by a high resistance H, which is gradually reduced as the zero-current adjustment is approached, and the key K should be closed only for an instant In some potentiometers the whole equipment, including galvanometer and standard cell, is contained in one compact case (L D W)

POTHEAD. In electrical distribution networks it is often convenient to run the conductors in a subterranean multi-conductor **cable.** Where such a cable is brought to the surface and either connected to some equipment or brought up a pole for connection to an overhead line, some means for terminating the cable insulation and connecting the conductors to the overhead wires must be provided This is relatively simple in low voltage cables, but most cables operate at a voltage which requires a special terminal This equipment, known as the pothead, is usually unnecessary below 2300 volts At the cable terminal the separate conductors are fanned out in the pothead, which not only affords the necessary insulation between conductors where they leave the cable, but also seals the end of the cable against the entry of moisture (F T M)



Three conductor cable pothead

POTOROO. Mammalia, Marsupialia *Potorous* Any of several species of small animals related to the kangaroos and known also as rat kangaroos They are found in Australia and Tasmania (A W L)

POTTER WASP Insecta, Hymenoptera A small **wasp** whose nest is built of mud in the form of a globular pot with a narrow neck The several species belong to the genus *Eumenes* All are solitary (A W L)

POTTO. Mammalia, Primates A name for the African slow **lemurs,** animals which resemble the lorises of Asia in many ways They are remarkable for the rudimentary index finger, which is a stub without a nail or joints, and for the very short tail The two species are Bosman's potto and the awantibo, *Perodicticus calabarensis* (A W L)

POUCHED MOLE. Mammalia, Marsupialia A rare pouched mammal of the Australian deserts, *Notoryctes typhlops,* highly specialized for burrowing Like the true moles it has enormous claws and rudimentary eyes (A W L)

POUCHED MOUSE. Dasyure.

POULTRY. A term applied to the domestic breeds of birds, exclusive of cage birds and such ornamental species as the peacocks The forms embraced by the term are the **chickens, turkeys, ducks, geese,** and **Guinea fowls.** Although pheasants are bred extensively in captivity they are classed as game birds rather than poultry, as are other species which are often raised for the stocking of preserves

The economic value of poultry varies with the species and with the breed Most eggs used as food are those of chickens but the flesh of all species is valued Geese produce the best feathers and down, with ducks a close second (A W L)

POUT Pisces, Teleostei A European fish (**Pisces**), *Gadus luscus,* related to the cod Also called the bib (A W L)

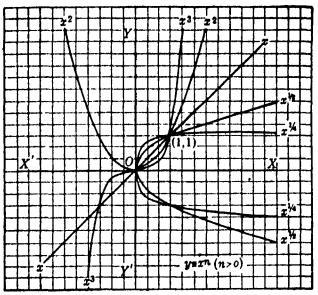
POWER. The time rate of the performance of **work** or of the transfer of **energy.** It may be expressed in units of work per unit time (e g, foot-pounds per minute or **ergs** per second), or more arbitrarily, as in **horse power** or in **watts** For most modern purposes, especially where electrically distributed energy is concerned, power is commonly expressed in watts or kilowatts Since the product of the power by the time during which it is operative is the work done, the product of a power unit by a time unit, such as the watt-hour or the horsepower-year, is a unit of work or energy Electrically delivered energy is thus commonly measured in kilowatt-hours, each of which is equal to 3.6×10^{13} ergs or 3.6×10^{6} joules The average power of large hydroelectric installations subject to wide seasonal variations is often rated in kilowatt-hours per year For electric circuits having appreciable reactance (See **Alternating Currents**), the power in watts is equal to the product of the voltage, the current in amperes, and a "power factor" dependent upon the reactance

The measurement of mechanically delivered power is usually effected by some form of power dynamometer or "ergometer" This commonly takes the form of a friction brake and a speed indicator, as in the "Prony brake" Since the power may be considered as the product of the force (of friction) by the linear speed, or the product of the torque by the angular speed, it is necessary only to measure these quantities and to deduce the power therefrom (L D W)

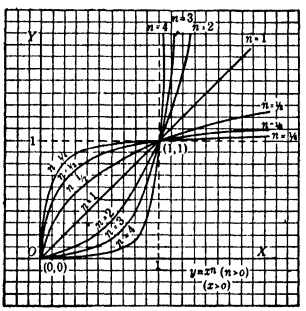
POWER FACTOR. This is a term connected with **alternating electric current.** In a direct current system, power equals the product of instantaneous voltage and current In an alternating-current system at any given instant it is the same, but the average alternating-current power may be much less than the volt-amperes, because the current and voltage waves are not necessarily in **phase,** and it is only the component of current that is in phase with the voltage that produces power In a **single-phase** alternating-current circuit, the power factor is the power divided by the product of volts and amperes In the three-phase circuit it is the power divided by the volt-amperes times $\sqrt{3}$ When the current and voltage waves are out of phase by an angular difference θ, the power factor is the cosine of θ When the current cycle lags the voltage cycle, the power factor is said to be lagging This situation is created by inductive equipment, such as furnaces, motors, coils, connected to the line A leading power factor, created by a capacitative load, has the current leading the voltage by the angle θ Power-factor meters are commercially avail-

able for both single and polyphase circuits. It may be calculated also from the readings of two wattmeters connected properly for measuring power in a three-phase circuit (F T M)

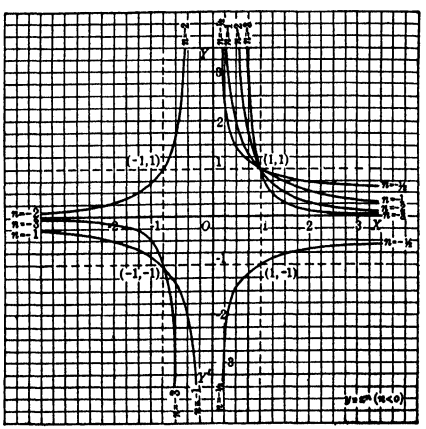
POWER FUNCTION. A power function is an **algebraic function** of the form ax^n, where a and n are **constants** (independent of x) and x is the **variable.** It has a variable base x and a constant **exponent** n The exponent may be a positive integer, or it may be a fraction or negative number, or even irrational.



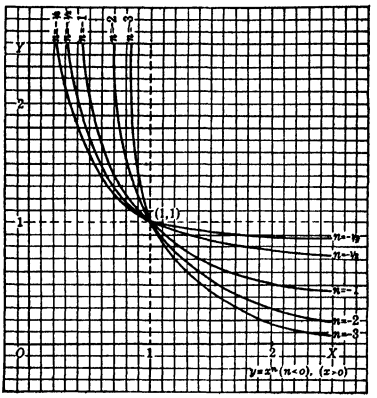
Power function



Power function.



Power function.



Power function

The graphs of the power function are shown in the accompanying figures (L L S)

POWER PLANT. A power plant is a machine or an assembly of machines and equipment, the purpose of which is to convert energy from a dormant or useless state to a useful one This usually takes the form of the conversion of the latent chemical energy of a fuel into mechanical or electrical energy, a conversion that is accomplished with difficulty, and then only at the expense of the loss of a major portion of the energy while it is in the form of heat

Power is the rate at which mechanical or electrical energy is produced We may regard a power plant as a factory for the production of a given commodity, energy, from fuel as a raw material, the rate of manufacturing being the power capacity of the plant as measured in horsepower or kilowatts

The possible sources of energy are as follows:

1 Fuels
2 Streams of water.
3 Ocean tides and waves.
4 Winds
5 Solar rays
6 Terrestrial heat.

The **fuels** are most abundant and easily utilized **Coal** continues the principal fuel for power generation Coal, oil, gas, and wood all contain **hydrogen** and **carbon** which in rapid chemical union with oxygen from the air liberate heat energy All fuels have been fired under boilers and gas and oil, in addition, are sources of power in internal combustion engines The greater portion of the power generated in the United States is produced from fuels

The hydraulic plant has as its source of energy the kinetic energy of a stream or the potential energy of impounded water Hydraulic plants are increasing in size and numbers, but it is obvious that a point will be reached beyond which the energy of a stream will not be exploitable in competition with the steam plant.

Power from the winds has served man for many centuries, but the total amount of energy generated in this manner is small While the expense of installation and the uncertainty of operation have prevented serious con-

sideration of the windmill for other than such intermittent services as pumping, there has been considerable experimentation relative to the generation of electrical energy by moderate-sized wheels for charging storage batteries

With the exception of terrestrial heat, all of the sources of energy may be traced indirectly to the sun Evaporation of surface water to form rain clouds which continually replenish the flow of water in streams is accomplished by the heat of the sun, gravitational effects account for tides, warming and cooling of different portions of the earth's atmosphere cause winds and thereby waves, and solar rays, nourishing tropical vegetation through the prehistoric ages, may be held responsible for the deposits of coal, oil, and gas which were formed from that vegetation

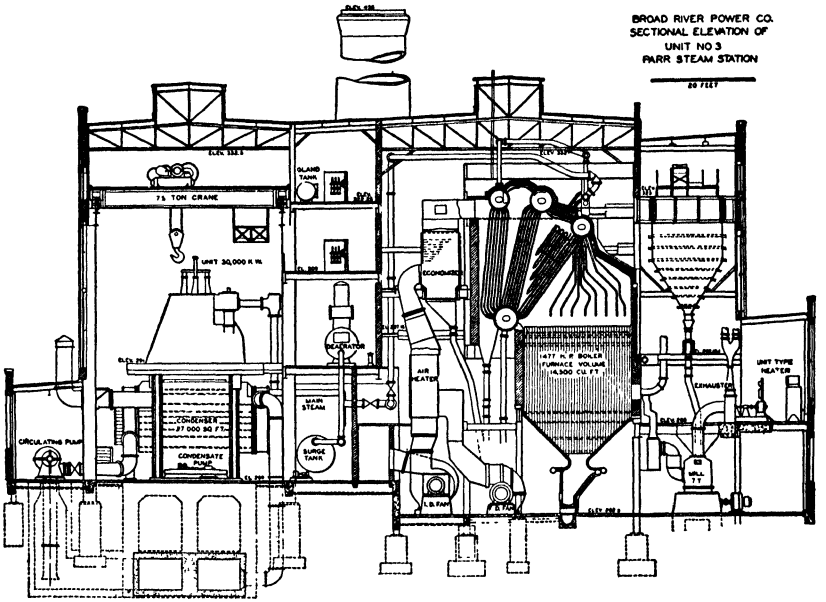
In a few instances the direct rays of the sun have been used to generate energy The obvious fault of this source is that it is effective during the daylight hours only, and, for continuous service, some reservoir of energy such as a storage battery or a heat accumulator tank is necessary to carry through the night operation Also, cloudy weather seriously handicaps the operation of such a plant In the solar plants that have been constructed, the heat in the rays is absorbed by water in a boiler. The rays are converged upon the boiler by parabolic mirrors set to follow the sun throughout the day, or the same thing may be accomplished by direct absorption on a large flat-surface boiler

The suggestion of tremendous unleashed power in the daily silent glide of the tides and the evidences of gigantic terrestrial reservoirs of heat to be seen in geysers and volcanoes have, for years, prompted many dreams of harnessing these sources

Natural steam escapes from surface vents in many portions of the earth It remained for an Italian, Prince Conti, to develop the use of natural steam. This he did in a successful way at Larderello in Tuscany, Italy, bringing the steam under control by drilling wells

The power plants other than **hydraulic** may today be classified as internal or external combustion types The internal combustion power plant is a self-contained unit using the products of combustion as the working medium Since it is compact, having all parts included in one machine or engine, and, since its efficiency is, on the average, higher than that of the external combustion cycle, it has been greatly used for automotive service and other uses where compactness and mobility were desired

Fuels which have been necessary in **internal combustion engines** have been of a more expensive type than those which may be successfully employed in the external combustion cycle, and so there is a need of large power capacity installed in external combustion power plants such as the modern steam plant A cross-section of a typical steam plant shows the complexity of the modern high capacity, external combustion cycle The plant shown in the accompanying figure illustrates the point The building housing this plant is set off roughly into four regions. Beginning at the left, there is the turbine room, next, a narrow multi-storied section containing electrical galleries and certain of the steam and water auxiliaries, next, the main boiler room with its boilers having fans and other auxiliaries, and lastly, the fuel preparation room, in which fuel is in storage, and from which the fuel is taken to be prepared for burning. (F T M)



Parr steam station.

POWER PUMP. A power pump is a reciprocating, **piston** and **cylinder** type **pump** not driven by steam, but by motor, line shaft, belt, or some other mechanical means The direct-acting steam pump and the steam-driven flywheel type pump are thus set off from the power pump The ordinary form of power pump is known as a triplex pump. It is three-cylindered, single-acting, having three **pistons** driven from a single

crankshaft. The triplex feature provides fairly uniform discharge, as well as a much steadier load on the motor than would be possible from a single-cylindered pump The triplex pump has three cylinders in line, and cranks at 120° The best crankshaft speed is much lower than the usual speeds of motors and gasoline engines, so that it is best to gear drive the pump from the source of power The efficiency of such pumps is rather high, and there is no limit to the pressures which may be carried (F T M)

POWER SERIES. An **infinite series** of the form

$$\sum_{n=0}^{\infty} a_n x^n = a_0 + a_1 x + a_2 x^2 + \cdots + a_n x^n + \cdots,$$

where a_0, a_1, , a_n, are **constants** and x is a **variable,** is called a power series

For every power series $\Sigma a_n x^n$ there exists a constant l such that the series is **absolutely convergent** for all values of x such that $|x| < l$, and is **divergent** for all values of x such that $|x| > l$ This number l is called the limit of convergence of the power series, and the interval $(-l, l)$ is called the interval of convergence The series may converge or diverge at the ends of this interval, for $x = l$ and $x = -l$

If $\lim_{n \to \infty} \left| \frac{a_n}{a_{n+1}} \right|$ exists, it is the limit of convergence

If $\lim_{n \to \infty} \sqrt[n]{|a_n|}$ exists, it is the **reciprocal** of the limit of convergence Two power series may be multiplied together for all values of x for which both series are absolutely convergent, i e , for the smaller of the two intervals of convergence

A power series is **uniformly convergent** within the interval $(-l', l')$, where $l' < l$ and l is the limit of convergence of the given power series

The function defined as the sum of a power series $\Sigma a_n x^n$ is a **continuous function** of x at all points within the interval of convergence

For the operations with power series, we have the following theorems

Two power series may be added together for all values of x for which both series are convergent, i e , for the smaller of the two intervals of convergence

A power series may be **differentiated** term by term for all values of x within its interval of convergence.

A power series may be **integrated** term by term between any limits lying within the interval of convergence

Power series are very useful in the analytical representation of functions by the **expansion of functions in series,** and for calculation by series (L L S)

POWER SYSTEM If power could be generated for the same cost at any point in the country there would be no serious questions arising from power distribution and the conditions that early prevailed would exist—each power user would operate his own plant But, unless use may be made of the exhaust steam, the small privately owned plant is hardly able to compete with the central system on an economic basis because of the inherently higher efficiency of large generating units and the lower overhead cost of quantity production So, while large numbers of small isolated plants are in operation at present, the major portion of installed power capacity is to be found in central stations The bulk of this capacity is in **steam engines** and turbines, mostly **steam turbines.** Power generated by industries may or may not be converted into the electrical form before use, but that generated by central stations is invariably electrical to permit transmission to distant points The central station is but one link of a chain joining the source of energy and its ultimate user

The distribution system may be separated into two parts, the primary and secondary systems The primary distribution system generally consists of a transmission line carrying three-phase current from the switchyard of the plant to a substation located near the load served The purpose of the substation is to transform the high voltage necessary for economical long-distance transmission to voltages suitable for lines in residential districts and for the primaries of the light pole-top transformers The secondary distribution system extends from the substation to the customer's meter through the medium of weatherproof pole-top transformers, strategically located with respect to a small group of customers which each one supplies

Power supply systems are owned and controlled both by municipalities and by public utility companies Power and light plants, at one time mostly municipally owned, have come more and more into the hands of public utility companies A utility company may own one or more generating stations and a network of transmission lines serving its territory The company must be so organized as to weld generating, distributing, and public relations departments into a smooth-working unit The small company operating one station and servicing one community easily accomplishes this, but the large company requires a complex organization (F T M)

POWERS AND EXPONENTS A power a^m with a positive integral exponent m is the repeated product of m factors each equal to a

$$a^m = a \; a \; a \qquad a \; (m \text{ factors})$$

The number a is called the base, m is called the exponent, and a^m is called the power

A power a^0 with a zero exponent is defined to be always equal to 1 (if $a \neq 0$)

A power $a^{m/n}$ with a positive fractional exponent m/n, where m and n are positive integers, is defined as the **principal** n^{th} **root** of the m^{th} power of a $a^{m/n} = \sqrt[n]{a^m}$

A power a^{-r} with a negative exponent $-r$ is defined as the reciprocal of the corresponding power with the positive exponent r $a^{-r} = 1/a^r$

The fundamental laws of exponents are expressed by the formulas

$$a^m \; a^n = a^{m+n},$$
$$a^m \div a^n = a^{m-n},$$
$$(a^m)^n = a^{mn},$$
$$(ab)^n = a^n b^n,$$
$$\left(\frac{a}{b}\right)^n = \frac{a^n}{b^n}$$

These laws hold for all types of exponents when $a > 0$, $b > 0$, and some of them sometimes for $a < 0$, $b < 0$ Care must be exercised in their use when $a < 0$, $b < 0$, if fractional exponents occur

Many collections of mathematical tables contain a table of powers of numbers, usually of squares and cubes and reciprocals (L L S)

POYNTING'S THEOREM. Electromagnetic Radiation.

POZZUOLANE. A leucite tuff occurring near Naples and famous for its use in making **cement** (R M F)

PRAIRIE CHICKEN. Aves, Galliformes *Tympanuchus* A **grouse** of the prairie regions of North America This species was once very abundant over a large area but it is now much more restricted in its range and in numbers The destruction has been due partly to hunting, partly to the spread of agriculture, and partly to wholesale trapping for the market In the Dakotas countless birds were taken for sale during the past century The eastern heath hen, which has recently become extinct, was a variety of the same species. (A W L)

PRAIRIE DOG. Mammalia, Rodentia *Cynomys* Burrowing animals of several species, found chiefly west of the Mississippi but introduced into a few eastern

localities They are small stout-bodied animals with shallow cheek pouches All are plant feeders and in settled regions they sometimes damage crops severely Also called the prairie marmot. (A W L)

PRASE. Chalcedony.

PRASEODYMIUM. Symbol Pr Atomic number 59 Atomic weight 140 92 Density 6 48 Melting point 940° C Type of compound Pr_2O_3, greenish-yellow Color of salts green Discovered by Welsbach in 1885 A member of the **cerium** sub-group of the rare earth metals (R K S)

PRATINCOLE. Aves, Charadriiformes *Glareola* Birds (**Aves**) of several species found on all continents of the Old World Their long wings and forked tail give them the appearance of swallows when in flight, but their moderately long legs are a point of resemblance with the plovers They live chiefly near water but are insectivorous in habits (A W L)

PRAWN. Crustacea, Decapoda Small marine **crustaceans** closely related to the shrimps They differ from the lobsters and crabs in the compressed body and in the use of the abdominal appendages for swimming Prawns are edible (A W L)

PRAYING MANTIS Mantis.

PREANTENNA. A sensory organ of the pair borne by the first segment of the body in the **Onychophora** Most arthropods have the first body segment developed in the embryo but lacking in the adult, hence their antennae are appendages of a more caudal segment The similar organs of Onychophora are named preantennae to distinguish them from the true antennae of the other classes (A W L)

PRECESSION An effect manifested by a rotating body when a torque is applied to it in such a way as to tend to change the direction of its axis of rotation If the speed of rotation and the magnitude of the applied torque are constant, the axis, in general, slowly describes a cone, its motion at any instant being at right angles to the direction of the torque

A familiar example of precession is an ordinary top If the axis of spin is not exactly vertical, the force of gravity exerts a torque tending to overturn the top, but instead of tipping over, it "wobbles" with a precessional motion about the vertical through the pivot-point The **gyroscope** exhibits similar behavior A hoop or a coin can roll on edge across the floor because, whenever it tends to tip either way, precession swerves its plane and changes its path, so that it automatically steers itself as a bicycle is steered by the rider

Precession is due to the fact that the resultant of the angular velocity of rotation and the angular velocity produced by the torque is an angular velocity about a line which makes an angle with the permanent rotation axis, and this angle lies in a plane at right angles to the plane of the couple producing the torque The permanent axis must turn toward this line, since the body cannot continue to rotate about any line which is not a principal axis of maximum moment of inertia, that is, the permanent axis turns in a direction at right angles to that in which the torque might be expected to turn it If the rotating body is symmetrical and its motion unconstrained, and if the torque on the spin axis is at right angles to that axis, the axis of precession will be perpendicular to both spin axis and torque axis Under these circumstances the period of precession is given by $T_p = \frac{4\pi^2 I_s}{QT_s}$, in which I_s is the **moment of inertia** and T_s the period of spin about the spin axis, and Q is the torque In general the problem is more complicated.

Precession, as it is manifested in astronomy, is a slow, rotary motion of the axis of a rotating body in space The term is, perhaps, most frequently used in connection with the earth, but all rotating bodies may exhibit the effect The earth is an oblate **spheroid** with the minor axis the axis of rotation Hence if we subtract from the earth a sphere with radius equal to the minor axis we shall have left a shell of continually increasing thickness as we pass from the pole to the equator Such a rotating shell, with the greatest amount of mass in the plane perpendicular to the axis of rotation, is a characteristic **gyroscope.**

The axis of rotation of the earth is inclined at an angle of 66° 5 to the plane of the **ecliptic.** The forces of **gravitational** attraction of the sun and the moon tend to pull the equatorial shell into the plane of the ecliptic and hence a torque is applied tending to change the direction of the axis of rotation This causes the axis to describe a cone in space (i e, produces precession)

As the axis of rotation describes a cone, the poles of rotation describe circles in space The radii of these circles, expressed in angular measure on the **celestial sphere,** are 23 5° The effect of this motion of the poles is to cause the **vernal equinox** (one point of intersection of the ecliptic with the **equator**) to move along the ecliptic The motion is slow, about 26,000 years being required for the vernal equinox to make a complete circuit of the ecliptic The motion is not perfectly regular because of the fact that both the sun and the moon are in different planes and are moving relative to each other, causing a variation in the torque applied to the earth The variations in the torque produce a slight irregularity in the motion of the poles known as **nutation.**

The motion of the equator among the stars causes slow, and slightly irregular, changes in the **equatorial coordinates** of the **stars** Since celestial **longitude** is measured from the vernal equinox, the motion of this point produces a change in this coordinate of the stars The motion of the vernal equinox also changes its location among the **constellations** along the zodiac, the "sign of Aries" (i e, the vernal equinox) now being located in the constellation of **Pisces** instead of in **Aries** At present the north pole of rotation of the celestial sphere is close to the star **Polaris** (α **Ursae Minoris**), but 12,000 years hence the star **Vega** (α **Lyrae**) will be close to the pole of rotation and hence be known as the pole star

Precession enters also in a very important way into the dynamics of **atoms** and **molecules.** (L D W, W K G)

PRE-CHELLEAN. Paleontology of man.

PRECIPITATION This process involves the separation of a solid from **solution** (1) by evaporation and cooling of certain solutions to **crystallization,** (2) by addition of or to a reagent which forms new insoluble product or products, e g, **sulfuric acid** to **barium** chloride solution, forming barium sulfate precipitate, and injection of viscose solution into the setting bath, (3) by addition or removal of a substance to decrease the solubility of another substance in the medium, e g, salting out of soap by salt, or removal of **carbon dioxide** from **calcium** hydrogen carbonate solution resulting in the precipitation of calcium carbonate, (4) by heating, e g, coagulation of certain **proteins**

The precipitate which is formed in a given case usually separates in a characteristic form, e g, **barium** sulfate as fine crystals, difficultly separable from the medium, **lead** chloride as medium crystals, easily separable, **ferric** hydroxide as gelatinous mass or slime, difficultly separable, **silicic** acid as gelatinous mass or as a gel, **silver** chloride as curdy mass The concentrations used and the temperature frequently affect the form of the precipitate Very fine crystals are increased in size by digestion, that is, by allowing to stand for some time to take

advantage of the fact that small crystals are more soluble than large ones (R K S)

PREGNANCY. (Cyesis, gestation gravidity) The condition of being with child The duration of pregnancy in humans is usually about 280 days, 9 calendar or 10 lunar months, dating from the time of the last menstrual period Presumptive signs of pregnancy are absence of the menstrual periods, nausea or vomiting in the morning (**morning sickness**) enlargement of the breasts with pigmentation of the nipples, and enlargement of the abdomen during the last half of pregnancy Absolute signs of pregnancy are palpitation of the fetal body, movement of the child, and sound of the fetal heart After the first two or three weeks of pregnancy the **Aschheim-Zondeck** test is always positive

Abdominal Pregnancy Here the **fetus** does not develop in the **uterus** as the fertilized ovum lodges in the abdominal cavity and grows there This is a rare condition and usually the fetus dies due to the insufficient blood supply

Bigeminal Pregnancy Twin pregnancy

Extra-Uterine Pregnancy A pregnancy taking place outside of the uterus This usually takes place somewhere along the **fallopian tube**

False Pregnancy Mistaken belief in pregnancy

Multiple Pregnancy Pregnancy in which more than one fetus is present

Phantom Pregnancy An abdominal enlargement in hysterical women who imagine that they are pregnant Even the periods may become absent (R S M)

PREHENSION. The flexion of an appendage to grasp an object by folding around it There are two types of grasping organs among animals forcipate and grasping The human hand illustrates both Objects may be taken between the thumb and fingers as between the jaws of a forceps, or they may be grasped between the fingers and the palm by the prehensile folding of the digits Less versatile organs are capable of one or the other type of action, as in the case of the forcipate chela of the lobster and the prehensile tails of some monkeys (A W L)

PREHISTORIC ART. **Paleontology of man.**

PREHNITE. The mineral prehnite is an acid **orthosilicate** of **calcium** and **aluminum**, $H_2Ca_2Al_2(SiO_4)_3$ It crystallizes in the **orthorhombic** system, usually in masses It has an uneven fracture, is brittle, hardness, 6-6 5; specific gravity, 2 80-2 90, luster, vitreous to pearly, color, various shades of light green to gray or white, translucent Though not a **zeolite** it is found associated with them and with **datolite, calcite,** etc , in veins and cavities of basic rocks, sometimes in **granites, syenites,** or **gneisses.** It is found in Austria, Italy, the Harz Mountains, France, Scotland, and South Africa, where it was originally discovered In the United States well-known localities are Somerville, Massachusetts, Farmington, Connecticut, Paterson, New Jersey, and Keweenaw County, Michigan Named for Colonel Prehn, its discoverer, who was an early Dutch Governor of the Cape of Good Hope colony in South Africa (E S C S)

PREISCHIOPODITE. A segment of the **biramous appendage** of **crustaceans** In some species the outer segment (basipodite) of the two that make up the base of the appendage is divided into two parts The proximal part is then called the probasipodite and the distal is the metabasipodite or preischiopodite (A W L)

PREMAXILLARY. A small bone lying in front of the **maxillary** bone of the upper jaw in the skull of **vertebrates** The two form the median portion of the jaw and bear the incisor teeth, if present Also called intermaxillary (A W L)

PREMENTUM. The palpiger of the insect **labium** (A W L)

PREMOLAR. A tooth lying between the canines and molars of mammals Premolars are broader teeth than the incisors and canines but are usually less broad than the molars Among the grazing animals, however, a number of forms have the premolars formed like the molars The human premolars are also called bicuspids. (A W L)

PRENATAL INFLUENCE. **Telegony.**

PREPUCE. **Foreskin.**

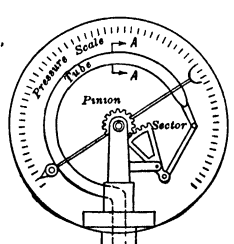
PRESENTATION. That portion of the **fetal** body that appears or presents at the **cervical** opening of the **uterus** during labor The most common presenting part is the head, usually the occipital portion This is the normal presentation and is best for an easy delivery. Various other portions of the head may also present, face, brow, etc

Breech presentation is presentation of fetal buttocks making labor more difficult Other portions of the body may also be presented, such as shoulders, either foot, etc. (R S M)

PRESSURE. A type of stress, characterized by its uniformity in all directions (as distinguished from compressive stress in one direction) Its measure, as with all other stresses, is the force executed per unit area, for example, the normal **atmospheric pressure** is about 14 7 pounds per square inch Pressure is usually associated with a decrease in volume, though the opposite stress, accompanying an increase in volume, is sometimes referred to as "negative pressure" This latter must be distinguished from the same term as sometimes used to denote pressures below atmospheric, the pressure of the atmosphere being in such cases taken as an arbitrary zero It is likewise important, especially in pneumatics, to indicate whether pressure is reckoned from vacuum or from atmospheric pressure as zero Thus when a tire is inflated to "thirty-five pounds," the actual pressure in the tire is about fifty pounds per square inch

Many different units are used in expressing pressure The absolute c g s unit is the **barye** or **bar** (one dyne per square centimeter) The usual engineering unit is the pound per square inch Very commonly, pressures are expressed in millimeters or inches of mercury or other liquid, meaning the **hydrostatic** pressure at the corresponding depth in that liquid Another common unit in physics is the "atmosphere," standardized as 760 millimeters of mercury at 0° C and equal to about 1,013,250 bars (See **Pressure Gages**) (L D W)

PRESSURE GAGES Pressure enters as a variable factor in a vast number of physical phenomena, and there is frequent need for its measurement over a very wide range For ordinary pressures there are two chief types of gage, viz, the familiar liquid manometer, of which the mercury barometer is an example, and those instruments dependent upon the deformation of a closed, thin-walled cell of elastic metal, such as the ordinary (Bourdon) steam gage and the aneroid barometer. Such gages are secondary instruments in that they must be calibrated in comparison with a primary gage, such as a manometer While the mechanical element of a gage may be a Bourdon tube, a



Pressure Gage
(Bourdon Tube)

diaphragm, or a bellows, space permits description only of the simple widely used Bourdon type of gage As shown in the figure, an oval tube is bent in the form of a portion of a circle and sealed at one end The other end is connected to a region whose pressure is to be measured If that pressure is above atmospheric, the tube tends to change from oval to circular cross-section, accompanied by an uncurling action This tendency is resisted by the elastic properties of the metal of the tube, but the tip executes a movement which is proportional to the internal pressure If the internal pressure were below atmospheric, the effect would be reversed and the tube would tend to curve in, moving the sealed tip inward. The extent of this motion is quite small, and it must be amplified by suitable mechanism, so that the limited movement of the tip of the tube may be converted into a full swing of the indicating needle Modification of the material of the tube, as well as the proportions and wall thickness, will adapt this instrument to a wide range of pressures

Physical and industrial research often involves very low gas pressures Gages for measuring low pressures may be classified under five principal heads (1) Pressure multipliers, represented by the well-known McLeod gage A measured volume of gas at the unknown low pressure is compressed isothermally into a known volume many times less, thus raising the pressure to within the range of an ordinary mercury manometer, the determination is then completed by applying **Boyle's law** (2) Viscosity or "molecular" gages, dependent upon the fact that the viscosity of a highly rarefied gas is a function of the pressure In the Langmuir and Dushman design, a horizontal circular disk is rotated rapidly under and near a similar disk suspended in the gas by a quartz fiber, the molecular drag between the disks exerts a measurable torque upon the suspension (3) Radiometric gages, like the **Crookes radiometer,** in which the force acting on its vanes depends upon the number of gas molecules present, and hence on the pressure Knudsen has developed gages of this class (4) The hot-wire type, illustrated by the Pirani gauge A hot filament is cooled by convection, i e , by the gas molecules coming into contact with it and carrying off its thermal energy, the rate depending, of course, upon the number of molecules present The cooling effect is determined by observing the resistance of the filament. (5) Ionization gages, in which a rarefied gas is subjected to ionization by thermionic emission from a heated filament, and a third electrode, of lower potential than the filament, carries off the positive ions formed The tube can be so designed that the ionization current is proportional to the gas pressure Such a gage was first designed by Buckley, and the Bell Laboratories have perfected a design said to be capable of measuring one-trillionth of an atmosphere

The highest pressures measurable with the mercury manometer are not over a few hundred kilograms per square centimeter ' For very high pressures—thousands of kilograms per square centimeter—some form of "free piston" gage is used, that is, one in which the unknown pressure is applied to a small piston, the force exerted on which can be counterbalanced with weights or otherwise Amagat used a double piston, the larger end balanced against the pressure of a mercury manometer, a sort of inverted hydraulic press (L D W , F T M)

PRESSURE SHIFT AND PRESSURE BROADENING. Spectrum lines are subject to various physical influences brought to bear upon the substance emitting the radiation, and among these is pressure When the pressure and density of a gas are greatly increased, the lines of its spectrum become less sharp, or broader (without change of total intensity) This broadening is not symmetrical but is greater in the direction of longer wave length, so that the peak or maximum is shifted toward the red Thus, when the pressure of mercury vapor is increased from 10 to 50 atmospheres, the 2536-angstrom line has its half-width increased from 0 2 angstrom to 0 8 angstrom, while its peak is shifted about 0 3 angstrom toward the red These effects are attributed to the influence of atomic collisions, which are of course more frequent at high pressure. (L D W)

PRIAPULIDA. Gephyrea.

PRIMARY. Transformer.

PRIMARY EMBRYO. An individual formed in the brood pouch or **ovicell** of some of the **bryozoans** It is nourished by the parent through a connection with the wall of the ovicell and produces other individuals by budding The small masses of cells which arise by this process are called secondary **embryos** Each develops into an adult. (A W L)

PRIMATES. Man, the **apes** and **monkeys,** the **marmosets, lemurs,** and related forms, constituting an order of the class **Mammalia**

Most primates are arboreal animals and all species either grasp by opposing the thumb to the fingers or show similarity to grasping appendages of this type in the anatomy of the hand With the exception of the marmosets, all primates have nails on at least part of the digits The lemurs retain a claw on the second toe and the marmosets have a nail only on the great toe The brain is more highly developed in the primates than in any other animals (A W L)

PRIMIPARA. A woman who is giving birth to or has borne but one child Compare with **Multipara** (R S M)

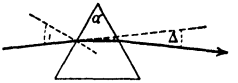
PRINCIPAL AXES Dynamics of Rotation; Moment of Inertia.

PRINCIPAL ROOT OF A NUMBER. Roots of Numbers.

PRIONODESMACEA. An order of **bivalve mollusks (Lamellibranchiata)** in one of the classifications now in use (A W L)

PRISM. Glass and other transparent materials are cut into many different forms of prism for various optical purposes Incident light may pass directly through a prism, or may emerge after one or more internal reflections, in some cases it is **polarized.**

The common triangular prism, familiar in the **spectroscope,** receives light upon one face and passes it through another after two refractions, resulting in a total deviation Δ dependent upon the angle of the prism and its refractive index for the light used If the light is incident at angle i on the first prism face,



Ray of light passing through triangular prism

and if the prism angle is α and the refractive index is n, the total deviation after passage through the prism in a plane at right angles to the prism edge is given by

$$\Delta = i - \alpha + \arcsin\left[n \sin\left(\alpha - \arcsin\frac{\sin i}{n}\right)\right].$$

A little experimenting shows that this deviation has a minimum value when the light traverses the prism symmetrically, entering and emerging at the same angle with the corresponding faces This angle of minimum deviation is easily shown to be

$$\Delta_{\min} = 2 \arcsin (n \sin \tfrac{1}{2}\alpha) - \alpha,$$

from which the refractive index may be obtained, by experiment, as

$$n = \frac{\sin \tfrac{1}{2}(\Delta_{\min} + \alpha)}{\sin \tfrac{1}{2}\alpha}$$

The effect of a prism on heterogeneous light may be deduced from the formulae for refractive **dispersion.** See **Amici Prism, Nicol Prism, Binocular, Monochromatic Illuminator.** (L D W)

PROBABILITY. The probability that, among several equally likely events, a given event will happen is the ratio of the number of favorable cases to the total number of cases, the probability that this event will fail is the ratio of the number of unfavorable cases to the total number of cases

It is important to emphasize the assumption in this definition that the events are equally likely

If the number of favorable cases is a and the number of unfavorable cases is b, the probability that the event will happen is $p = \frac{a}{a+b}$, and the probability of failure is $\frac{b}{a+b}$

The probability of certainty is 1 and the probability of impossibility is 0

In many important cases it is not possible to determine the exact probability of the happening of an event by enumerating all the possible equally likely ways in which an event can happen or fail This is the case, for instance, in the probabilities involved in life insurance and fire insurance But it is often possible to make a practical determination of the probability by statistical data based on experience and observation over a large number of cases If it is found by observation that an event has happened m times out of a total of n cases, we may take m/n as an approximation to the probability of the event, if n is large

The events of a set are said to be mutually independent or dependent according as the occurrence of one of them does not or does affect the probability of occurrence of others of the set

The probability that two independent events will both happen is equal to the product of their separate probabilities $\cdot$ $p = p_1 \ p_2$ This also holds for three or more independent events

For dependent events, if the probability of a first event is p_1, and if, after this has happened, the probability of a second event is p_2, then the probability that both events will happen in the order stated is $p = p_1 \ p_2$

Two events are said to be mutually exclusive if the happening of one excludes the happening of the other

The probability that one or other of a set of mutually exclusive events will happen is the sum of the probabilities of happening for the separate events $p = p_1 + p_2 +$

The probabilities of happening of the separate events of a set of mutually exclusive events are called the partial probabilities, and the probability that one or other of the events will occur is called the total probability The total probability is therefore the sum of the partial probabilities

If p is the probability that an event will happen in any single trial, and $q = 1 - p$ is the probability that the event will fail in any single trial, then the probability that this event will happen exactly r times in n trials is $C(n,r)p^r q^{n-r}$, and the probability that it will happen at least r times in n trials is

$$p^n + C(n,1)p^{n-1}q + C(n,2)p^{n-2}q^2 + \ldots + C(n,r)p^r q^{n-r}.$$

(L L S)

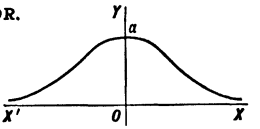
PROBABILITY CURVE. In the mathematical theory of **probability,** it is shown that the probability of committing an error of magnitude x is given by the ordinate of the curve whose equation is

$$y = \frac{h}{\sqrt{\pi}} e^{-h^2 x^2},$$

where h measures the accuracy of the observer This curve is called the probability curve and is shown in the accompanying figure (L L S)

PROBABLE ERROR. Least Squares.

PROBASIPODITE. A segment of the **biramous appendage of crustaceans.** It is the proximal part of the basipodite where this segment is subdivided In such appendages it usually bears the exopodite (A W L)



Probability curve

PROBOSCIDEA. The **elephants** An order of **mammals** including only two species now living (A W L)

PROBOSCIS. A protruding or protrusible organ associated with the mouth and therefore at the front of the head in most animals It is used in feeding and in some cases for other purposes

Among the more primitive animals, such as the flatworms (**Platyhelminthes**) and **annelids,** a portion of the alimentary tract can be everted through the mouth, and is called a proboscis It may ingest food merely by muscular action but in the annelids it may also be armed with sharp teeth for grasping prey The proboscis of the flatworm appears near the middle of the lower surface of the body The **nemertine** worms also have a proboscis but in the phylum it arises independently, although it is associated with the mouth in the adult Many **arthropods** have an elongate structure which may be termed a proboscis, although there is little uniformity in the different groups A familiar example is the long sucking tube of the butterflies and moths, formed of the maxillae

In the **vertebrates** the proboscis consists of the elongated nose and upper lip, and is developed only in the elephants to a conspicuous degree It serves the animal in respiration, since it is traversed by the nasal passages, and is a delicate and powerful grasping structure It grasps larger objects by **prehension** and smaller ones by means of small lobes at the tip (A W L)

PROBOSCIS MONKEY. Mammalia, Primates A moderately large **monkey** of Borneo, *Nasalis larvatus,* characterized by the long, fleshy, and somewhat drooping nose This part is largest in adult males and is relatively small and upturned in the young The nostrils open near each other on the lower surface The species is closely related to the **langurs** (A W L)

PROCELLARIIFORMES The **albatrosses** and **petrels** An order of marine birds known for their powerful flight The feet are webbed and the horny sheath of the beak is composed of several parts. (A W L)

PROCTITIS. Infection of the lining of the rectum which may be caused by a variety of organisms The most frequent organisms causing infection are the various kinds of **Streptococci, Staphylococci, Gonococci,** etc Proctitis is characterized by pain and spasm of the rectum Constitutional symptoms are not usually marked (R S M)

PROCTODAEUM. A hollow structure formed by the invagination of the outer layer of the body (ectoderm) It associates with the gut of the **embryo** to form the caudal end of the alimentary tract In the **insects** the proctodaeum is relatively long, forming the entire hind intestine, which consists of the small and large intestines and the rectum The proctodaeum of **vertebrates** is less extensive, forming only the **anus** (A W L)

PROCTOLOGY. That division of surgery that deals with the diagnosis and treatment of diseases of the rec-

tum The most common rectal disorders are **hemorrhoids**, fissure, fistula, pruritus, abscess formation, stricture, inflammation of the rectal membrane, **polyp** formation, **cancer**, **spasm**, ulcer formation, and local infection (R S M)

PROCYON. Procyon (α **Canis Minoris**) is a brilliant star which receives its name from the fact that it precedes the star **Sirius** in its nightly journey across the sky These two "dog stars" are referred to in the most ancient literatures and were objects of veneration and worship both by the Babylonians and the Egyptians Astrologically, the star portended wealth, fame, and good fortune

Procyon, like the other "dog star" Sirius, has a faint companion which is suspected to be a **white dwarf** (W K G)

PRODUCT FORMULAS. Multiplication.

PROEPIPODITE A process of the **biramous appendage** of **crustaceans** borne by the pleuropodite An epipodite (A W L)

PROGESTERONE. Sex Hormones.

PROGLOTTID A reproductive segment of a tapeworm (**Cestoda**) These segments are budded from the head or **scolex** in a long series which makes up the ribbonlike body of the worm Each proglottid contains reproductive organs of both sexes and is traversed by the longitudinal nerve cords and the excretory canals As they mature, the proglottids break away from the caudal end of the worm and pass out of the body of the host with the feces (A W L)

PROGNATHISM. Protrusion of the lower jaw Some animals are normally prognathous but the term is usually applied only to abnormal prominence of the jaw in man Some breeds of bulldogs are conspicuously prognathous, here the term undershot is used with the same meaning (A W L)

PROGRESSIONS. This term covers the topics of **arithmetic progression**, **geometric progression**, and **harmonic progression** (L L S)

PROJECTION, OPTICAL By far the most common form of projecting apparatus is the stereopticon or magic lantern This instrument consists essentially of a concentrated source of light L, as an arc, divergent rays from which are caught by a condensing lens system C

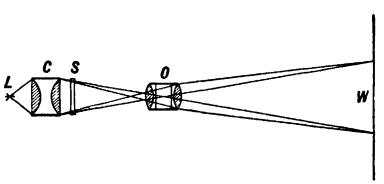


Diagram of stereopticon lens system.

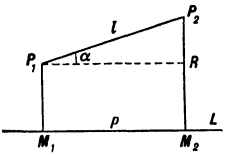
(see figure) and made to illuminate the transparent slide S, which thus becomes a secondary source, like the slit of a spectroscope The objective O, a system of achromatic lenses, forms an enlarged, inverted image of S on a distant white wall at W For the image to appear right side up, the slide itself must, of course, be inverted. The ratio of enlargement, or magnifying power, M, depends in a simple manner upon the distance D from the stereopticon to screen and the focal length f of the objective $M = (D - f)/f$

In order to exhibit an opaque object, like a postal card or the page of a book, it must be placed at S and illuminated by very strong light focused upon it obliquely from one side by means of lenses or mirrors. Any such picture will appear reversed, right to left, on the screen unless a more complicated optical system is used

A moving-picture projector differs in no essential way from the stereopticon The "slides" are, of course, films, and much smaller than standard slides, and the machine is provided with a mechanism for abruptly shifting from one picture to the next on the film while the shutter is closed, and for holding the film stationary while it is open (L D W)

PROJECTIONS If M_1 is the foot of the perpendicular from P_1 to a line L, then M_1 is called the projection of P_1 on L

If M_1 and M_2 are the projections of two points P_1 and P_2 on a line L respectively, then the line-segment M_1M_2 is called the projection of the line-segment P_1P_2 on L



Similarly, the projections of a point and of a line segment upon a plane are defined by drawing perpendiculars to the plane

The length of the projection of a line-segment l upon a line L is equal to the length l of the given segment multiplied by the cosine of the angle between the lines $p = l \cos \alpha$

The projection of any area upon a plane is equal to the original area multiplied by the cosine of the angle between the given area and the plane

A fundamental projection theorem is: the projection of a broken line is equal to the sum of the projections of the parts (L L S)

PROJECTIVE GEOMETRY. Projective geometry may be described as dealing primarily with the properties of figures which are unaltered by central projection By central projection we mean that, from a fixed point or center of projection, straight lines are drawn through the various points of a given figure, and then a section is taken of these projecting rays by a fixed line or plane, giving a new figure (L L S)

PROLAMINES. Aminoacids, Polypeptides, and Proteins.

PROLAPSE. The falling or protrusion of an organ or structure due to lack of support or weakness of the ligaments or surrounding muscle Prolapse of the rectum—a protrusion of a part of the rectal wall externally Prolapse of the **uterus**—a protrusion of the uterus through the **vagina**, inverting of the vagina so that in an extreme case the uterus hangs between the legs (R S M)

PROLEG A fleshy appendage developed in the larvae of certain insects to support the hinder part of the wormlike body The prolegs bear numerous small hooklets called crochets which grip the supporting surface Whether these appendages are derived from jointed appendages of the abdomen or not is uncertain, there are evidences to show that such is the case

The larvae of many sawflies (Hymenoptera) have six to eight pairs of prolegs and those of most butterflies and moths have five pairs (A W L)

PROLINE. Aminoacids, Polypeptides, and Proteins.

PROMINENCES. Prominences are regions of the solar **chromosphere** which, for some unexplained reason, extend out to a considerable height from the normal upper surface of this region of the solar atmosphere In common with the chromosphere the prominences usually appear with a brilliant scarlet color Up to the middle of the nineteenth century prominences could be observed

only during a total **eclipse** of the sun. In 1868 Lockyer and Janssen discovered a method for observing these interesting phenomena at any time. A high dispersion **spectroscope** will spread out, and hence greatly dilute, the continuous **spectrum** of the sun The prominences, however, shine by means of hot hydrogen and calcium, elements which have strong isolated bright lines which will appear strongly against the dispersed sunlight By setting the view telescope of the spectroscope to observe any of these strong lines, usually the red line of hydrogen, the slit of the instrument may be set tangent to the limb of the sun and widened until the entire prominence may be observed

Prominences are of two general types. The quiescent prominences bear considerable resemblance to clouds in our own atmosphere but are very large and extend out frequently as much as 50,000 miles from the sun Eruptive prominences are smaller than the quiescent ones, but extend out from the sun to much greater distances, frequently more than 500,000 miles, and are found to have high velocity, as great as 200 miles per second, out from the sun Both the quiescent and eruptive prominences contain hydrogen, calcium, and helium, but the eruptive prominences are also found to contain iron, magnesium, and other elements apparently carried up from the lower atmosphere of the sun

There is no adequate explanation for the enormous force necessary to project matter out from the sun with such high velocity against the strong surface gravity. The number of prominences is directly correlated with the number of **sun spots.** The quiescent prominences may appear at any portion of the sun's disk, but the eruptive type are limited to the latitude zones in which the sun spots are found, and frequently rise from the vicinity of active spots (W K G.)

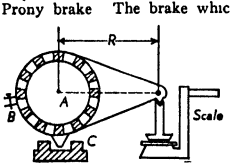
PROMOTER. Catalysis.

PRONG-HORN ANTELOPE. Mammalia, Artiodactyla *Antilocapra* A plains animal of the western half of North America It is distinguished by the erect horns, hooked at the tip, and bearing a short branch in front The prong-horn differs from all true **antelopes** in the branching of the horn sheaths and in the periodical shedding and renewal of these sheaths It is, however, much like the antelopes in appearance. Also called the prongbuck. (A W L)

"PRONTYLIN." Sulfanilamide.

PRONUBA MOTH, AND YUCCA. Pollination.

PRONY BRAKE. Mechanical horsepower is often conveniently determined by measuring the reaction on a **brake** which bears against a **pulley** or brake drum in such a way as to create a friction drag which converts the mechanical **energy** of the rotating shaft into **heat** Engines and motors are often tested with the use of the Prony brake The brake which is shown diagrammatically in the figure consists of the brake drum or wheel mounted on the shaft and surrounded by a band of steel, belting, or some other flexible material, to which are fastened, internally, blocks of wood A band-tightening mechanism allows the operator to adjust the pressure between the brake blocks and the drum In this way the frictional drag and the load upon the engine can be varied To the brake band is rigidly attached an arm having a radius R by means of which the band is kept from rotating The torque effect of the friction drag is found by measuring the force necessary to keep the brake arm from moving This scale reading in pounds, multiplied by R, is equal to the pound-feet of **torque** set up as a frictional drag at the surface of the drum. The torque, when multiplied by the angular speed, radians per minute, is the power delivered in foot-pounds per minute The brake horsepower, then, equals



Prony brake.

$$\frac{2\pi RWN}{33{,}000}$$

N is the rotative speed of the drum, revolutions per minute, W is the net weight on the scales, net weight meaning the gross recorded weight less the weight necessary to support the dead weight of the unbalanced brake arm This deduction is known as the tare The tare could be found by balancing the brake on a knife edge to locate its center of gravity, and then applying the principle of **moments** to determine the reaction at the end of the brake arm If it is possible to rotate the brake drum slowly backwards, the brake band should be loosened, and the drum rotated slowly forward, then backward If during this time the weight on the scales is w_1 for forward rotation, and w_2 for backward rotation, the tare is $\frac{1}{2}(w_1 + w_2)$

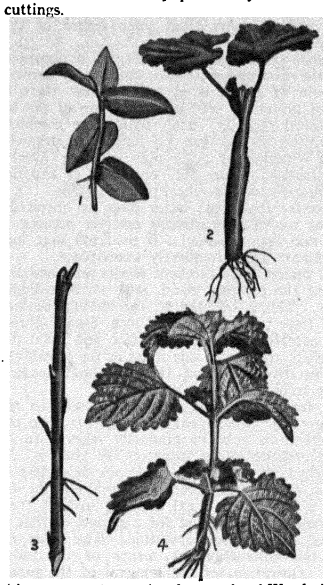
The mechanical energy must be absorbed by the brake itself, as this is an absorption type **dynamometer.** For every horsepower 42 4 B T U are generated by friction each minute The large flywheels of engines have so much windage or fan action that this heat can usually be dissipated to the atmosphere Small brake drums suitable for motors must be water-cooled to prevent their overheating To accomplish cooling of this nature, the drum should be provided with internal flanges, and a layer of water will be held against it by centrifugal force Water can be admitted from a stationary supply tube and removed by a scoop which clears the circumference of the rim (F T M)

PROPAGATION; VEGETATIVE REPRODUCTION. It is often very convenient and even essential that plants be propagated by other means than by seeds One of the principal reasons for this is to insure absolute identity of nature or kind, another to increase the stock rapidly One way of accomplishing this is by **grafting** Another is by vegetative propagation, by means of cuttings or slips Various parts of the plant may be used, advantage being taken of the ability of the part used to form **adventitious roots or buds.**

A few plants can be propagated by root cuttings These sections or pieces of the root form buds and also put out roots The sweet potato is mainly propagated by this method Roses are also sometimes increased by root cuttings In many plants the formation of adventitious buds on the roots is advanced by exposure to light If the roots of a poplar tree are exposed, in a short time adventitious buds grow and form erect stems Cutting the root which connects this plant with the parent causes the latter to become independent Such adventitious buds are freely formed on the roots of many thistles Since the latter become troublesome weeds the habit is one of annoyance, but not of importance to man in this case

Vegetative propagation is also obtained by means of stem cuttings, often called slips The stem of the plant to be propagated is cut into sections, each section having several nodes Usually all or many of the leaves are removed to reduce transpiration The cuttings are then placed erect and half buried in moist sand In a short time the **parenchyma** cells just back of the cut surface begin to divide rapidly, forming a loose spongy mass of cells, called a callus, which completely covers the wounded end From this callus tissue, adventitious roots are formed and in some cases adventitious buds also Not every plant can be rooted with equal facility by this means Some, like the common *Pelargonium*, usually called geranium, and *Coleus*, root very quickly and easily The cuttings may be rooted as easily by sticking in water as by burying in sand Others can be propagated by stem cuttings only when the proper condition obtains In some plants only young actively growing

stems can be used; in others mature hardened wood is necessary. Often such cuttings remain for months before any roots are formed. It has been said that if proper conditions are obtained any plant may be increased by stem cuttings.



Adventitious roots. 1, growing from node of Wandering Jew; 2, growing from cut end of geranium; 3, growing from lenticels of willow; 4, growing from internode of *Coleus*.

Modified stems, such as **rhizomes** and tubers, usually propagate much more readily. The white potato is propagated by cuttings of the ripened tubers, or potatoes. **Bananas** are increased by planting sections of the rhizome. The ubiquitous pest, witch grass, *Agropyron repens*, propagates itself readily by this method. Cultivation by hoe or cultivator breaks the creeping rhizome into sections, each of which becomes a new plant, which seems to grow with increased vigor.

Some plants are propagated by their leaves. Many species of *Sedum*, common rock garden plants, may be thus propagated, the fleshy leaves being removed from the plant and pushed part way down into moist soil. Adventitious roots and an adventitious bud form from the base of the leaf. Some begonias may be readily reproduced by their leaves. The latter are placed flat on the surface of moist sand, partially covered with sand and left undisturbed. Tiny plants soon form on the upper surface of the leaf, along the veins. Cutting across the main veins often helps to cause formation of new plants. *Sanseveria zeylanica*, the common bow-string hemp plant, can be readily propagated by leaf cuttings. The long linear tough leaves are cut into three- or four-inch sections and treated like stem cuttings. Species of *Bryophyllum* and the related *Kalanchoë* naturally reproduce by means of their leaves, tiny plants forming in great abundance in the notches or at the apex of the leaves.

Plants produced by vegetative means are always exactly like the parent plant, if environment does not enter and cause changes. (R.M.W.)

PROPANE. Hydrocarbons.

PROPER ENERGY. Energy.

PROPER MOTION. The individual motion of a star relative to the other stars is known as the proper motion of the star. Up to the early part of the eighteenth century the belief was current that the stars were all fixed on a sphere commonly known as the **celestial sphere.** Since this sphere was apparently rotating about the earth and possessed other motions such as **precession** and **nutation**, all of the stars had certain motions in common. In 1718, Edmund Halley, while reducing his observations of the positions of the stars, noted that the positions which he obtained for **Sirius** and **Arcturus** differed in position relative to the other stars from the positions given by Ptolemy. Since the differences were greater than could be ascribed to errors in observation, Halley concluded that these two stars were actually not fixed on the celestial sphere but were in motion.

Since Halley's time, many stars have been observed to have proper motion and many long programs are at present under way to study these motions. The standard method of procedure is to compare positions of the stars at two epochs as widely separated as possible. Visual observations made with extreme precision with a **meridian circle** may be used for this purpose, but the photographic methods are far more fruitful since a large number of star positions may be obtained on a single plate. The longer the interval of time between the observations, the more accurate is the determination of the proper motion, and also the smaller the proper motion which can be detected.

Proper motion can only be determined in angular units, and the results are usually expressed in terms of seconds of arc per year. In case the **stellar parallax** of the star is known the velocity in linear units may be computed in accordance with methods discussed under **space velocity** of a star. The largest known proper motion is 10″.25 per year and was found by Barnard for a tenth **magnitude** star. Such a star would require about 200 years to change its position by an amount equal to the apparent diameter of the moon. There are only about fifty stars known to have proper motions greater than 2″ per year and not more than a thousand with values greater than ½″ second per year. Hence, we should not expect the **constellation** figure to have altered appreciably in the 5000 years since they were first described. (W.K.G.)

PROPLIOPITHECUS. Paleontology of **man.**

PROPODITE. A segment of the **biramous appendage.** (A.W.L.)

PROPOLIS. A material gathered by **honey-bees** and used for closing crevices in the hive and for filling in sharp angles and attaching loose parts. It is also applied as a varnish to the combs and to the smooth surfaces in the hive. The substance is composed chiefly of resins gathered from plants and has an aromatic fragrance much like that of the leaf buds which furnish some of these resins. (A.W.L.)

PROPORTION. A proportion is a statement of equality between two **ratios.** It may be written in the form $a:b=c:d$ (formerly $a:b::c:d$), or perhaps better $a/b=c/d$.

In a proportion $a:b=c:d$, we call the first and fourth numbers a and d the extremes, and the second and third numbers b and c the means of the proportion.

Properties of a proportion, as $a:b=c:d$, are expressed by the following:

(1) In any proportion, the product of the means is equal to the product of the extremes: $ad=bc$.

(2) In any proportion, the terms are in proportion by inversion, that is, $b:a=d:c$.

(3) In any proportion, the terms are in proportion by alternation, that is, $a:c=b:d$.

(4) In any proportion, the terms are in proportion by composition, that is, $a+b:b=c+d:d$.

(5) In any proportion, the terms are in proportion by division, that is, $a - b \;\; b = c - d \;\; d$

(6) In any proportion, the terms are in proportion by composition and division, that is, $a + b . a - b = c + d : c - d$

If $a \cdot b = c \cdot x$, then x is called a fourth proportional to a, b, and c.

If $a \;\; b = b \;\; x$, then x is called a third proportional to a and b

If $a \;\; x = x \;\; b$, then x is called a mean proportional between a and b, this is the same as the **geometric mean** of a and b. (L L S)

PROPORTIONAL LIMIT. The maximum unit **stress** which can be obtained in a structural material without causing a change in the ratio of the unit stress to the unit **deformation** is called the proportional limit See **Ultimate Strength, Modulus of Elasticity.** (C W C)

PROPYLITIZATION. Processes, both magmatic and post magmatic, by which **andesitic** rocks are altered through the action of water, **carbon dioxide**, and **sulfur** (R M F)

PROSAURIA. Reptilia.

PROSOBRANCHIATA. Synonym of Streptoneura. **Gasteropoda** (A W L)

PROSOMA. Cephalothorax.

PROSOPYLE. A minute pore connecting the inhalant and radial canals of sponges **Porifera** (A W L)

PROSOSTOMATA. Trematoda.

PROSTATE GLAND. A gland associated with the ducts of the male reproductive system Its secretion forms part of the seminal fluid

The name is applied to a gland of some flatworms The spermiducal glands of earthworms are also called the prostates, although they do not open into the sperm ducts Some of the **cephalopod** mollusks also have a prostate associated with the sperm duct In the **mammals** the gland is well developed, lying at the junction of the urinary bladder and the urethra.

In man, this gland is chestnut-shaped and measures 1¼ by 1½ inches It is composed of glandular and fibrous tissue The openings of the glandular ducts empty into the urethra It is not known whether there is any **hormone** secretion by this gland The function of the prostate is to secrete a fluid which forms a part of the seminal fluid This gland is subject to infection (prostatitis), **hypertrophy**, and **cancer** Prostatitis may occur in an acute or chronic form Infection of the prostate is an exceedingly common disease which affects the adult male It is usually seen as a complication of **gonorrhea**, but may at times be caused by other organisms such as the *Streptococcus*, *Staphylococcus*, and *tubercle bacillus*

The symptoms of prostatitis are many and may be divided into three groups (1) Sexual, (2) Urinary irritation and obstruction of urinary flow, (3) Referred symptoms These referred symptoms are usually those of pain, which is often severe, involving the hips, buttocks, legs, thighs, back, or groin The sexual disorders are numerous and may be of many varieties Chronic prostatitis is responsible for much of the neurasthenia seen in the male, and is often the causative factor for many ailments mis-diagnosed as **lumbago**, **sciatica**, **rheumatism**, etc Certain forms of **arthritis** are due to a focus of infection in this gland Many functional ailments result from prostatitis. These include nervous disturbances Heart disorders such as **palpitation**, **myocarditis**, and in some instances **angina pectoris** have been relieved or cured by proper treatment of the diseased prostate. Abscess of this gland may occur following an acute infection It requires surgical drainage.

Tuberculosis of the genito-urinary system may be due to a focus in the prostate Hypertrophy (enlargement) of the prostate is exceedingly common in men over fifty years of age More than 20% of the men past middle life are said to suffer from some degree of this enlargement

The chief symptoms resulting from hypertrophy are due to the obstruction to the outflow of urine The usual chain of events is as follows first there is frequency of urination, gradual contracture of the bladder with lessened capacity, later, with more complete obstruction, the bladder can no longer be emptied, and complete retention of urine may develop Once complete obstruction occurs only operation or a permanent indwelling catheter can relieve the condition

It is better that these latter cases be operated upon before the use of a permanent catheter becomes necessary for too long a period If used too long infection of the urinary tract frequently takes place

At the present time excellent results are obtained with surgery of the prostate gland, with an exceedingly low mortality This is remarkable, considering the fact that many of these patients are aged men, usually chronically ill with **arteriosclerosis**, or cardiac and renal diseases The excellent results are due more to the advances made in pre-operative treatment than to the refinements of operative technique

There are two surgical approaches used for removal of the prostate Before either of them is done the urinary obstruction must be gradually relieved to remove the back pressure of the urine on the kidneys This is accomplished by one of two methods, depending on the individual case One method is to drain the bladder through a lower abdominal incision, so that the urine can be removed by suction for a period of time before doing the second stage operation The other method relieves the obstruction by means of the indwelling catheter Operation for the removal of the prostate is done at a later date, either (1) through the inside of the bladder by an abdominal incision, or (2) through the perineal route Both methods give excellent results

The prostate gland is a common site for the development of cancer The symptoms are similar to those of the benign hypertrophy

If diagnosed sufficiently early radical surgical removal and the use of radium give the best results Inoperable cases can only be treated by palliative measures. (A W.L, R S M)

PROSTATITIS. Prostrate Gland.

PROSTOMIUM. A protuberance of the first segment of **annelid** worms, lying in front of the mouth In the earthworms it is a simple rounded structure In the **leeches** it enters into the formation of the anterior sucker Its most remarkable form is the long proboscis, forked at the tip, which appears in the annelids of the genus *Bonellia* (Gephyrea) (A W L)

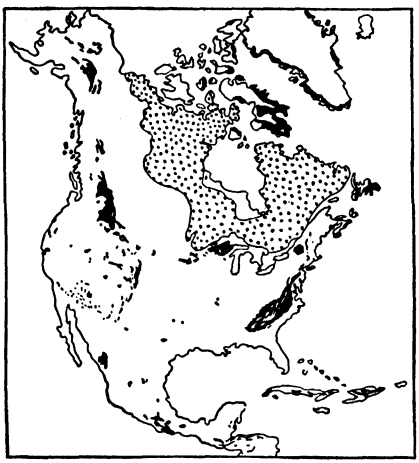
PROTAMINES. Aminoacids, Polypeptides, and Proteins.

PROTEINS. Aminoacids, Polypeptides, and Proteins.

PROTEOMYXA. Sarcodina.

PROTEROZOIC (Algonkian). Next to the oldest of the five **Eras** of the earth's history Separated from the **Archeozoic** (the oldest Era) by a profound **unconformity.** The formations of the Proterozoic contain a preponderance of red sandstones and shales suggesting increasing aridity **Tillites** also prove that continental glaciers existed in Eastern Canada, Australia, Tasmania, Norway, South Africa and India The only undoubted forms of life appear to have been low forms of marine

plants called calcareous algae. The sedimentary formations of the Proterozoic, especially in North America,



Map showing the surface of pre-Cambrian (Archeozoic and Proterozoic) rocks in North America. Largest area shown by dotted pattern; smaller areas by solid black. (Modified after Willis, U. S. Geological Survey.)

contain important ores of **iron** and **copper**. Length of time since the beginning of the Proterozoic, 1000 million years. (R.M.F.)

PROTHALLUS. Ferns.

PROTOACTINIUM. Symbol: Pa. Atomic number: 91. Atomic weight: 231. Recognized by the International Committee on Atomic Weights in 1937. A radioactive element of the actinium series. (See **Radioactive Changes.**) (R.K.S.)

PROTOBRANCHIATA. Lamellibranchiata.

PROTOCEREBRUM. The first of the three principal parts of the **arthropod** brain. It is derived from the pair of ganglia in the first segment of the head and innervates the eyes, both simple and compound. In some **arthropods** a median archicerebrum lies in front of this pair of ganglia and the two components together make up a procerebrum. The remaining two regions of the **brain** are the **deutocerebrum** and the **tritocerebrum.** (A.W.L.)

PROTOCILIATA. Ciliophora.

PROTOCLASTIC STRUCTURE. The type of structure which results from differential flow during fractional and granular differentiation of the crystals from the partly congealed **magma.** (R.M.F.)

PROTOGINE. An old and obsolete term proposed by Turine in 1806 for the central crystalline core of the Alps. Of historic significance because intimately connected with the origin of **granites, gneisses** and mountain building. (R.M.F.)

PROTOHIPPUS. Fossil Mammals.

PROTOMONADIDA. Mastigophora.

PROTON. The proton is most familiar as the nucleus of the **atom** of ordinary **hydrogen** (H^1); that is, as the ionized hydrogen atom. But there is ample evidence that protons exist also in the nuclei of other atoms. Until recently it was supposed that all atomic nuclei are built up of protons and **electrons;** now it appears that thefe may be other constituents (See **Neutron** and **Positron**), and the existence of electrons as such in the nucleus is in doubt. The mass of the proton is equal to the mass of the hydrogen atom minus the mass of the electron, that is, to about 1.661×10^{-24} gram. (L.D.W.)

PROTONEMA. Bryophytes.

PROTOPLASM. The material of which all living things are formed, usually a jellylike or fluid substance of grayish translucent appearance.

Protoplasm is a complex mixture in which the elements, **carbon, oxygen, hydrogen** and **nitrogen** are always present. **Sulfur** is another constituent of most protoplasm and many other elements, such as **iron, phosphorus, calcium** and **iodine** frequently occur in it. These elements appear in three complex types of chemical compounds and in many others which are intermediate or waste products in the chemical processes of the living body. The three are proteins (See **Aminoacids**), **carbohydrates** and fats (See **Esters**). Proteins are made up of carbon, hydrogen, oxygen and nitrogen and usually sulfur. Both carbohydrates and fats contain carbon, hydrogen and oxygen but in carbohydrates the hydrogen and oxygen are in the same proportions as in water while in fats there is relatively much less oxygen. The proteins are chiefly materials of construction and the carbohydrates and fats are sources of energy.

These materials are associated in a finely divided state known as a **colloid,** in which the extensive surface contacts of particle with particle or with surrounding fluids facilitate all chemical interactions of which they are capable.

Living matter displays several physiological properties which are of paramount importance. First among them is **metabolism,** the power of chemical interchange with the environment by which the organism secures materials and energy. As a result of metabolism **growth** by intussusception is accomplished and the animal adjusts itself to its surroundings by the property of **adaptability,** carried on through the four subordinate properties, **irritability, conductivity, contractility,** and **secretion.** The substance is capable of **reproduction.** By this process any unit characteristic of the **organization** of a given kind of protoplasm is repeatedly produced. These units are not simpler than a single cell; any simpler structure is an end product of the cell and is not capable of complete exercise of these vital properties. (A.W.L.)

PROTOPLAST. The living unit of **protoplasm** contained within the wall of a **cell** forms the protoplast of the cell. This protoplast is an organized unit of protoplasm. (R.M.W.)

PROTOPODITE. A segment of the **biramous appendage.** (A.W.L.)

PROTORE. Enrichment.

PROTOTHERIA. Mammalia.

PROTOZOA. The one-celled animals, constituting a major division (**Phylum**) of the animal kingdom. They occur in soil or water and many species live as parasites or symbionts in the bodies of other animals. Some protozoans are colonial and in some colonies a division of labor occurs, accompanied by structural specialization of the individuals. Some species are very widely distributed.

Since the body of a protozoan is a single cell it has the subordinate structures of the cell in addition to other specialized parts. It contains one or more nuclei surrounded by cytoplasm. The body may be naked and

without permanent form or held in a definite shape by a delicate surface membrane called a pellicle Some species secrete a shell or test and some form internal hard parts

The structures which perform special functions are called organelles, since they resemble the multicellular organs of other animals in function but are simpler than the cell itself in structure. Among the more evident and important are the external organelles for locomotion and for securing food. In the various forms of protozoans these are **pseudopodia, cilia, flagella,** cirri, **membranelles, undulating membranes,** or **tentacles.** Some are associated with a depression in the surface of the body called the cytosome through which food is ingested Within the body the cytoplasm is differentiated into a clear layer of ectoplasm at the surface and an inner granular endoplasm containing the nucleus Here also masses of food with a little water form the food vacuoles in which digestion takes place. One or more pulsating or contractile vacuoles are interpreted as excretory organelles They fill periodically with clear liquid and then discharge Slender rodlike defensive structures, the trichocysts, lie in the ectoplasm of some species and are discharged when the animal is irritated

In the bodies of the species which carry on a type of nutrition like that of green plants colored bodies (chromatophores) containing chlorophyll are found in the cytoplasm These organisms have been interpreted both as plants and as animals, and have in reality some properties of each kingdom They and some of the parasitic species absorb dissolved foods and do not ingest solids

The protozoans reproduce commonly by the asexual process known as **fission** although sexual reproduction also takes place at intervals through the process of **conjugation.**

Protozoans are economically important chiefly as the causes of several serious diseases, among them amoebic dysentery, African sleeping sickness, and malaria

The phylum is divided into two subphyla and five classes as follows·

Subphylum **Plasmodroma. Cilia** never present.
- Class **Mastigophora.** Animals with **flagella.**
- Class **Sarcodina.** Animals which form pseudopodia
- Class **Sporozoa.** Usually incapable of locomotion as adults but sometimes able to form pseudopodia in immature stages

Subphylum **Ciliophora.** Ciliated either throughout life or when young.
- Class **Ciliata.** Always ciliated or with related organelles such as membranelles and cirri
- Class **Suctoria.** Cilia present only in immature individuals Adults with tentacles (A W L)

PROTRACTOR. A muscle that draws some part of the body forward (A W L)

PROTURA. Minute insects of very primitive form. The body is elongate Neither antennae nor eyes are present. The mouth is formed for sucking. There are three pairs of thoracic legs as in the insects, and a few rudimentary abdominal appendages Also named Myrientomata and variously considered as a class of **arthropods** and an order of the class **Insecta.** (A W L)

PROUSTITE. A silver-bearing **arsenical** mineral corresponding to the formula Ag_3AsS_3 sometimes with a little **antimony.** It rarely is found in **hexagonal** crystals, being usually in compact or disseminated masses or crusts It is a brittle mineral, hardness, 2 –2 5, specific gravity, 5 57–5 64, color, scarlet vermilion, luster adamantine sometimes very brilliant, streak, same as color; transparent to translucent It is found associated with **pyrargyrite.** Well known deposits occur in the Harz Mts, Bohemia, Chile and Mexico In the United States proustite has been found in Colorado, Idaho and Nevada. It was named for the famous French chemist, Louis Joseph Proust (E S C S)

PROXIMATE ANALYSIS. The proximate analysis of coal is the determination of moisture, volatile material, fixed carbon, and ash Much information regarding the firing characteristics and fuel value of coal will be conveyed by the proximate analysis. The ordinary engineer may perform a test for proximate analysis with a small amount of laboratory equipment For that reason it is useful for checking, from time to time, the quality of coal bought The proximate analysis is of little use in combustion calculations which are essentially chemical equations The chemical, or **ultimate, analysis** is required for that work (F T M)

PRUNE. Rose Family.

PRUNING. The removal of parts of a plant for the purpose of improving it in some desired way is called pruning Pruning may have as its aim the formation of a plant of more desirable shape It may be done to reduce the transpiring surface of the plant and so aid it in its struggle to survive when the available water supply is inadequate, a practice of particular value when plants are transplanted and much of the root system destroyed Pruning may be done to improve the product of the plant, whether flower or fruit, by throwing greater amounts of food materials into fewer branches Finally diseased or damaged portions may be removed to prevent spread of disease and further damage to the plant.

Plants growing in competition with one another naturally prune themselves. In a dense stand of pines, or other trees, increasing size causes decreased light to the lower branches Gradually the latter cease to grow and finally die and fall off, leaving the trunk straight and unbranched These dead branches usually remain on the tree for some time before falling

Artificial pruning may be done at any time, but is usually best done during the winter or early spring before active growth starts The wound made heals over by means of **callus** tissue which results from increased activity of the **cambium** cells When a large branch is removed, some time, often years, may be required before the wound is covered To prevent entrance of disease- and decay-producing organisms, the wound is generally covered with some antiseptic substance, such as white lead paint When branches are to be pruned, the cut should be made as close as possible to the main trunk and parallel to the surface of the latter, so that the cut surface may be covered as soon as possible by the callus tissue which forms around its edges Long stumps are rarely covered and usually lead to the development of diseased tissues (R M W)

PRURITUS. Intense itching, a symptom of many skin and some constitutional diseases Pruritus is found at times in the aged due to the degeneration of the skin It is also present in **jaundice.**

Pruritus of the anus is very common The causes of this rectal condition are many, such as **hemorrhoids,** fissure, various intra-abdominal disorders, local infection around the anus by **bacteria,** and by **parasites** and **fungi.** Another great group of anal pruritus falls into a vague neurogenic class which is very difficult to cure. (R S M)

PRUSSIAN BLUE. Ferrocyanic Acid and Ferrocyanides.

PSAMMITIC. Arenaceous.

PSEUDOACONITINE. Alkaloids.

PSEUDOBRANCHIA. A small respiratory structure on the inner surface of the **operculum** in certain fishes The pseudobranchiae serve as supplementary **gills.** (A W L)

PSEUDOEPHEDRINE. Alkaloids.

PSEUDO-HERMAPHRODITISM. Hermaphroditism

PSEUDOMORPHINE. Alkaloids.

PSEUDOMORPHS. In mineralogy, defined as minerals having the crystal form of one species and the chemical composition of another. Typical pseudomorphs are **malachite** in the form of **cuprite, barite** in the form of **quartz, limonite** in the form of **pyrite.** In such cases as these the evidence seems to be that there has been a complete chemical and molecular change but without any change of the original outward form. (R.M.F.)

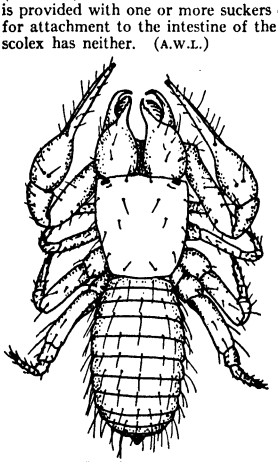
PSEUDOPHYLLIDEA. Cestoda.

PSEUDOPODIOSPORE. A form of reproductive body or spore produced by some of the one-celled animals. It is a naked cell like *Amoeba* and is able to form **pseudopodia.** Also called an amoebula. (A.W.L.)

PSEUDOPODIUM. A cytoplasmic protuberance formed at the surface of the body of one-celled animals, especially those of the class Sarcodina. Pseudopodia are temporary or semipermanent structures whose formation and retraction can be observed in many species during brief observation. They serve for securing food and as organs of locomotion.

Four types of pseudopodia are recognized. Lobopodia are temporary and relatively thick structures containing both ectoplasm and endoplasm. The common species of **Amoeba** form them. Filopodia are also temporary. They are more slender and usually contain only ectoplasm. Rhizopodia are temporary projections which branch and anastomose. Axopodia are very slender and usually straight radiating pseudopodia. They are semipermanent. This form is characteristic of the **heliozoans** and **radiolarians.** (A.W.L.)

PSEUDOSCOLEX. The anterior end of a tapeworm (**Cestoda**) which lacks a true **scolex.** The true scolex is provided with one or more suckers or a group of hooks for attachment to the intestine of the host. The pseudoscolex has neither. (A.W.L.)



Pseudoscorpion.

PSEUDOSCORPION. A small animal resembling the **scorpions** slightly in appearance. The abdomen is rounded and has no slender posterior part and no sting, but the pair of chelate pinchers at the anterior end of the body resemble those of the scorpions. Pseudoscorpions are commonly found in leaves at the surface of the ground and under the bark of decaying logs. They are only a few millimeters long. The relatively few species make up the order Chelonethida of the class **Arachnida.** (A.W.L.)

PSEUDOSCORPIONES. Synonym of Chelonethida. **Arachnida.** (A.W.L.)

PSEUDOSTIGMATIC ORGAN. A bristle, often clubbed at the tip and conspicuously large, which occurs in some of the **mites.** A pair of these structures arise from pits near the anterior end of the body. (A.W.L.)

PSEUDOTROPINE. Alkaloids.

PSEUDOVELUM. A narrow rim of tissue near the margin of the body of **jellyfishes.** These animals lack the true **velum** as found in hydrozoan medusae; the pseudovelum differs in its lack of muscle fibers and a nerve ring. (A.W.L.)

PSILOMELANE. Psilomelane is a massive black mineral of indefinite composition, being chiefly **manganese** oxide with various amounts of **barium, potassium** and **sodium** with water. It may be considered as **colloidal** manganese dioxide plus impurities. It is commonly associated with **pyrolusite** and is of secondary origin. Psilomelane is found in Saxony; France; Cornwall, England; India; Brazil and in the United States in Michigan. It is an ore of manganese. The word psilomelane is derived from the Greek words meaning smooth, and black, in reference to the smooth black surfaces so often exhibited. (E.S.C.S.)

PSITTACIFORMES. The **parrots** and related species, including **cockatoos,** macaws, **paraquets,** etc. The strong hooked beak, adapted for opening nuts and seeds, is the most conspicuous character of the group. Two toes are directed forward and two back. An order of the class **Aves.** (A.W.L.)

PSITTACOSIS (Parrot fever). A very contagious epidemic disease occurring chiefly in parrots but easily transmissible to human beings who handle infected parrots. Epidemics of this disease have been reported in Europe, South and Central America. Recently there have been outbreaks in various North American cities. In 1929 during one of the epidemics in the United States a filterable **virus** was isolated from patients and parrots who had contracted this disease. They were able, by using the virus, to transmit the disease from parrot to parrot.

The onset of the disease is sudden with chill, high fever, and malaise resembling influenza. Great weakness and mental depression are present. Convulsions may occur. Complications of the lung are frequent. The mortality rate varies in different epidemics but has been as high as 30 to 40%. There is no specific curative treatment. (R.S.M.)

PSOCID. Corrodentia.

PSORIASIS. A chronic inflammatory disease of unknown origin characterized by dry scaling patches of various sizes on the skin. The disease usually begins on the scalp and around the back of the elbow region. It may remain localized, disappear, recur or spread to other parts of the body. In most cases the patient is subject to recurrences through life. Most observers believe the cause to be parasitic.

There are numberless forms of treatment that in general is palliative only. Only occasionally the disease seems to arrest itself spontaneously. In many cases the lesions tend to disappear in the summer when the body is exposed to sunlight. (R.S.M.)

PSYCHALGIA. Pain of mental or hysterical origin. (R.S.M.)

PSYCHOANALYSIS. A method of eliciting from patients their past emotional experiences, dreams, and sub-conscious feelings to interpret and explain their present mental state or actions and use them for psychotherapeutic procedures. This form of treatment should only be used by an expert **psychiatrist.** (R.S.M.)

PSYCHROMETER. Hygrometers.

PSYLLIUM SEED. Plantains.

PTARMIGAN. Aves, Galliformes. *Lagopus.* Birds (**Aves**) related to the true grouse but with the feet and legs fully clothed with feathers. They are found in the far northern parts of Europe, Asia and North America and at high altitudes, above timber line, as far south

as Colorado They are largely mottled gray and brown in the summer but assume white plumage in winter The change is not, however, always complete but is somewhat conditioned by the climate The red grouse and the willow grouse or ripa of northern Europe are closely related to the ptarmigans (A W L)

PTERANODON. Cretaceous.

PTERASPIS. Fossil Fishes.

PTERICHTHYS. Fossil Fishes.

PTERIDOPHYTES. Ferns, and Paleobotany.

PTERIDOSPERMS. Paleobotany.

PTEROBRANCHIA. Hemichordata.

PTEROPOD. A marine mollusk whose foot is formed as winglike processes used in swimming These **mollusks** belong to the class **Gasteropoda.** (A W L)

PTEROPOD OOZE. Oceanic Deposits.

PTEROPSIDA. Members of the Pteropsida have large leaves, and definite gaps in the **vascular** cylinder, where a vascular strand, or leaf trace, passes from the **stele** to the leaf It is also characteristic of the Pteropsida that the **sporangia** are located on the lower surface of the leaf Most of the vascular plants of today, including all **ferns, gymnosperms** and **angiosperms,** belong to this group (R M W)

PTEROSAUR. Fossil Reptiles.

PTERYGOTA. One of two subclasses into which the class **Insecta** is divided The members of this subclass are either winged or closely related to winged forms Some show evidence of derivation from groups which are typically winged The great majority of insect orders belong here, only three falling into the suborder **Apterygota.** (A W L)

PTOLEMY (2nd Century A D) Other than that Ptolemy lived during the second century of the Christian era and that he lived in the vicinity of Alexandria and did his astronomical observing in that region, there is comparatively nothing known concerning his life There are certain Arabic traditions which give some account of the details of his life, but they can hardly be considered as biographical source material

Concerning the works of Ptolemy there is no question His writings and theories formed the scientific texts for more than 1300 years and were translated and transcribed many times Copies of practically all of his works are in existence at the present time Before we enter upon even a brief account of his writings it should be clearly understood that Ptolemy wrote collections of scientific works of his predecessors and included with them his own additions and conclusions In part cular we find that he copied a great deal of material from the writings of Hipparchus, and it is practically impossible to determine just what is the original work of Ptolemy and what is collected from Hipparchus and other writers

Certainly the best known of all of his writings is the so-called **Almagest,** certain of the astronomical features of which are covered elsewhere In the so-called syntaxes we find the astronomical work of Hipparchus described, including a discussion of the discovery of **precession.** In addition to a complete discussion of the observational work of Hipparchus on the five planets, we find Ptolemy himself propounding a theory explaining the motions of these objects The so-called Ptolemaic theory, which was the standard down through the next fourteen centuries, postulates that the sun is the center of the universe and that everything else revolves about it on concentric spheres The idea of the axial rotation of the earth, which was certainly hinted at by Hipparchus, Ptolemy abandons completely. The motion of the planets in simple circles did not represent Ptolemy's own observations with sufficient accuracy and he added to the fundamental spheres small spheres on which the planets moved, which spheres in turn rolled along on the fundamental spheres. This introduced the epicyclic type of motion to the planets which **Copernicus** challenged and attempted to remove by his heliocentric theory In the syntaxes we also find such astronomical subjects as the length of the **month** and the motions of the **moon** considered, together with descriptive chapters dealing with all of the then known astronomical objects and also a discussion of the **milky way.**

Space does not permit of more than a brief mention of Ptolemy's mathematical contributions In the ninth and tenth chapters of the first book of the Almagest we find the first written description of the modern method of dividing the circle into 360 parts and then subdividing each of these parts by a sexagesimal system. It must not be supposed that this idea was original with Ptolemy, in fact, we find traces of this same system in certain other far more ancient writings, but to Ptolemy goes the credit of first making a clear exposition of the method We also find the trigonometry of Hipparchus discussed and many improvements added, including the so-called Theorem of Ptolemy

The subject of geography owes much to Ptolemy The concept of the sphericity of the earth was well established and Eratosthenes, nearly three hundred years before, had attempted to determine the value of the radius of the sphere Ptolemy, with his familiarity with the use of the circle, developed the idea previously suggested by Hipparchus of representing the positions of points on this spherical earth by means of **latitude** and **longitude.** He constructed a general map of the world and departed from the traditional idea that beyond all the known lands was water, suggesting that there might well be "unknown land" He attempted to make flat maps of the spherical world developing a system of conical projection In his famous "Guide to Geography," Ptolemy discusses all of his theories regarding the methods of locating points on the earth and also includes a table giving the positions of various places in terms of latitude and longitude His atlas does not, however, enter upon any discussion of the geographical features of the different countries

In addition to the Almagest and the Guide to Geography, his two best known works, Ptolemy wrote a number of treatises on a great variety of subjects He developed various methods for making maps of the heavens using a type of stereographic projection In two different books he attempted to prove that there can be only three dimensions to space We find him writing a series of books on optics in which he develops a theory for **refraction** of light and discusses astronomical refraction in a manner that was not improved upon for over thirteen centuries He also wrote a five-book treatise on the general theory of music (W K G)

PTOMAINE. A class of **amines** formed by the action of **bacteria** or by **metabolism** of **amino-acids** which are broken down into toxic products (R S M)

PTOMAINE POISONING. A misnomer as generally used in describing gastric and intestinal disorders which are usually caused by food poisoning. No ptomaines are present in such disorders (R S M)

PTOSIS. (1) A weakness of the muscles of the eyelid causing it to droop over the eye (2) Falling of any organ or part due to lack of support of its ligaments or loss of fat around the organ (R S M)

PUBERTY. That period when the human reproductive organs begin to function This usually occurs between the twelfth and seventeenth years It is marked by development of secondary sexual characteristics, by the appearance of hair in the pubic, **axillary,** and facial

regions, development of the breasts, voice changes, seminal discharges of the male and menstruation in the female (R S M)

PUBIS. The anterior ventral bone in each half of the pelvic girdle of the vertebrates **Skeletal system.** (A W L)

PUDDINGSTONE. Conglomerate.

PUDDING WIFE. Pisces, Teleostei A marine fish (**Pisces**), *Iridio radiatus*, of the wrasse family (Labridae), found in warmer seas Also called the pudding fish and blue-fish (A W L)

PUFF-BALLS. Basidiomycetes.

PUFFIN. Aves, Charadriiformes Marine birds (**Aves**) of several species whose thick compressed beaks are almost as large as the head They are found on both sides of the Atlantic, nesting in northern latitudes and wintering south to New York and the Mediterranean Related species of the Pacific are commonly called shearwaters All belong to the genus *Puffinus* (A W L)

PUKU. Mammalia, Artiodactyla A moderately large African **antelope** with fairly long horns which curve forward and are ringed throughout their length (A W L)

PULASKITE. A variety of **alkali-syenite** containing soda-rich **orthoclase**, usually with **aegirite-augite** and biotite. The type locality is Pulaski County, Arkansas, whence the name (E S C S)

PULLEY. Machines.

PULMONARY DISEASES. Diseases of the lung The most common pulmonary diseases are **tuberculosis**, the various kinds of **pneumonia**, **bronchiectasis**, **silicosis**, abscess and **cancer** of the lung (R S M)

PULMONATA. Gasteropoda.

PULSE. The expansion and contraction of a blood vessel which may be felt, or in thin subjects, be seen The pulse is usually felt in the radial artery at the wrist, but it may be felt in any artery which lies near the surface of the body

With each beat or contraction of the heart a certain additional quantity of blood is forced into the arterial system Owing to the elasticity of the arterial wall this onrush of blood to the blood already there causes the vessels to distend As soon as the contraction of the **heart** (systole) stops, the elastic play of the vessel wall causes a recoil The elastic play of the artery lessens the strain on the heart, for if the heart had to pump blood through a system of rigid tubes, each beat of the heart would have to displace or dislodge an equivalent amount before the new amount could be accommodated within the vessel By distending the vessel wall, the extra amount of blood can be accommodated without fluctuation in pressure and flow Secondly, by the recoil action of the arteries the initial gliding force of the heart is continued through the resting period of the heart (diastole), so that blood escapes into the capillary system in a steady stream instead of by spurts

In hardening of the arteries (**arteriosclerosis**) a system of rigid or semi-rigid tubes does exist, as the arteries lose their elastic properties. This is the reason why the heart tires easily and also why high blood pressure is present A high blood pressure is needed to drive the blood through these non-elastic tubes

The frequency of the pulse varies in health but usually the rate lies between 70 and 78 beats per minute The rate is increased in illness, especially when accompanied by fever, and with exercise, emotion, fear, etc. The pulse in health is usually regular, the same time interval occurring between each beat In certain heart disorders not only is the rate disturbed but the interval between beats is irregular. In other conditions effecting the nerve conductive mechanism of the heart some of the impulses causing the heart to beat may be blocked and the rate is slower than normal

Besides rate and regularity of the pulse, much is learned from the feel of the pulse, such as its elasticity and volume or fullness In grave illness or surgical shock the pulse feels thin or thready from lack of volume, and is also very rapid

The term pulse is also used in physics. See **Vibrations and Waves** (R.S M)

PULVERIZED COAL. The burning of **fuel** in pulverized form has its advantages and its disadvantages, but present trends indicate a continually increasing use of pulverized **coal** as fuel costs rise, as supplies of the better grades of coal are exhausted, and as pulverizing practice becomes widespread The capacity for heat liberation in a pulverized coal furnace is not limited by the capacity of the burners, but by the inability of the **furnace** walls to resist the effects of high temperature, and by the limitations inherent in the physical characteristics of the ash Pulverized coal therefore can be selected for high capacity firing The combustion of pulverized coal is readily adaptable to automatic control, responding rapidly to control manipulation There is but little loss analogous to the banking loss of stoker fires High capacity **boilers** with their high exit gas temperatures require some heat saver such as the air preheater if they are to operate efficiently Pulverized coal firing utilizes preheated air to good advantage and without limitation of the preheated air temperature. Boiler room cleanliness is another asset of the pulverized coal installation

These advantages are not secured without some undesirable features Pulverized coal brings with it additional costs and complications of equipment Forty per cent of the finely divided flocculent ash would pass up the stack and spread itself upon the surroundings were not strenuous efforts made to precipitate most of it. More power is required than for stokers Low excess air and high capacity raise the temperature of the furnace to where it must be water cooled to avoid excessive refractory maintenance Low fusion point ash in particular must be carefully handled or else the boiler will be out of service for slag removal most of the time

The extremely small size of the coal particles must be realized A typical pulverized coal sample will have better than 99% through a 40 mesh screen, 90% through 100 mesh, and 65% through 200 mesh Two hundred mesh U S Standard means 200 openings to the inch, each opening being 0 0029 in One hundred mesh openings are 0 0059 inch each Thus, it can be seen that the particles are extremely small, and an enormously larger combustion surface is presented than with lump coal Hence, combustion occurs rapidly—from ¼ to 4 seconds is required with different fuels and burners

There are two pulverized coal systems, each having its own proponents claiming advantages outweighing those of the rival system In the opinion of the author, both will continue side by side in future power plant practice They are called the central system (bin system) and the unit system A central pulverizing system employs a limited number of larger capacity pulverizers at a central preparation point to prepare coal for all the burners The driers as well are conveniently installed at this preparation point From the pulverizers the coal is transported to a central storage bin where it is deposited and its transporting air vented through a "cyclone" The central bin will contain from 12 to 24 hours' supply. The coal is then transported from the central bin to secondary bins, each supplying a burner or group of burners through the medium of "feeders" of varied design. Primary air is added at the feeders.

The central system advantages are:

1. The pulverizing mill may work at nearly constant load because of the storage capacity between it and the burners.

2. The large storage is a protection against interruption of fuel supply to burners
3. Good control of coal fineness
4 More latitude in the arrangement and number of burners is allowed the designers
5. The boiler aisles are unobstructed

Its disadvantages are.

1. Additional cost and complexity of a coal transportation system
2 Central preparation may require a separate building
3. Driers are usually necessary.

The unit system is so called from the fact that each burner, or burner group, and pulverizer constitute a unit Crushed, and sometimes dried, coal is fed to the pulverizing mill at a variable rate governed by the combustion requirements of the boiler and furnace Preheated primary air is admitted to the mill and is the transport air which carries the coal through the short delivery pipe to the burner

The advantages of this system are

1 For moderate numbers of burners it is cheaper than the central system
2 It allows direct control of combustion from the pulverizer
3 Coal which would require drying to function satisfactorily in the central system may often be used successfully without drying
4. In a replacement of stokers, the old conveyor and bunker equipment can be used
5 There is no complex transportation system
6 With mobility provided, one pulverizer can serve as standby for the entire installation

Its disadvantages are:

1 The mills operate at variable load, a condition that is conducive neither to economy nor good pulverization
2. With load factors in common practice, the total mill capacity must be more than for central systems
3 Firing aisle is filled with pulverizing equipment.

The pulverizing mills of present design may be classified as (1) impact mills in which a series of swinging hammers or falling balls pulverize the coal, (2) roller mills in which grinding is done by crushing between rollers or balls and a race, (3) chopping or attrition mills.

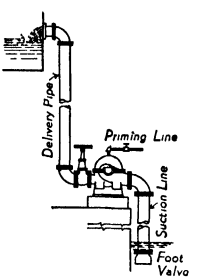
Pulverized coal can be transported mechanically or pneumatically Screw conveyors are generally short, straight, and horizontal The pneumatic system offers more flexibility The air pressure system is one of intermittent delivery, suitable for transporting from bin to bin. In the air mixture system primary air, representing a weight several times that of the coal, is mixed with the coal and carries the coal along in suspension. The air pumping system uses much less air, only enough to render the coal sufficiently fluid to be pumped by pumps

Type of burners depends on fineness of coal, moisture and volatile content, method of mixing air and fuel, percent total air as primary, and characteristics of the furnace There are two general types of burners, the long and the short flame. The long flame is produced by moderate-tip velocities coupled with an admission of secondary air through openings in the setting located along the traverse of the flame These long flame burners are generally in multiple, directed vertically downwards into the furnace Short flame burners are ordinarily set in horizontal position A short flame burner produces complete mixture just beyond the burner tip by violently whipping the secondary air through the primary air and fuel. (F T.M.)

PUMA. Mammalia, Carnivora. A large North American cat of uniform tawny to brownish color. The puma proper, *Felis concolor*, is—or was—a species of the eastern half of the continent, ranging from Virginia into Canada It is now extinct in the settled parts of the country but may still exist in wilder areas A darker species, *F coryi*, is found in Florida, a third species, *F arundivaga*, in Louisiana, and a fourth variable species called the western puma or mountain lion, *F oregonensis*, ranges from Mexico into Canada The eastern species has been variously called the cougar, mountain lion, panther, catamount, and painter. It is a menace to stock and sheep but is cowardly in its relations with man (A W L)

PUMICE. Rhyolitic lavas with a high gas content will often form a molten froth which on chilling produces a remarkably vesicular rock, light enough to float on water, called pumice When ground, mixed with an appropriate binder and pressed into cakes it is the "pumice stone" of commerce which is used as a light abrasive (E S C S)

PUMP EFFICIENCY. The static **head** is the height (usually in feet) of the surface of the water above the gage point. The pressure head is the static head plus gage pressure on the water surface plus friction head, all being reduced to the same unit of pressure Velocity head is the head required to produce a flow of water The dynamic head is the pressure head plus the velocity head Except for water velocities considerably above average, or for large volumes handled at low heads, the velocity head can be neglected For water at atmospheric temperature, 8 33 pounds = 1 U S gallon = 231 cubic inches, also 2 31 feet head of water = 1 pound per square inch pressure Hot water weighs less If the suction head is less than atmospheric, it is given a minus sign When the suction arrangement is as shown in the accompanying figure, the suction head = — (static head + velocity head + suction pipe and fittings friction loss + loss at entry to suction pipe (which is usually taken at $\frac{1}{2}V^2/2g$)).



Pump with vacuum suction.

Hydraulic efficiency

$$= E_h = \frac{\text{operating head}}{\text{operating head} + \text{pump head losses}},$$

Overall pump efficiency

$$= E_p = \frac{\text{water horsepower}}{\text{drive horsepower}},$$

Mechanical efficiency

$$= E_m = \frac{\text{theoretical pump head} \times \text{capacity}}{\text{drive horsepower}},$$

$$E_p = E_h \times E_m. \qquad \text{(F T M)}$$

PUMPKIN. *Cucurbita pepo* **Gourd Family.**

PUMPKIN-SEED. Pisces, Teleostei The common **sunfish**, *Eupomotis gibbosus* A pond fish of the eastern and north central states, found also to a limited extent in streams. A good pan fish. (A W.L)

PUMPS. The function of a pump is to add to the pressure existing in a gas or liquid an increment sufficient for the required service This service may be the production of a velocity, or the overcoming of friction or external pressure. One of the earliest types of pump

to be used was the suction or lift pump (Figure 1). The upward movement of the piston *P* lowers the pressure in the cylinder and pipe below it, and the liquid is forced up into this space by the atmospheric pressure On the down-stroke, the valve V_1 closes, imprisoning the

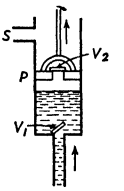


Figure 1
Suction or lift pump.

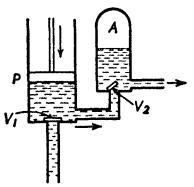


Figure 2
Cylinder force pump

liquid in the cylinder; while the piston valve V_2 opens, allowing the piston to plunge into the liquid and draw it up on the subsequent up-stroke, so that it can escape through the spout *S*. An ordinary cistern pump is of this type.

Another elementary type of pump is the cylinder force pump (Figure 2). In this the first operation is the same as in the lift pump There is, however, no valve in the piston, but instead one in the outlet at the side of the cylinder, opening outward, so that the down-stroke forces the liquid out against a pressure limited only by the force available to operate the piston Such pumps usually have an air-chamber *A* to equalize the outflow of liquid

Power pumps are generally classed as follows.

A Reciprocating pumps
- 1 Direct acting steam, simplex and duplex.
- 2 Power, single acting simplex and triplex.

B Centrifugal pumps
- 1 Single and multi-stage
- 2 Volute and turbine types

C. Rotary pumps
- 1 Gear and screw pumps (mostly used for pumping oil)
- 2 Propeller pumps.

D Jet pumps
- 1 Steam jet injectors and ejectors
- 2 Water jet ejectors

Essential data relating to any pump include the head in feet, capacity in gallons per minute, and properties of the liquid such as viscosity, temperature, corrosiveness, grittiness Secondary data concerning the pump equipment are speed of rotation, power required, and first cost

The **direct-acting** steam pump is a simple, inexpensive, and reliable piece of equipment—but inefficient as a pumping unit. However, as the heat of the exhaust steam can often be recovered in the feed water the low thermal efficiency is not of much importance

Pumps driven by electric motors, or by steam used expansively, are called power pumps Their overall efficiencies are high because of the efficient drives The triplex pump is often used when the conditions indicate the reciprocating pump in preference to the centrifugal, and where an efficient pumping unit is required Calling *n* the number of pumping strokes per minute, $D \times S$ the diameter $\times$ stroke, and *E* the volumetric efficiency of the pump (about 90% for pumps in good order) the

$$\text{Capacity} = \frac{ESnD^2\pi}{4 \times 231} \text{ gallons per minute.}$$

The **centrifugal pump** is a velocity machine, that is, its pumping action requires first, the production of a water velocity, second, the conversion of velocity **head** to pressure head The velocity is given by the rotating impeller, the conversion accomplished by diffusing guide vanes in the turbine type, and in a volute casing surrounding the impeller in the volute type With few exceptions, all single-stage pumps are of the volute type

The injector is limited to regular service on small boilers and stand-by service on small and medium-sized boilers Like the centrifugal pump, the injector operates on the principle of a velocity-pressure conversion but differs from the centrifugal in the manner of creating the velocity The water acquires its velocity by impact with high-velocity steam leaving an expanding nozzle The injector will produce a pressure about 50 pounds per square inch higher than the steam pressure used, but the water temperature should not exceed 150° F The injector is simple, compact, inexpensive, and with no moving parts to wear or require adjustment As a combined feed-water heater and pump its efficiency is high, but, as a pump alone, very low (less than 5%). Its characteristics recommend it to locomotive service but not to regular service in an efficient stationary plant where feed water is heated by other than live steam.

The selection of any pump is to be made with due regard to the drive Reciprocating pumps are slow-speed machines, centrifugal pumps high-speed Power pumps and centrifugal pumps require a driving motor, engine, or turbine Variable capacity is obtained by throttling the discharge or changing the driver speed

Mistakes are liable to be made in pump installation by overestimating the possible suction lift For instance, suppose water is at 140° F It is found, from steam tables, that water will begin to produce steam at this temperature as soon as the pressure is reduced to 2 887 pounds per square inch Hence, the theoretical maximum static head is 2 31 (14 7–2 887), or 27 feet But, under dynamic operating conditions, steam would be formed at this lift To be safe against steam binding and separation of the water column, the maximum suction head should be limited to 15 feet for the centrifugal, and 22 feet for the reciprocating pump when pumping cold water, these values to be uniformly decreased to zero lift as the water temperature increases to 160° F Hot water above 160° F should be supplied under a positive head—at 200° F there should be from 5 to 10 feet head on the pump Pumps, especially centrifugal, must be filled with water when starting under considerable suction head A foot valve on the suction intake, if tight, will retain water in the pump, but the foot valves frequently leak slowly if the water contains grit or debris To prime the pump a check valve by-pass line is satisfactory if there will always be water against the check valve, otherwise an independent fill line can be run to the pump Steam jet ejectors and other vacuum equipment are often used to prime large pumps (F T M)

PUNKIE Insecta, Diptera. Small biting **midges**, also called sandflies They are found in abundance at certain times along streams in the eastern mountains, and at some parts of the seashore. (A.W L)

PUPA. The third stage of **insects** with complete **metamorphosis.** The pupa is a more or less inert stage but in some insects it retains the power of locomotion to a high degree The pupae of mosquitoes are an example, they swim as freely as the larvae when disturbed In contrast the pupae of butterflies and moths can merely move the abdominal segments and those of many flies are quite rigid Among these inactive pupae some, like those of the **beetles** and **wasps,** have the legs and wings free and are called exarate Others have the appendages closely attached to the body and are said to be obtected Those of **Diptera** in some cases are enclosed in a hardened larval skin, the puparium, and are called coarctate pupae The pupae of butterflies, often brightly colored and strangely shaped, are called chrysalids (singular, chrysalis or chrysalid). (A W L)

PUPIL. The opening in the center of the iris of the **eye** for transmission of light. The normal pupil is cir-

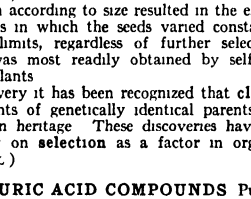
cular and regular in outline and is larger in the young than in adults Both pupils should be of the same size They become smaller in bright light and when looking at nearby objects, and larger in darkness and upon looking at distant objects The characteristics of the pupil, that is, size, quality, and reaction, are of considerable value in the diagnosis of various diseases of the nervous system In certain forms of late syphilis such as locomotor **ataxia** and **paresis,** pupils do not dilate or contract and may be irregular and unequal in size When **morphine** is given the pupils contract and with large doses the pupil becomes pin point in size **Belladonna** or **atropine,** and **cocaine** dilate the pupil (R S M)

PURE CHEMISTRY. Chemistry.

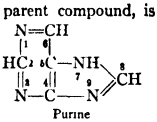
PURE LINE. The descendants of a single self-fertilized individual The term was established by the botanist, Johanssen, in his work with beans He found that rigid selection according to size resulted in the establishment of strains in which the seeds varied constantly between certain limits, regardless of further selection This constancy was most readily obtained by self-fertilization of the plants

Since this discovery it has been recognized that **clones** and the descendants of genetically identical parents are equally uniform in heritage These discoveries have an important bearing on **selection** as a factor in organic **evolution.** (A W L)

PURINE AND URIC ACID COMPOUNDS Purine compounds are derivatives of the dicyclodiureide of **malonic** and **oxalic acids** The dicyclodiureide compound is uric acid



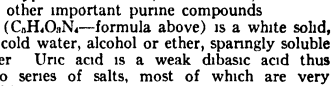
and purine, the parent compound, is



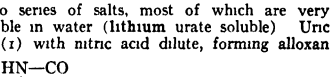
Purine

so that uric acid is 2,6,8-trioxypurine or the keto form of 2,6,8, trihydroxypurine Caffeine, theobromine, and theophylline are other important purine compounds

Uric acid ($C_5H_4O_3N_4$—formula above) is a white solid, insoluble in cold water, alcohol or ether, sparingly soluble in hot water Uric acid is a weak dibasic acid thus forming two series of salts, most of which are very slightly soluble in water (**lithium** urate soluble) Uric acid reacts (1) with nitric acid dilute, forming alloxan

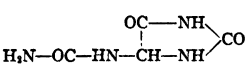


plus urea

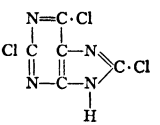


more vigorous treatment yielding oxalyl urea

plus **ammonia** plus **carbon dioxide.** The murexide test for uric acid is related to this reaction Uric acid plus **nitric acid** dilute is evaporated to dryness, yielding red residue, which with **ammonium** hydroxide turns purple or with **sodium** hydroxide blue, (2) with **potassium** permanganate in sodium hydroxide solution, forming allantoin



(3) with **phosphorus** oxychloride, forming 2,6,8-trichloropurine



and 2,6-trichlor-8-hydroxypurine In these compounds chlorine may be replaced by such groups as methoxy (CH_3O—), ethoxy (C_2H_5O—), hydroxyl (HO—), hydrosulfide (HS—), iodide (I—), hydrogen (H—), and thus many derivatives are obtainable

Uric acid is found in the urine, blood, and muscle juices of carnivorous animals (herbivorous animals secrete hippuric acid), in the excrement of birds, serpents and insects, and is an oxidation product of the complex nitrogenous compounds of the animal organism

The following are other important purine compounds, which are also **alkaloids.**

1	Caffeine (theine)	1,3,7-trimethyl-2,6-dihydroxypurine
2	Theobromine	3,7-dimethyl-2,6-dihydroxypurine
3	Theophylline	1,3-dimethyl-2,6-dihydroxypurine
4	Xanthine	2,6-dihydroxypurine
5	Hypoxanthine	6-hydroxypurine
6	Guanine	2-amino-6-hydroxypurine
7	Adenine	6-aminopurine

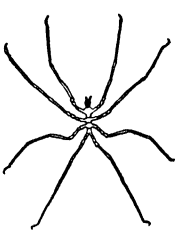
Caffeine is present in tea leaves (2 to 5%) in coffee beans (0 75 to 1 75%), in cola beans (Soudan coffee) (1 to 2 5%), in cocoa beans (0 1 to 0 8%), theobromine in cocoa and cola beans, in small amount in tea leaves, and absent from coffee beans, xanthine in beet root juice, in tea leaves, and in sprouting seeds, hypoxanthine and guanine in beet root juice and in tea leaves (R K S)

PURPURA. A condition of unknown cause characterized by localized hemorrhages into the skin and mucous membranes This condition may occur as a symptom of many diseases, may be seen in old age, and in deficiency of **vitamin** C in the diet Some cases seem to be on an **allergic** basis, there being present sensitivity to some **protein.** Still others may be due to a disorder of the **endocrine gland** system

In another group of the purpura cases—thrombocytopenic purpura—there is great diminution of the **blood** platelets and **anemia** is usually present In the acute form the course may be short and fatal, although recovery may take place In the chronic form, removal of the **spleen** has a beneficial effect, possibly curative, although sufficient time has not passed since the operation was first recognized as suitable for this disorder, to judge Blood transfusion, liver and iron therapy, are used with advantage (R S M)

PUS. The liquid product of infection in the body It is made up of cellular debris, micro-organisms, and white **blood** cells (leukocytes) Pus varies greatly in color, consistency and odor When pus is present as a localized collection in tissue, an abscess is said to be present Treatment is incision and drainage of the abscess (R S M)

PUSULE. A large vacuole opening to the exterior by a canal It is found in the body of some of the one-celled animals of the order Dinoflagellida (**Mastigophora**) (A W L)



Sea spider

PYCNOGONIDA. The sea spiders, a small number of species constituting a class of **Arthropoda.** All are marine, crawling about on plants and sessile animals The body is very small and the legs very long, hence the

animals seem like clusters of legs attached to each other. They have a sucking mouth. (A W L)

PYCNOMETER. A device for measuring densities of liquids It is a container, usually in the form of a bottle or a pipette-like tube, the capacity of which is accurately known and which may be completely filled with the liquid The difference in weight when filled and when empty, together with the known volume of the liquid, gives the density The pipette form has a mark to show how far to fill it, and is bent into a V shape to facilitate immersion in a temperature bath A familiar design is the "specific gravity bottle," a small flask with a ground and perforated stopper, and sometimes provided with a thermometer In one of the most precise forms the stopper has a conical top with the capillary leading to the apex, and both neck and stopper are covered by a tight-fitting ground glass cap to prevent evaporation

A preliminary step necessary to precise work with the pycnometer is the determination of its two volume constants, that is, the constants of the linear equation expressing the capacity as a function of the temperature This is done by filling with distilled water and weighing accurately several times at each of two temperatures near the ends of the range for which the pycnometer is to be used The bottle form is also adapted to the precise measurement of densities of solids (See **Density and Specific Gravity.**) (L D W)

PYELITIS An infection of the pelvis of one or both of the **kidneys** The cause of this disease is invasion by **bacteria**, the colon bacillus being most common Infection may occur from the blood stream Normally the kidney can eliminate many forms of bacteria from the body without infection of the kidney structure In certain instances exposure to cold, lowering of the resistance, due to respiratory infections and fevers, cause infection in the kidney Certain local causes in the pelvis of the kidney predispose to pyelitis, such as the presence of kidney stones or stasis, due to obstruction to the flow of urine at any point in the urinary tract In pregnancy pyelitis is common due to pressure of the enlarged **uterus** on the **ureters** Infection of the kidney may also occur by the ascending route, spreading upward from the urinary tract below the kidney as from a **cystitis** or infection of the urinary bladder

The symptoms of acute pyelitis are usually of sudden onset with high "spiking" fever, chills, pain in the side, and severe constitutional symptoms The urine is cloudy with many pus cells The acute symptoms may subside rapidly with early treatment or the disease may run a chronic course or complications may develop The complications of pyelitis are usually quite serious and may require surgery

Pyelonephritis With this complication infection spreads to the kidney tissue (kidney abscess) if on one side only, surgical removal of the infected kidney is usually necessary The symptoms are those of severe sepsis

Pyonephrosis Dilation of the pelvis of a kidney with pus This usually occurs when there is an obstruction to the urinary flow as with a stone or tumor formation. Operation with removal of stone or kidney may be required

The treatment of pyelitis is best carried on in a hospital as in the acute cases the patient is quite ill. Antiseptic drugs are given, irrigations, **cystoscopy**, x-rays and possible surgery may be necessary in the diagnosis and treatment of a sometimes stubborn case. (R S M)

PYELOGRAM. A diagnostic **x-ray** picture of the **kidney** and **ureter.** This is done by one of two methods In one, opaque fluid is injected upward through fine catheters inserted into the ureters, after a **cystoscope** has been passed into the bladder. With the other method a dye is injected into the blood stream This is secreted by the kidney and the dye shows up the urinary passages when the x-ray is taken (R S M)

PYGIDIUM. 1 The united caudal segments of the extinct **trilobites**, a group of **arthropods** ancestral to the insects 2 A caudal portion of the body of some scale insects made up of four fused segments 3 The terminal segment of the abdomen of a **beetle** when exposed beyond the elytra (See **Invertebrate Paleontology**) (A W L)

PYLORUS. The narrow muscular passage from the stomach into the **duodenum.** The pylorus is under a complex nerve control and food can only pass from the stomach when this muscular **sphincter** relaxes It is in the immediate vicinity of the pylorus that **ulcers** most frequently occur Ulcer formation or **cancer** in this location may obstruct the passage of food through the pylorus and make surgical interference imperative. (R S M)

PYORRHEA. A discharge of pus Pyorrhea of the alveolaris is a chronic infection of the dental **periosteum** around the roots of the teeth The disease originally starts as an infection of the gum margins Altogether there have been some 350 theories of the cause and etiology of pyorrhea Probably the theory of choice is that of **vitamin** deficiency, but other factors are probably involved with it, such as lack of exercise of the gums, modern soft diet, with resulting poor circulation in the gums, mechanical injury to the gums from brush cleaning of the teeth, and certain **glandular** deficiencies especially related to the utilization of **calcium, phosphorus,** etc The debilitating conditions, poor health, and **anemia** also play a part (R S M)

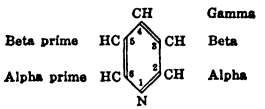
PYRARGYRITE. An **antimony**-bearing **silver** mineral corresponding to the formula Ag_3SbS_3 It crystallizes in the **hexagonal** system, commonly in **rhombic** prismatic forms It displays a rhombohedral **cleavage**, fracture, conchoidal to uneven, brittle, hardness 2 5, specific gravity 5 77–5 85, luster, metallic, color, grayish black to black In thin fragments deep red by transmitted light, otherwise practically opaque, streak purplish red Pyrargyrite occurs with **proustite**, other silver minerals, and **galena, sphalerite,** etc It is found in the Harz Mountains, in Czechoslovakia, Bolivia, Chile, Mexico, and in the United States in Colorado, Idaho, and Nevada In Canada it is found in the Cobalt region of the Province of Ontario It derives its name from the Greek words meaning fire and silver (E S C S)

PYRHELIOMETER. The pyrheliometer is an instrument designed for the purpose of measuring the radiation from the sun In the instrument the radiation from the sun of all wave lengths is transformed into heat and then measured in calories The earliest form, devised by Pouillet in 1838, was essentially a water **calorimeter** with one blackened external surface exposed to the sun's rays Tyndall improved the apparatus by using mercury instead of water, mercury having a much lower **specific** heat The Smithsonian Institution developed a form using a solid silver disk as the body to be heated by the solar radiation and measuring the rise in temperature by a very sensitive **thermometer**

More recently an instrument employing the **blackbody** cavity principle has been perfected The radiation is allowed to enter a long cylinder terminating in a hollow cone, in which it is almost completely trapped, and the calorimeter water circulates around the cylinder walls The whole is enclosed in a Dewar flask or "thermos bottle" for insulation. This somewhat elaborate form has been used chiefly as a standard for calibrating the more convenient silver disk pyrheliometer (L D.W., W K G)

PYRIBOLE. A convenient term for the **hornblende** and **pyroxene** groups of dark minerals which are easily distinguishable with the naked eye from the black **mica**, biotite, but not from each other, when they occur in a fine-grained rock (R M F)

PYRIDINE AND RELATED COMPOUNDS. Pyridine, monazine (C_5H_5N), contains a ring of 1 nitrogen and 5 carbons with 1 hydrogen attached to each carbon·



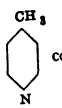
Pyridine is a colorless liquid, boiling point 115° C, of unpleasant odor, miscible in all proportions with water, alcohol, or ether, forms salts with acids, the **perchlorate** and **ferrocyanide** sparingly soluble in water and used in the separation and identification of pyridine, reacts only under drastic conditions with **chlorine**, **bromine**, **sulfuric acid** (forms beta-pyridine sulfonic acid at 300° C with concentrated sulfuric acid), non-reactive with **nitric acid**, **chromic acid**, **potassium** permanganate Pyridine may be reduced by **sodium** and **alcohol** to piperidine (below), and by heating with **hydriodic acid** to normal-pentane Pyridine is obtained in the destructive distillation of fat-containing bones—in Dippel's oil—and in small proportions in the similar distillation of coal, peat, carboniferous shales, wood, and in the treatment of various **alkaloids** with **alkalis**, or when they are heated alone or with zinc dust Pyridine may be detected by the appearance of a red color on addition, to the aqueous solution, of a trace of cyanogen bromide and a few drops of aniline Pyridine is used as a solvent, especially in the purification of **anthracene**, and as a denaturant of **ethyl alcohol**

Picolines and pyridine carboxylic acids Alpha-picoline, alpha-methylpyridine, 2-methylpyridine

colorless liquid, boiling point 128° C, on oxidation yields picolinic acid, pyridine-alpha-carboxylic acid, sublimes 135° C

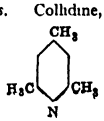
Beta-picoline, beta-methylpyridine, 3-methylpyridine

colorless liquid, boiling point 144° C, on oxidation yields nicotinic acid, pyridine-beta-carboxylic acid, sublimes 228° C

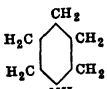
Gamma-picoline, gamma-methylpyridine 

colorless liquid, boiling point 143° C, on oxidation yields isonicotinic acid, white solid, melting point 300° C

Lutidines Six dimethylpyridines and three ethylpyridines are known

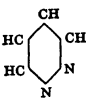
Collidines. Collidine, symmetrical-trimethylpyridine (2,4,6), is 

colorless liquid, boiling point 172° C Other isomerides numbering 21 are theoretically possible.

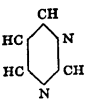
Hexahydropyridine, piperidine 

colorless liquid, boiling point 106° C, miscible in all proportions with water, alcohol, ether, or benzene, is formed by the action of sodium and alcohol on pyridine Piperidine may be obtained by treatment of the **alkaloid** piperine of the pepper plant, by heating with **alkali**.

Azines When **carbons** of pyridine (monazine) are replaced in succession by **nitrogen**, polyazoles are formed, thus.

Orthodiazine (pyridazine) 

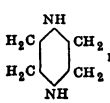
colorless liquid, boiling point 205° C (755 mm).

Metadiazine (pyrimidine) 

melting point 21° C, boiling point 124° C This nucleus is contained in purine compounds and cyclic ureides Derivatives of pyrimidine are of great importance in physiological processes, e g, 5-methyl-2, 6-dihydroxypyrimidine (thymine) of the **cell** nucleus

Paradiazine (pyrazine)

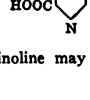
melting point 55° C, boiling point 115° C, of agreeable odor

Reduction of pyrazine yields hexahydropyrazine (piperazine) 

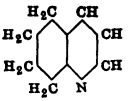
melting point 104° C, boiling point 145° C, soluble in water, and strongly basic

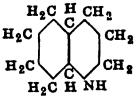
Quinoline and isoquinoline are benzopyridines (C_9H_7N)

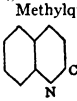
Quinoline

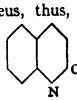
is a colorless liquid, boiling point 238° C, of characteristic odor, slightly soluble in water, miscible with alcohol, ether, and many organic liquids in all proportions, forms **salts** with **acids**, the dichromate sparingly soluble in water, reacts with concentrated sulfuric acid by sulfonation of the **benzene** nucleus, with nitric acid with difficulty (5-nitroquinoline and 8-nitroquinoline), with **chromic** acids in sulfuric acid not reactive, with **permanganate** forms quinolinic acid 

melting point 192° C., plus oxalic acid. Quinoline may be reduced to tetrahydroquinoline

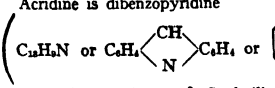


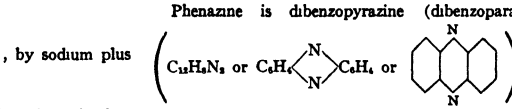
boiling point 245° C, by sodium plus alcohol, or zinc plus hydrochloric acid, and to decahydroquinoline  solid, melting point 48° C, boiling point 204° C, by **hydriodic acid** and **phosphorus** heated Quinoline is found in bone oil and coal tar, and is produced by distillation of many **alkaloids**, e g, cinchona alkaloids The classical synthesis of quinoline by Skraup is the reaction of aniline plus **glycerol** (CH_2OH CHOH CH_2OH), using **nitrobenzene** in **sulfuric acid** heated as oxidizing agent

Methylquinolines are quinaldine, 2-methylquinoline  boiling point 247° C, lepidine, 4-methylquinoline boiling point 257° C When either of these is treated with ethyl iodide plus ethyl orthoformate in the presence of pyridine, cyanine compounds are formed Cyanines are dyes used in color photography

Carboxylic acids of quinoline are of two types, (1) those where the carboxyl group (—COOH) is attached to the **benzene** nucleus These can be made by the Skraup method using the desired aminobenzoic acid, (2) those where the carboxyl group is attached to the pyridine nucleus, thus, quinoline-2-carboxylic acid, quinaldinic acid  melting point 156° C, quinoline-4-carboxylic acid, cinchoninic acid melting point 254° C, 6-methoxyquinoline-4-carboxylic acid, quininic acid melting point 280° C (decom).

Isoquinoline white solid, melting point 23° C, boiling point 243° C, forms salts with acids, the sulfate sparingly soluble in water Isoquinoline is important as a constituent of certain vegetable **alkaloids.**

Acridine is dibenzopyridine  white solid, melting point 108° C, boiling point 346° C

Phenazine is dibenzopyrazine (dibenzoparadiazine)  yellow solid, melting point 171° C, from which important dyes, e g, safranines, are derived

Phenoxazine is white solid, melting point 148° C

Where **nitrogen** of pyridine is occupied by **oxygen**, pyrone is the compound, and where occupied by **sulfur**, penthiophene, similarly, where nitrogen of quinoline by oxygen chromone is the compound, and where by sulfur, thionaphthalene, and where nitrogen of acridine by oxygen, xanthene, and by sulfur, thioanthracene

Compounds containing 1 (or more) nitrogens and 4 (or less) carbons in the ring (5-membered) are discussed under **Pyrrole and Related Compounds** (R K S)

PYRIFORM GLAND. Glands of the **spiders** which secrete silk for the formation of the disks by which threads are anchored (A W L)

PYRIFORM ORGAN. An organ of unknown function found in the Cyphonautes **larvae** of **bryozoans** (A W L)

PYRITE. The mineral pyrite or iron pyrites is **iron disulfide**, FeS_2, its **isometric** crystals usually appearing as cubes or **pyritohedrons** It has a slightly conchoidal to uneven fracture, brittle, hardness, 6-6 5, specific gravity, 4 95-5 10, metallic luster, color, pale to normal brass yellow, streak, greenish black, opaque **Arsenic, nickel, cobalt, copper,** and **gold** may be found in small quantities in pyrite, auriferous pyrite being sometimes a very valuable ore Pyrite is the commonest of the sulfide minerals, and is of world-wide occurrence It is found associated with other sulfides, or with oxides, in **quartz** veins, in **sedimentary** and **metamorphic** rocks, in coal beds, and as the replacement material in **fossils** There are many well-known pyrite localities, among which are the Rio Tinto mines in Spain, where copper-bearing pyrite is obtained from huge deposits. In the United States pyrite is found in California, New York, and Virginia in workable deposits Pyrite is used in the production of sulfur dioxide for the paper industry and the making of sulfuric acid Its use seems to be on the wane because of the cheapness of Louisiana sulfur By-product pyrite, obtained from coal, however, is a commercial source of sulfur dioxide in the Illinois region The name pyrite is derived from the Greek word meaning fire, because of the sparks which result when pyrite is struck with steel (E S C S)

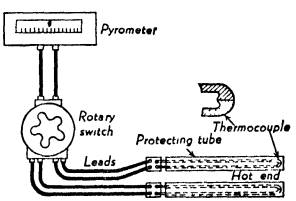
PYROCLASTS. A general term for fragmental, volcanic ejectamenta such as **agglomerates,** ashes and **tuffs** (R M F)

PYROGENETIC MINERALS. A term for the primary **magmatic** minerals of **igneous rocks** as distinguished from those minerals which are the result of special and later processes such as come under the head of pneumatolytic, hydrothermal, etc (R M F)

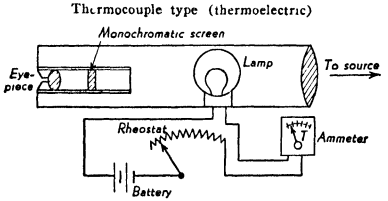
PYROLUSITE The mineral pyrolusite, **manganese** dioxide, MnO_2, appears to be **orthorhombic,** but may be only **pseudomorphous after manganite** It is found massive or in indistinct crystalline aggregates, often acicular. It is soft, hardness 2-2 5; specific gravity 4 73-4 86; luster, metallic; color, steel gray to black, streak black; opaque Pyrolusite is found as replacement deposits and as residual and sedimentary masses.

Psilomelane is its usual associate European localities for pyrolusite are in Bohemia, Saxony, the Harz Mountains, England, and elsewhere. Other deposits occur in India and Brazil In the United States it is found in Arkansas and Michigan It is an ore of manganese, is used as a pigment and as an oxidizing agent in glass manufacture It is from this latter use that it derives the name pyrolusite from the Greek words meaning *fire* and *to wash* (E S C S)

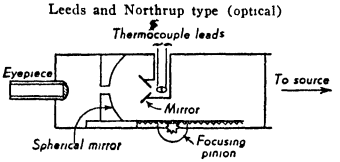
PYROMETER. By common usage, the pyrometer is the device for measuring high temperatures Actually, there are pyrometers which are much used for measuring temperatures in the same range as thermometers, but several of the pyrometers are suitable only for high temperatures Three types of pyrometers are described as being typical of the entire group These are (1) the thermoelectric (See **Thermel**) pyrometer, (2) the **optical pyrometer;** (3) the **radiation pyrometer.** (A fourth type, the **resistance pyrometer,** is not commonly used for high-temperature industrial work)



Thermocouple type (thermoelectric)



Leeds and Northrup type (optical)



Fery type (radiation)
Pyrometers

The thermocouple pyrometer is a convenient meter for measuring a number of high-range temperatures By means of the rotary switch shown in the diagram a number of thermocouples may be connected in turn to the indicator The thermocouple is a pair of electrical conductors of different material permanently joined at one end, the other ends being free to connect to an instrument for measuring electromotive force The indicating instrument is essentially a potential **galvanometer** measuring e m f 's of the magnitude of 50 to 70 millivolts The thermocouple itself is delicate and is enclosed in a protecting tube

An optical pyrometer, as the diagram shows, is one in which the eye compares the radiation emanating from an incandescent object whose temperature is to be measured, with that of a filament electrically heated in the tube of the pyrometer By interposing between the eye and the hot body a red glass screen, monochromatic light is received by the eye The current to the bulb is adjusted by rheostat until the intensity of emission from the filament exactly equals that from the light source It is readily possible to make this adjustment, as with monochromatic light received both from the hot body and the filament, the filament appears black against the image of the hot body when the filament temperature is lower than that of the hot body, white when it is higher than that of the hot body, and disappears when the temperature is the same In use, the pyrometer is pointed at the hot body, which is viewed through the eyepiece The pyrometer is held in one hand, and the rheostat manipulated by the other until the filament disappears against the background A sensitive **ammeter,** which measures the current flowing in the filament circuit, is calibrated directly in degrees of temperature

Total radiation pyrometers are equipped with a mirror which concentrates energy received by radiation from the source upon a thermocouple This thermocouple is connected to a measuring instrument in a manner similar to that of the thermoelectric pyrometer Since the total radiation received by a body at T_2 from one at T_1 is $K(T_1^4 - T_2^4)$, no great error is involved in high-temperature pyrometers by neglecting the term T_2^4 The heat energy received, then, is proportional to the fourth power of temperature, so the galvanometer in the thermocouple circuit may be calibrated in degrees of temperature of the source which is radiating energy to the mirror, which converges it on the thermocouple

Radiation and optical pyrometers have this advantage over the thermoelectric pyrometer, no part of them need come into direct contact with the hot body, and no part need be raised to a high temperature (F T M)

PYROMETRY. High-temperature **thermometry** The importance of this subject is realized upon noting that not only are many purely scientific researches carried on at very high temperatures, but also there are innumerable industrial operations which require an accurate knowledge of the temperatures of gas or electric furnaces or of the materials treated therein, and in which guesswork would be costly

Since most ordinary thermometers would be destroyed by furnace temperatures, and since the ordinary range of thermometric scales is limited to temperatures not far above the boiling point, specially adapted instrumental methods and extended scales must be employed in pyrometry Chief among the devices adaptable to this use (**pyrometers**) are (1) the **thermel,** (2) the **optical pyrometer;** (3) the **radiation pyrometer;** (4) the **resistance thermometer**

Just as the melting point and the boiling point of water are the fixed points in ordinary thermometry, so the melting points of sulfur, silver, and gold, carefully determined as 444 6° C, 960 5° C, and 1063° C, respectively, serve as reference points in calibrating pyrometers For extremely high temperatures, the centigrade scale must be extrapolated by means of the established laws of black-body **thermal radiation.** (L D W.)

PYROMORPHITE. The mineral pyromorphite is **lead chloro-phosphate** with a formula corresponding to $(PbCl)Pb_4(PO_4)_3$ The phosphorus is sometimes replaced by arsenic and the lead by calcium It occurs in prismatic, sometimes hollow, **hexagonal** crystals or may appear in massive forms It is brittle, hardness, 3 5-4, specific gravity, 6 5-7 1, luster, resinous, color, green, yellow green, yellow, brown, and less often gray or white, translucent to opaque Pyromorphite is a secondary mineral associated with other lead minerals, but is seldom found in large quantities It has probably resulted from the action of waters bearing phosphoric acid upon the pre-existing lead minerals Localities for pyromorphite are in the Ural Mountains, Saxony, France, Spain, Cornwall and Cumberland, England, in Scotland, the French Congo, and Australia In the United States pyromorphite has been found in Chester and Mont-

gomery Counties, Pennsylvania; in Davidson County, North Carolina, and in the Coeur d'Alene mining district of Idaho The name is derived from the Greek words meaning fire and form (E S C S)

PYRONE. Furane and Related Compounds.

PYROPE. Garnet.

PYROPHOSPHATE. Phosphoric Acid.

PYROPHYLLITE. The mineral pyrophyllite is a hydrous silicate of aluminum corresponding to the formula $H_2Al_2(SiO_3)_4$ **Orthorhombic** with a basal cleavage, it is usually, however, in foliated, lamellar, or fibrous masses, sometimes compact It is a soft mineral with a greasy feel, hardness, 1-2, specific gravity, 2 8–2 9, luster, pearly to dull, color, white, greenish, grayish, yellowish, and brownish, translucent to opaque It is found making up **schists** or in **foliated** masses in the Ural Mountains, in Switzerland, Sweden, Brazil, and in the United States in Pennsylvania, North Carolina, Georgia, and California It is used to some extent as is the mineral **talc**, and also for making slate pencils, hence the name pencil stone sometimes applied to pyrophyllite (E S C S)

PYROXENE. This is the name given to a closely related group of minerals, all of which show a distinct **cleavage** angle of 87° or 93° parallel to the fundamental prism Chemically the pyroxenes are **metasilicates** corresponding to the formula $RSiO_3$, where R may be **calcium, magnesium, iron,** or less commonly **manganese, zinc, sodium,** or **potassium** Rarely **titanium, zirconium,** or **fluorine** may be present

The pyroxenes crystallize in the **orthorhombic, monoclinic,** and **triclinic** systems, like the **amphiboles,** the chief difference between the two groups being the cleavage angles, which for amphibole are 56° and 124°. Pyroxene crystals tend to be short, stout, complex prisms as opposed to the long, slender, and simpler amphiboles

The pyroxenes are common in the more **basic igneous** rocks, both intrusive and extrusive, and may be developed by the **metamorphic** processes in **gneisses, schists,** and marbles

The following members of the pyroxene group are described under their own headings **acmite, aegirite, augite, babingtonite, bronzite, diallage, diopside, enstatite, hypersthene, jadeite, rhodonite,** and **spodumene**

Pyroxene was so named by Hauy from the Greek meaning fire and stranger, hence a stranger in the domain of fire Nothing could be more unlike the truth, for the various pyroxenes are typically minerals of the igneous rocks (E S C S)

PYROXENITE. A coarse-grained rock related to **gabbro** which consists almost wholly of **pyroxene** It may also carry small amounts of **quartz** or **olivine**

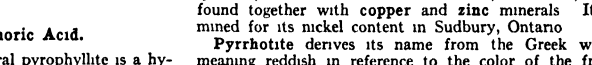
Pyroxenite is a rare rock type and of relatively little quantitative importance. (E S C S)

PYROZALE. Pyrrole and Related Compounds.

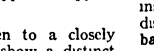
PYRRHOTITE. The mineral pyrrhotite, sometimes called magnetic **pyrites,** is a sulfide of **iron** with varying amounts of **sulfur** Analyses indicate formulas from Fe_6S_6 to $Fe_{16}S_{17}$ Pyrrhotite exists in two modifications it is **hexagonal** below, and **orthorhombic** above 138° C It is a brittle mineral, hardness 3 5–4 5, specific gravity 4 58–4 64; luster, metallic, color, reddish bronze yellow when fresh, otherwise tarnished, **streak,** grayish black, magnetic It may carry nickel, generally as **pentlandite,** when it becomes a valuable nickel ore as at Sudbury, Ontario Pyrrhotite is commonly associated with the **basic igneous rocks** like **gabbro, norite,** etc, and occurs with **chalcopyrite, magnetite, pyrite,** etc Besides being apparently of **magmatic** origin, it has been found as contact **metamorphic** and as vein deposits. Austria, Italy, Saxony, Bavaria, Switzerland, Norway, Sweden, and Brazil have deposits of more or less importance, and in the United States it has been found associated with **andalusite** crystals at Standish, Maine, also at Brewster, New York, Lancaster County, Pennsylvania, and elsewhere At Ducktown, Tennessee, it is found together with **copper** and **zinc** minerals It is mined for its nickel content in Sudbury, Ontario

Pyrrhotite derives its name from the Greek word meaning reddish in reference to the color of the fresh ore (E S C S)

PYRROLE AND RELATED COMPOUNDS. Pyrrole (monoazole, C_4H_5N or C_4H_4NH), contains a ring of 1 nitrogen and 4 carbons, with 1 hydrogen attached to nitrogen and to each carbon.



Pyrrole is a colorless liquid, boiling point 131° C, insoluble in water, soluble in alcohol or ether Pyrrole dissolves slowly in dilute **acids,** being itself a very weak **base, resinification** takes place readily, especially with more concentrated solutions of acids, and on warming with acid a red precipitate is formed Pyrrole vapor produces a pale red coloration on pine wood moistened with **hydrochloric acid,** which color rapidly changes to intense carmine red Pyrrole may be made (1) by

reaction of succinimide  with zinc and

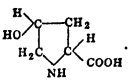
acetic acid, or with **hydrogen** in the presence of finely divided **platinum** heated, (2) by reaction of **ammonium** saccharate or mucate ($COONH_4$ $(CHOH)_4$ $COONH_4$) with glycerol at 200° C by loss of **carbon dioxide, ammonia,** and water

When pyrrole is treated with **potassium** (but not with **sodium**) or boiled with solid potassium hydroxide, potassium pyrrole (C_4H_4NK) is formed, which is the starting point for N- derivatives of pyrrole, since reaction of the potassium with halogen of organic compound and with carbon dioxide, readily occurs When pyrrole is treated with **magnesium** metal and ethyl bromide in ether, pyrrole magnesium bromide plus ethane is formed, which may be used as the starting point for C- derivatives of pyrrole, since reaction with sodium alcoholates readily occurs (with separation of magnesium oxybromide)

The pyrrole nucleus has been shown to be present in the complex substances, **chlorophyll** (the green coloring matter of plants), haematin (the red coloring matter of **blood**), and in the coloring matter of **bile**

Hydropyrrole compounds are 2,5-dihydropyrrole, pyrroline boiling point 91° C, and tetrahydropyrrole, pyrrolidine boiling point 81° C

Keto-pyrrolines are called pyrrolones, e g, 1-phenyl-4, 5,-dimethylpyrrolone (2) ("antipyrine") and keto-pyrrolidines are called pyrrolidones, e g, 2-keto-pyrrolidones Two aminoacids are derivatives of pyrrolidine, namely, proline (pyrrolidine-alpha-carboxylic acid, melting point 221° C, decomp, and

oxyproline (4-hydroxypyrrolidine-2-carboxylic acid  . Certain **alkaloids** contain the pyrrolidine nucleus

Azoles When the **carbons** of pyrrole (monoazole) are replaced in succession by **nitrogen**, di-, tri-, and tetrazoles are formed, thus

1, 2,–diazole (pyrazole), melting point 70°C., boiling point 188°C.

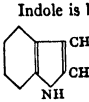
1, 3,–diazole, iminazole, glyoxaline, melting point 88°C., boiling point 256°C.

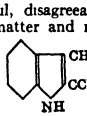
1, 2, 3,–triazole

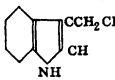
1, 2, 4,–triazole (pyrrodiazole) melting point 121°C., boiling point 260°C.

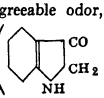
tetrazole (pyrrotriazole) melting point 155°C., sublimes

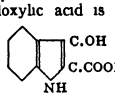
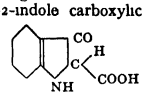
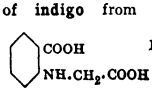
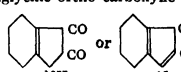
Hydrazole compounds are known 4,5-dihydropyrazole is pyrazoline boiling point 144°C. and tetrahydropyrazole is pyrazolidine

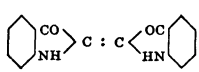
Indole is benzo-pyrrole (C_8H_7N or $C_6H_4CH \cdot CHNH$ or  white, odorous solid, melting point 52° C., boiling point 254° C., soluble in hot water, soluble in ether or alcohol Indole behaves similarly to pyrrole with acids, and with pine wood moistened with **hydrochloric acid** (cherry red coloration)

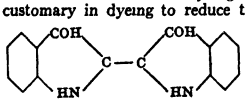
Three methyl indoles are (1) C-methyl indole (3), skatole white, solid, melting point 95° C., boiling point 268° C., of powerful, disagreeable odor, present in putrefied **albuminous** matter and in human feces, (2) C-methyl indole (2)  white, odorous solid, melting point 60° C., boiling point 268° C, (3) N-methyl indole colorless, liquid, boiling point 240° C., without unpleasant odor

Carboxylic acids of indole are (1) indole-3-acetic acid white solid, melting point 164° C., heated above this temperature decomposes into skatole plus **carbon dioxide**, (2) indole-3-alpha-aminopropionic acid, tryptophane  melting point 289° C (decomp.), which gives rise to the derivatives of indole formed during the putrefaction of **proteins**, and yields indole-3-ethyl alcohol, trypophol white solid, melting point 59° C., by **fermentation** with **yeast** in the presence of sugar

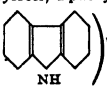
Indoxyl is 3-hydroxyindole yellow solid, melting point 85° C, disagreeable odor, reacts also as keto-form, pseudo-indoxyl  hypothetical, on exposure to air oxidizes to indigotin

Indoxylic acid is 3-hydroxy-2-indole carboxylic acid  or  white solid, melting point 178° C. (decomp.), and forms an intermediate product in the technical synthesis of **indigo** from phenylglycine-ortho-carboxylic acid  Isatin  red solid, melting point 199° C, sublimes, is related to indole and indigo.

Indigo blue, indigotin 

may be made synthetically by reaction of anthranilic acid (ortho-aminobenzoic acid), and monochloroacetic acid to form phenylglycocoll ortho-carboxylic acid, which with fused sodium hydroxide yields indoxyl carboxylic acid and then indoxyl Indoxyl, upon exposure to air, oxidizes spontaneously to indigotin Since indigotin is insoluble and has no dyeing properties as such, it is customary in dyeing to reduce to soluble indigo white  by **calcium** hyposulfite (CaS_2O_4) in alkaline solution, to immerse the cotton fiber in the solution (vat-dyeing), and then withdraw the fiber from the bath and expose to the air, whereupon indigotin is formed in the fiber. In dyeing wool, soluble indigo disulfonic acid, "indigo-carmine," is used

Monobromo and dibromoindigotin are valuable **dyes**, sometimes used instead of indigo.

Carbazole is dibenzopyrrole, diphenyleneimine ($C_{12}H_9N$ or $C_6H_4 \cdot NH \cdot C_6H_4$ or ) white solid, melting point 245° C., boiling point 355° C.

Indazole and isindazole hypothetical

are benzopyrazoles, derivatives of which have been prepared.

Benziminazole is melting point 170° C.

Where **nitrogen** (group —NH) of pyrrole is occupied by **oxygen**, furane is the compound, and where occupied by **sulfur**, thiophene; similarly, where nitrogen of indole by oxygen, coumarone is the compound, and where by sulfur, benzothiophene; and where nitrogen of carbazole by sulfur, diphenylene sulfide.

Compounds containing 1 (or 2) nitrogen and 5 (or 4) carbons in the ring (6-membered rings) are discussed under **Pyridine and Related Compounds.**

Oxygen-nitrogen ring compounds:

Oxazole Isoxazole

Benzoxazole melting point 30° C., boiling point 182° C.

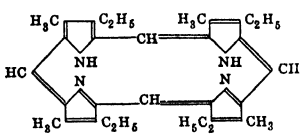
The following tetrapyrrole pigments are known:

I. Chain-compounds. Bile pigments.
1. Bilirubin . ($C_{33}H_{36}N_4O_6$). The orange pigment of **bile.**
2. Biliverdin..... ($C_{33}H_{36}N_8O_8$). The green pigment of bile
3. Mesobilirubinogen By reduction of bilirubin.
4. Mesobilirubin..... The brown pigment of **urine.**
5. Uteroverdin..... The green pigment of egg-shells, of the **placenta** of the dog, and of the gall-stones of the ox.

II. Ring-compounds. Porphyrins: chlorophyll and blood pigments.
6. Ooporphyrin..... ($C_{34}H_{38}N_4O_4$). The brown pigment of egg-shells.
7. Uroporphyrin..... ($C_{38}H_{38}N_4O_{16}$). Found in the **blood** and urine in cases of congenital porphyrinuria.
8. Haematoporphyrin ($C_{34}H_{38}N_4O_6$).
9. Aetioporphyrin.... ($C_{32}H_{38}N_4$).

III. Metallic compounds. Porphyrans.
10. Aetiophyllin..... The **magnesium** porphyran of **chlorophyll.**
11. Haematin..... The **iron** porphyran of **haemoglobin.**
12. Cytochrome..... The respiratory iron porphyran of tissues.
13. Turacin.. ... The **copper** porphyran of the feathers of birds.

Aetioporphyrin has been derived from natural sources, and also made synthetically. Chlorophyll, the green pigment of leaves, and haemoglobin, the red pigment of blood, are related to aetioporphyrin. The formula of aetioporphyrin is



(R.K.S.)

PYRROLIDINE. Pyrrole and Related Compounds.

PYTHON. Reptilia, Sauria. Large **snakes** related to the boas The several species are distributed through Asia, Africa, and Australia. They are largely arboreal, living in forests, usually near the water, which they enter freely. Some of these snakes are very large, the Regal python, *Python reticulatus*, attaining a length of thirty feet, and one of the African species, *Python sebae*, more than twenty. They are not poisonous, but because of their size and strength they may be dangerous to man under some conditions. (A.W.L.)

Q

QUADRANT ELECTROMETER. Electroscopes and Electrometers.

QUADRANTAL ANGLES. Angles.

QUADRATE BONE. A small bone of roughly quadrangular shape in the **vertebrate** skull In the **reptiles** and lower forms it is included in the articulation of the lower jaw with the skull, and a similar condition persists in the birds. In the mammal the incus or anvil, one of the three small bones of the middle **ear**, is regarded as the homologue of this bone. (A.W.L.)

QUADRATIC EQUATIONS IN ONE UNKNOWN. A quadratic equation in one unknown is an **equation** of the form

$$ax^2 + bx + c = 0 \quad (a \neq 0),$$

where a, b, c are **constants** (independent of x), and x is the unknown.

A quadratic equation may be solved: (a) by **factoring**, (b) by completing the square, (c) by the quadratic formula, or (d) graphically.

If a quadratic equation can be factored by inspection into linear factors, as $a(x-\alpha)(x-\beta) = 0$, then the **roots** are α and β.

The method of completing the square consists in transposing the constant term, adding a term to both sides to make the left-hand side a perfect square of a binomial, extracting the square root of both sides and solving the resulting **linear equations.**

The roots of the quadratic equation $ax^2 + bx + c = 0$ may also be found immediately by use of the quadratic formula:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$$

One graphical method for solving a quadratic equation $ax^2 + bx + c = 0$ is to plot in **rectangular coordinates** the **graph** (a **parabola**) **of the function** $y = ax^2 + bx + c$, and then find the **abscissas** of the points where this parabola cuts the X-axis. This gives only the real roots of the equation.

Another graphical method for the solution of the equation $ax^2 + bx + c = 0$ is obtained by drawing the graph in rectangular coordinates of the equation $y = x^2$ and on the same diagram the graph of the straight line $ay + bx + c = 0$, and finding the abscissas of the points of intersection of these two graphs.

The character of the roots of a quadratic equation is determined by an inspection of the discriminant of the equation, as follows:

If the coefficients a, b, c of the quadratic equation $ax^2 + bx + c = 0$ $(a \neq 0)$ are real numbers, then:

if $b^2 - 4ac > 0$, the roots are real and unequal,
if $b^2 - 4ac = 0$, the roots are real and equal,
if $b^2 - 4ac < 0$, the roots are complex numbers.

If the coefficients a, b, c are rational numbers and if $b^2 - 4ac > 0$, then:

if $b^2 - 4ac$ is a perfect square, the roots are rational,
if $b^2 - 4ac$ is not a perfect square, the roots are irrational.

For this reason, the expression $b^2 - 4ac$ is called the discriminant of the equation.

The relation between the roots x_1 and x_2 and the coefficients of the equation $ax^2 + bx + c = 0$ are given by:

the sum of the roots $x_1 + x_2 = -b/a$,
the product of the roots $x_1x_2 = c/a$.

An equation is said to be in the quadratic form if it can be transformed into a quadratic equation by means of the substitution of a new variable representing an expression involving the original unknown. Such equations can be solved by use of the methods for quadratic equations. (L.L.S.)

QUADRATIC EQUATIONS, SYSTEMS OF. The usual types of **systems of equations** involving **quadratics** are: the linear-quadratic systems, in which one equation is **linear** and one quadratic, and the quadratic-quadratic systems, in which both equations are quadratic.

Both types of systems of equations may be solved graphically, by constructing the **graphs** of the equations on the same diagram and finding their intersection points. In the case of the linear-quadratic system, the graphs will be a **straight line** and a **conic**, which will intersect in, at most, two points. For the case of the quadratic-quadratic system, the graphs will be two conics, which will intersect in, at most, four points. The **coordinates** of the intersection points in either case will give only the real solutions

Linear-quadratic systems of equations may be solved algebraically by solving the linear equation for one unknown in terms of the other, and this result substituted in the quadratic equation gives a **quadratic equation** in one unknown.

There is no single uniform method for solving quadratic-quadratic systems, but several simple methods will handle the majority of cases.

If both equations of the system are of the form $ax^2 + by^2 = c$, they can be solved as a linear system in x^2 and y^2, and then x and y immediately found.

If both equations are of the form $ax^2 + bxy + cy^2 = d$, we may eliminate the constant terms between the two equations and obtain a single equation of the form $Ax^2 + Bxy + Cy^2 = 0$; this quadratic equation may be solved to obtain one unknown as a **linear function** of the other. Substitution of the linear expressions in one of the given equations and solving the resulting equation for the remaining unknown enables us to obtain the corresponding values of the other unknown by substitution.

Another method for this case is to substitute $y = vx$ in both equations, solve each resulting equation for x^2 and equate them, and solve the resulting equation for v, then substitute these values of v in one of the equations giving x^2, and thus find x; y can then be found from $y = vx$.

Other special devices can also be used Systems of equations symmetrical in x and y can often be solved by special devices preserving symmetry, or often by the substitution $x = u + v$, $y = u - v$. (L.L.S.)

QUADRATIC FORM, EQUATIONS IN. Quadratic Equations.

QUADRATIC FORMULA. Quadratic Equations.

QUADRATIC FUNCTION. A quadratic function is a **polynomial function** of the second degree, and is therefore a **function** of the form $ax^2 + bx + c$, where a, b, c are **constants** and x is the **variable.**

The **graphic representation** in **regular coordinates** of a quadratic function $y = ax^2 + bx + c$ is a **parabola** with principal axis vertical (i.e., parallel to the Y-axis).

The value of x for which the quadratic function $ax^2 + bx + c$ takes its least value if $a > 0$, and its greatest value

if $a < 0$, is $x = -b/2a$. This extreme value of the function is $\frac{4ac - b^2}{4a}$. (L.L.S.)

QUADRATURE. Planetary motions.

QUADRIC SURFACES. A surface represented by an equation (in rectangular coordinates) of the second degree in x, y, z of the form $Ax^2 + By^2 + Cz^2 + Dyz + Ezx + Fxy + Gx + Hy + Iz + J = 0$ is called a quadric surface or a conicoid.

Every plane section of a quadric surface is a conic section.

By translation and rotation of axes, the general equation of the second degree in x, y, z may be reduced to one of several type forms, representing the types of surfaces: ellipsoid (including the sphere), paraboloid, hyperboloid, cone, cylinder.

A quadric surface which has a center of symmetry is called a central quadric. The ellipsoid and the hyperboloids are surfaces of this character. (L.L.S.)

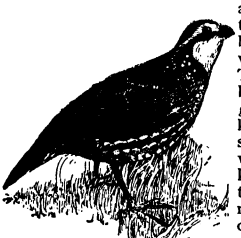
QUADRUPLE PRODUCTS OF VECTORS. Important formulas for products of four vectors are:

$$(\mathbf{a} \times \mathbf{b}) \cdot (\mathbf{c} \times \mathbf{d}) = (\mathbf{a} \cdot \mathbf{c})(\mathbf{b} \cdot \mathbf{d}) - (\mathbf{a} \cdot \mathbf{d})(\mathbf{b} \cdot \mathbf{c}),$$
$$(\mathbf{a} \times \mathbf{b}) \times (\mathbf{c} \times \mathbf{d}) = [(\mathbf{c} \times \mathbf{d}) \cdot \mathbf{a}]\,\mathbf{b} - [(\mathbf{c} \times \mathbf{d}) \cdot \mathbf{b}]\,\mathbf{a}.$$

(L.L.S.)

QUAGGA. Mammalia, Perissodactyla. A South African animal, *Equus quagga*, related to the zebras and asses. It is reddish brown above, blending to white on the legs, and is marked with dark brown stripes on the head, neck, and fore part of the body. A dark stripe also runs along the middle of the back and down the tail, but otherwise the hind quarters are unmarked. Also spelled couagga. (A.W.L.)

QUAIL. Aves, Galliformes. Small compactly built game birds (Aves) related to the partridges. Every continent has species of this name, but those of North and South America and those of the Old World belong to different divisions of the family. The widely distributed bob-white *Colinus virginianus*, is the best known North American species. Some of the western species are known both as partridges and as quails, notably the valley quail of California, *Lophortyx californica*, and in the south the bob-white also receives the name partridge. Quails are swift-footed but their wings are short and they fly only short distances. Although their colors are mostly very quiet, they are beautiful birds. Both their appearance and their interesting habits make them desirable residents in any locality. (A.W.L.)



Quail (partridge, bob-white) *Colinus virginianus*. Above, mottled reddish brown and gray; under parts white barred with black. White spots on head in male; yellow in female.

QUALITY. Quality is a term used in connection with musical sounds. It is also used technically to describe the condition of a saturated vapor. A vapor in a condition intermediate between liquid and a dry vapor is said to have a certain quality which may be defined as the ratio of the vaporized portion to the total weight of liquid and vapor. The vaporization of a liquid requires the expenditure upon it of the latent heat of vaporization. When heat to this amount is added, the liquid is converted to a dry vapor. If x per cent of this heat is added, only x per cent of the liquid is vaporized. x is the quality. It is the percent of dryness of a wet vapor. (F.T.M.)

QUANTIC. A quantic is a homogeneous algebraic function of two or more variables, in general containing only positive integral powers of the variables, and so is usually a polynomial in several variables. Quantics are classified into quadratic, cubic, quartic, quintic, etc., according to degree, and into binary, ternary, quaternary, etc., according to the number of variables involved. (L.L.S.)

QUANTUM MECHANICS. A very general physical theory, or method of physical reasoning, recently recognized as necessary in dealing with entities so small that our laboratory instruments cannot furnish direct observations upon them. The underlying, revolutionary idea, developed primarily by Heisenberg, is that we are not justified in assuming any precisely foreordained and determinate position or motion for such a thing as an atom or an electron. If one throws a baseball, there are instruments which can measure its position and its velocity within limits small as compared with the size of the ball and the speed of its motion; and its subsequent behavior can be calculated with such precision as is afforded by those measurements. But with an atom or an electron, no corresponding proportionally accurate data can be obtained by any method of measurement at our command. Hence any prediction as to the particle's future performance is subject to error or ambiguity, large as compared with the quantities concerned. Instead of saying that an electron will be at such and such a place and have such and such a momentum at a given time, it is possible only to say that the position or momentum in question is more probable than any other, and to calculate how much more probable one assumed value is than another, neighboring value. Thus, the idea of a definite point occupied by an electron is replaced by a whole distribution of possible points, like the spatter of shots on a target. One curious feature, incidentally, is that the more accurately the position of one of these minute particles can be specified, the less determinate is its velocity, and *vice versa*. To deal with problems involving this "uncertainty principle," Heisenberg has developed a mathematical procedure involving the use of matrices, and this phase of the subject is known as "matrix mechanics." Wave mechanics is also an important feature of the more general theory. (L.D.W.)

QUANTUM NUMBERS. Quantum Theory.

QUANTUM THEORY. A general physical theory wherein it is recognized that in many, if not all, processes involving transfer of energy, the energy must be regarded as having an atomistic character, that is, as passing from one system to another only in discrete, finite increments or "quanta." Processes which, on the mass scale, directly observable to our senses appear to be quite continuous, may, when carried to atomic or electronic orders of magnitude, prove to be "quantized," that is, to proceed by small but finite jumps or readjustments. When water is poured from a tub, we observe no discontinuity in its flow, but when allowed to trickle from a pipette, it flows drop by drop. This is only a very crude analogy. A more valid illustration is this: If a spinning grindstone slows down, it appears to do so gradually; but there is reason to believe that when a molecule loses angular speed of rotation, it passes abruptly from one speed to another that is sometimes a little and sometimes much slower, and that the lost energy is emitted as a small or a large quantum of radiation (See Molecular Spectra).

The quantum theory had its inception when, in 1900, Max Planck first recognized, in the spectral energy distribution of thermal radiation, a statistical distribution of individual entities. This may be illustrated by supposing a whole season's crop of apples graded as to

size, and the number of bushels of each size tabulated in order. Likewise the radiation output of a hot body can be graded into different sized quanta (corresponding to wave length), and the total amount of energy made up of each tabulated as the spectral energy distribution It was only by adopting this view that Planck was able to reconcile theory with experiment in the study of **black-body** radiation

Today we are accustomed to thinking of nearly all phenomena in terms of quantized processes Radiation is supposed to emanate from atoms or molecules in quanta of definite frequency and wave length as the result of abrupt changes from one quantum state or energy level to another, the frequency being determined by the amount of energy released in accordance with **Planck's law.** But the mechanism whereby these definite frequencies are produced is as yet unknown. In general, there is associated with each quantum state of an atom or a molecule an integral number, whose physical significance is not fully understood but which changes from one value to another whenever there is an accession or a release of energy These integers, called quantum numbers, appear in the empirical formulae for the series terms in **atomic spectra**, and each exchange of one quantum number for another corresponds to a radiation quantum or a photon of light of definite frequency Series of spectral lines are thus built up from different combinations of quantum numbers, corresponding to transitions between different pairs of quantum states or levels Since an atom or a molecule may be quantized as to different **degrees of freedom**, there are different sets of quantum numbers, characterized, respectively, as azimuthal, radial, rotational, vibrational, etc.

Among the outstanding features of the quantum theory may be mentioned the interpretation of the laws of radiation, of the details of atomic, **molecular**, and **x-ray spectra**, of the **Compton effect** and the **Raman effect**, of the **Stern-Gerlach experiment**, of certain **magneto-optical** and **electro-optical** phenomena, and of the laws of **specific heat.** See also **Quantum Mechanics.** (L D.W.)

QUARTER-WAVE PLATE. Double Refraction.

QUARTIC EQUATIONS A quartic (or biquadratic) equation in one unknown is a **polynomial equation** of the fourth degree and has the general form

$$a_0x^4 + a_1x^3 + a_2x^2 + a_3x + a_4 = 0$$

The quartic equation $y^4 + py^2 + qy^2 + ry + s = 0$ may be reduced by the substitution $y = x - \frac{p}{4}$ to the form $x^4 + ax^2 + bx + c = 0$ Let l, m and n denote the roots of the resolvent **cubic equation**

$$t^3 + \left(\frac{a}{2}\right)t^2 + \left(\frac{a^2 - 4c}{16}\right)t - \frac{b^2}{64} = 0.$$

The required roots of the reduced quartic are then:

$$x_1 = \pm(-\sqrt{l} - \sqrt{m} - \sqrt{n}),$$
$$x_2 = \pm(-\sqrt{l} + \sqrt{m} + \sqrt{n}),$$
$$x_3 = \pm(\sqrt{l} - \sqrt{m} + \sqrt{n}),$$
$$x_4 = \pm(\sqrt{l} + \sqrt{m} - \sqrt{n}),$$

where the upper signs are to be used if $b > 0$, the lower if $b < 0$ (L L S)

QUARTIC FUNCTION. This is a **polynomial function** of the fourth degree and is therefore of the form $ax^4 + bx^3 + cx^2 + dx + e$, where a, b, c, d, e are **constants** (independent of x) and x is the **variable**; it is also sometimes called a biquadratic function. (L L S)

QUARTZ. The mineral quartz, oxide of the non-metallic element **silicon**, is the commonest of minerals, and appears in a greater number of forms than any other Its formula is SiO_2. Quartz commonly occurs in prismatic **hexagonal** crystals terminated by a pyramid. This pyramid is due to the equal development of two **rhombohedrons**, as may be observed in cases where one rhombohedron predominates Cleavage is not observed, the fracture is typically conchoidal, hardness is 7.; specific gravity, 2 65, luster, vitreous to greasy or dull; colorless to white, pink, purple, yellow, blue, green, smoky brown to nearly black, transparent to opaque. There seem to be two distinct modifications of quartz, depending upon the temperature at which they were formed The low-temperature variety is formed below 573° C and is the more common sort, being found in veins, geodes, etc. It is called low-quartz The high-temperature modification is formed between 573° C. and 870° C, and is found chiefly in granites and **granite** or **rhyolite porphyries.** This is called high-quartz. Above 870° C. **tridymite** is the stable form of SiO_2. The differences between high- and low-quartz are entirely crystallographic, low-quartz having a vertical axis of three-fold symmetry and three horizontal axes of two-fold symmetry, while high-quartz has a vertical axis of six-fold symmetry and six horizontal axes of two-fold symmetry. It is usual to separate the many kinds of quartz into· (1) Crystalline or vitreous varieties, actual crystals or vitreous crystalline masses, and (2) **Cryptocrystalline** varieties, mostly compact non-vitreous sorts, but which may show a crystalline structure under the microscope

(1) Crystalline or Vitreous. Rock crystal, colorless crystals or masses Amethyst, clear violet or purple, either crystals or masses Rose quartz, usually massive but rarely in crystals, delicate shades of pink or rose, sometimes red Citrine or yellow quartz, sometimes called false or Spanish topaz, light to deep yellow Smoky quartz, smoky brown to almost black, often called cairngorm stone from Cairngorm, Scotland Milky quartz, often showing delicate opalescence, translucent to nearly opaque, often with a greasy luster. Aventurine quartz includes glistening scales of mica or hematite Ruthated quartz includes needle-like prisms of rutile called "fleches d'amour" Other acicular minerals such as **actinolite, tourmaline, epidote,** etc, may also be thus included, Cat's Eye shows a peculiar opalescence, probably due to included masses of some fibrous mineral Tiger's Eye is a siliceous pseudomorph after crocidolite of a golden yellow brown color (2) Cryptocrystalline. the following cryptocrystalline varieties of quartz are treated under their own headings. **agate, basanite, bloodstone, carnelian, chalcedony, chert, chrysoprase, flint, heliotrope, jasper,** moss agate, **onyx, plasma, prase, sard,** and **sardonyx** Quartz readily forms **pseudomorphs** after various minerals or structures Silicified wood is a quartz pseudomorph after the organic material of which it originally consisted Quartz is often pseudomorphic after **calcite, barite, fluorite,** etc Quartz is an essential constituent of many **igneous rocks,** for example, **granites, granite porphyries,** and **felsites,** as well as quartz **diorites** and their surface equivalents, the **dacites** In the **metamorphic** rocks quartz figures very largely in the **gneisses** and **schists,** and, of course, in **quartzite** In the sedimentary rocks most sandstones are composed chiefly of grains of quartz, and quartz forms veins and nodules in limestones Of the many foreign localities that have yielded fine specimens of quartz, a few only can be mentioned as· the Swiss Alps, the Piedmont of Italy, the Island of Elba, Dauphine in France, Cumberland in England, Banffshire, Scotland, and Madagascar Fine amethysts come from the Urals, Ceylon, Madagascar, Uruguay, Mexico, and Brazil In the United States the following localities are well known· Paris, Maine, especially for rose quartz, Herkimer County, New York, for small but very brilliant crystals found in the Cambrian dolomites or in the soil Amethyst County, Virginia, furnishes amethysts, as do Lincoln and Alexander Counties, North Carolina Other localities for amethyst and smoky quartz are South Dakota in the Black Hills,

the Pike's Peak district, Colorado; Yellowstone Park, Wyoming, Jefferson County, Montana, and in Canada in the Province of Ontario in the Thunder Bay region. The word quartz is believed to have been originally of German origin Besides the use of the different varieties of quartz for jewelry and other ornamental purposes, this mineral has extensive industrial uses in the ceramic arts, optical and other sorts of scientific instruments (See **Polarized Light**), abrasive, scouring, polishing materials, and for refractories. (E S C S)

QUARTZITE. A hard, tough, and compact metamorphic rock composed almost wholly of quartz Sand grains which have been recrystallized to form a particularly massive siliceous rock The term is also used for non-metamorphosed quartzose **sandstones** and grits whose **clastic** grains have been firmly cemented by **silica** which has grown in optical continuity around each grain (R.M F)

QUARTZ PORPHYRY. One of the **hypabyssal** or effusive rocks chemically related to the **granite** or alkali family but rich in silica, which occurs as **quartz phenocrysts** in a crypto- or microcrystalline ground mass (R M F)

QUATERNARY. Pleistocene.

QUEBRACHO. Tannins.

QUENCHING. The operation of quenching is that of immersing a hot object in liquids or gases in order to cool it Quenching of steels in water or oil is part of the process of **annealing** The tempering or hardening of steels also involves quenching Different structures of the finished product are obtained by quenching from different temperatures, and in different media, i e, air, oil, or water (F T M)

QUEZAL. Trogon.

QUICK RETURN MECHANISM. Machine tools which cut with a straight stroke in one direction, alternated with non-cutting return strokes, are more efficient of operators' time if the return stroke is performed more rapidly than the forward stroke The **shaper** offers an example of a machine tool in which the cutting is done by moving the work past a fixed cutting tool which cuts in one direction The work reciprocates, and

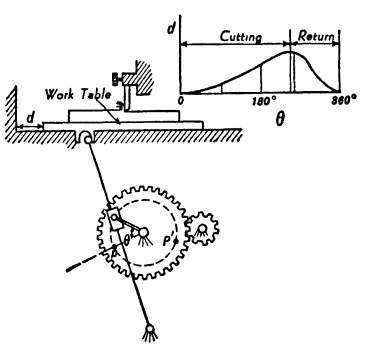


Diagram of the crank shaper.

in order to save as much time as possible on the non-cutting portion of the **cycle**, quick return mechanisms have been developed, one of which is illustrated in the accompanying figure This is a variation of a slider crank chain, one of the most common of linkages A pinion engages a large gear to which is affixed a crank arm. The outer end of the crank is pinned to a slider block, which is free to slide on a long swinging arm As the crank revolves, this arm oscillates back and forth, and by means of a yoke reciprocates a table on suitable ways The work to be shaped or planed is clamped to this table The point at which the oscillating arm is **tangent** on either side to the crank pin circle separates the cutting from the return stroke Since the crank arm turns uniformly, time is proportional to crank angle The return stroke is accomplished in a much smaller crank angle than the cutting stroke, and consequently consumes less time A typical displacement diagram for return mechanisms is shown Many quick return mechanisms which are patented have features superior to those of the crank mechanism, such as more uniform speed on the cutting stroke, larger quick return ratio, etc These features are obtained at the expense of more complicated mechanism. (F T M)

QUILL. The portion of a feather which bears none of the slender lateral branches The hollow shaft which is attached to the skin of the bird Also the thickened and barbed spines of the porcupines, which are modified hairs (A W L)

QUILLBACK Pisces, Teleostei One of the **buffalo fishes**, *Carpiodes velifer*, of the Mississippi River system Also called the carp sucker, a name which belongs more properly to a related species, and skimback or river carp (A W L.)

QUILLWORTS. These curious plants, species of the genus *Isoetes*, grow, as a rule, under water They have short thick corm-like stems and slender **dichotomously** branching roots. The leaves are slender and somewhat grass-like and are crowded on the upper surface of the short stem Within the basal portion of the leaf are borne **sporangia** of two kinds One, containing large **spores** or megaspores, is called a megasporangium The other is a microsporangium and contains numerous very small spores The megaspores give rise to small multicellular **gametophytes** on which the **archegonia** are formed The microspores become minute multicellular bodies in which are formed the small **sperms** A sperm swims to the egg and unites with it to form a **zygote** From this a new quillwort is formed. The quillworts are living relics of a once important group. They are of no importance. (R M W)

QUINCE. Rose Family.

QUINHYDRONE. Phenols.

QUININE. Alkaloids, and **Cinchona.**

QUINNAT. Pisces, Teleostei A **salmon** of the west coast of North America, ranging from Alaska to the Ventura River It is among the most important of the food fishes and is the leading salmon of the Columbia River fisheries Also known as the chinook or king salmon This fish attains a maximum weight of one hundred pounds and a length of more than four feet, but most of those taken weigh only a quarter of this amount (A.W.L)

QUINOLINE. Pyridine and Related Compounds.

QUINONES. Phenols and Quinones.

QUINSY. Abscess formation in and about the tonsils, a complication of acute **tonsillitis** Symptoms are those of acute tonsillitis The **lymph glands** in the neck become swollen and tender Swallowing is extremely painful Both local and constitutional symptoms are more severe than those in acute tonsillitis Unless the abscess ruptures spontaneously incision is required at the proper time. (R.S M)

R

RABBIT. Mammalia, Rodentia. **Rodents** with long ears, large hind legs, and small front legs. Some species burrow and others occupy similar retreats which they do not make for themselves. Many members of the group are called **hares.** There is no sharp distinction between the terms except in their established application to certain species

Rabbits are found on all continents, although they were introduced into the Australian region. In New South Wales the introduced stock threatened to crowd out even the settlers by its destruction of vegetation. Millions of the animals have been killed per year and the exportation of their hides has somewhat offset their destructiveness.

In North America the common or cottontail rabbit, *Sylvilagus floridanus*, and a few closely related species are widely distributed. One of these species is the brush rabbit, *S. bachmani*, of the Pacific northwest, and two others are the southern marsh rabbit or pontoon, *S palustris*, and swamp rabbit or cane-cutter, *S aquaticus*. The large western species are sometimes called hares but more commonly rabbits. The snowshoe rabbit, *Lepus americanus*, also known as the white rabbit or varying hare, lives in the north and in the mountains as far south as Virginia and Colorado. The white-tailed jack rabbit or prairie hare, *L. townsendi*, ranges from the Mississippi River to eastern California. This species becomes white in winter in the northern part of its range. Other species of jack rabbits are found farther west.

The flesh of rabbits is excellent. In the more heavily settled parts of the country they are an important game animal The fur is thick and soft but the hides are weak, hence they are used chiefly for linings, for cheaper fur garments, and for making felt After shearing and dyeing rabbit fur reaches the market as northern seal.

Rabbits are bred extensively in captivity as pets, as laboratory animals for use in medicine and bacteriology, to some extent for food, and for the study of heredity. Since they are very prolific they have been among the most useful mammals to the geneticist. (A W.L)

RABIES (HYDROPHOBIA). An acute infectious disease of certain animals caused by a **virus**, transmitted to man by the bite of an infected animal The disease has been known since 300 B C , but just how the disease was transmitted was not known until 1804. Pasteur in 1884 demonstrated that the nerve tissue of infected animals contained the virus in a concentrated state and prepared a preventative **vaccine.** This same method is used today in all cases of bites by dogs or other animals which are infected with rabies. Untreated cases that develop rabies die

The period of incubation, or time that the disease takes to develop, varies. The average time is three to eight weeks or longer. The nearer the bite to the brain the shorter the incubation period.

During the disease three stages develop. In the first stage the premonitory symptoms, irritability, depression, and attacks of great fear develop, with huskiness of voice and difficult swallowing. Temperature and pulse become elevated. This period lasts for one to two days. The second stage is the stage of excitement Irritability becomes more marked and restlessness is marked. Spasms develop, particularly of the mouth and throat. These are brought on by any stimulus and particularly by drinking water, from which fact the disease acquires its name. Maniacal symptoms may develop. Temperature is elevated. Between spasms the patient is quiet. This stage lasts for two to three days. In the third, or paralytic, stage, the patient gradually becomes quiet, unconsciousness develops, heart action becomes weak, and death ensues within six to twelve hours.

In neurotic persons bitten by an animal that does not have rabies, a condition known as pseudohydrophobia develops. This is an hysterical manifestation, as evidenced by imitation of the barking and biting of a dog.

Once the disease begins, it is hopelessly incurable and nothing can be done to save the patient.

When a person has been bitten by an animal known to have rabies, either through the suspicious actions of the animal or by laboratory tests done on it, preventative inoculations (The Pasteur Treatment) are always given. If this is done in time rabies will not develop.

The **vaccine** used in the treatment of rabies is made from the spinal cords of rabbits inoculated with the disease. By drying the cords at a certain temperature or exposing them to chemical action, a graduated series of the attenuated virus may be obtained The exposed patient is inoculated daily for three weeks with gradually increasing doses of the vaccine By this means a temporary immunity may be built up and the patient can overcome the toxin of the virus.

It is exceedingly important that a surgeon treat a dog bite as soon as possible. By cauterizing the wound the virus can be killed before it is absorbed by the bite. If this is done immediately, rabies can very often be prevented by this simple method alone. (R S.M)

RACCOON. Mammalia, Carnivora. Stoutly built American animals of moderate size. The head is broad and short, with a sharply pointed muzzle, and the tail is bushy and marked with alternating light and dark rings.

The common raccoon, *Procyon lotor*, ranges over North America east of the Rockies Two related species live on the Pacific coast and southward into Central America, and one or more additional species have been recorded from South America.

Raccoons are chiefly nocturnal animals. They climb readily and usually nest in hollow trees. In many sections of the country coon hunting at night with specially bred and trained dogs is regarded as among the best sports of the kind.

Raccoon fur is among the better grades, although it is neither very fine nor very beautiful. It is used extensively in making coats. (A.W.L.)

RACE RUNNER. Reptilia, Sauria. Slender **lizards**, reaching a length of about ten inches, including the long tapering tail. They are found throughout the United States with the exception of the most northern part. One species is known as the swift, *Cnemidophorus sexlineatus*. (A.W.L.)

RACEME. Flower.

RACEMIC ACID. Tartaric acid.

RACEMIC COMPOUND. Isomerism.

RACHIS. A shaft. The term may be applied to the vertebral column, but its most common use designates the central shaft of a feather. (A.W.L.)

RADIAL VELOCITY. The component of the **space velocity** of a star which is directed toward the sun is known as the radial velocity of the star, or the velocity in the line of sight. Radial velocity is measured by means of the **Doppler-Fizeau** principle and is deter-

mined directly in linear units (i e., either in miles per second or in kilometers per second)

For the determination of accurate radial velocities the use of the slit type **spectrograph** is necessary Since this instrument is wasteful of light, and only one star can be observed at a time, the number of radial velocities that are known is woefully small in comparison with the total number of known stars In the hope of increasing the speed of determination of this important astronomical measurement of the stars, various attempts have been made to determine radial velocities by means of the **objective prism** The difficulty with this method is that a comparison spectrum cannot be applied as easily as is the case with the slit spectrograph Within the last few years promising results are being obtained by Bok at the Harvard College Observatory by sending the star light through a Neodymium screen as well as through the objective prism This substance produces several **absorption lines** which may be used for approximate determination of Doppler displacement of the stellar spectral lines While the results as yet are not too accurate, nevertheless, they are of sufficient accuracy for use in statistical analysis in connection with problems dealing with the structure and motions of the **sidereal system**

By means of measurement of variations in radial velocity of certain close **binary stars**, known as **spectroscopic binaries**, the relative **orbits** of these objects may be obtained (W K G)

RADIAN MEASURE OF ANGLES. For theoretical purposes, **angles** are generally measured in circular or radian measure If a circle is drawn with its center at the vertex of an angle, the radian measure of the angle is the ratio of the length of intercepted arc to the radius The unit angle in this measure is the radian, defined as the angle whose intercepted arc is equal to the radius The fundamental relation between radian measure and degree measure is given by the equation π radians $= 180°$ The symbol (r) is often used after the numerical value of the circular measure to indicate radians, but it is often omitted when no misunderstanding can arise It follows from the fundamental relation above that

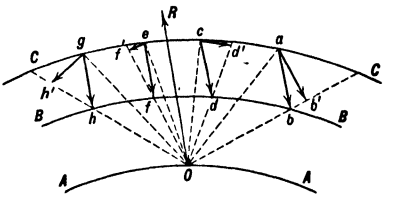
1 radian $= 180°/\pi = 57\ 20578° = 57°\ 17'\ 44\ 6''$ approximately, or 57 3° roughly, and

$1° = \pi/180$ radians $= 0\ 017453^{(r)}$ approximately, or $0\ 017^{(r)}$ roughly

In terms of radian measure, any circular arc intercepted by an angle with vertex at its center is given in length by the formula $s = r\ \theta$, where r is the radius of the circle and θ is the radian measure of the angle (L L S)

RADIANT POINT. If the paths of all of the **meteors** observed from a single station on a given night are plotted on a chart of the sky, it will usually be found that a number of them seem to be coming from a certain particular point in the sky Such a point is known as a meteor radiant point, and the group of meteors associated with the radiant point is known as a **meteor shower** It will further be noticed that, among the meteors belonging to the shower, those at the greater distance from the radiant point will have the longer trails

This observed effect is merely due to the perspective view of a number of meteors actually entering the atmosphere of the earth in parallel paths The accompanying figure represents the cause of the radiant point The circular segment *AA* represents the surface of the earth with the observer at *O*. *CC* represents the upper part of the atmosphere of the earth where the meteors first become visible, and *BB* the lower atmosphere where the meteors burn out and disappear *ab*, *cd*, *ef*, and *gh* represent the actual parallel paths of four meteors through this layer of atmosphere, and *ab'*, *cd'*, *ef'*, and *gh'* represent the paths as observed from *O* Examination of the figure will show that the apparent paths all radiate from a point in the direction *R*, the radiant



Explanation of radiant point

point, which is a direction parallel to that in which the meteors are actually entering and traveling through the atmosphere It will further be noted that the meteors more distant from the radiant point, e g, *ab'* and *gh'*, have apparently longer trails than the nearer ones, *cd'* and *ef'*

The location of the radiant point remains approximately fixed with reference to the **constellations** throughout the duration of the shower and is usually named for the constellation in which it appears, e g, the **Perseid** shower has its radiant in the constellation of **Perseus**, the **Leonids** in **Leo**, etc Occasionally a shower has a name indicating other characteristics, e g, the Leonid shower is sometimes referred to as the November meteors because the shower occurs during that month each year, and the **Andromedes** are frequently referred to as the **Bielids** because of their established relation with Biela's **Comet**

The various showers differ from each other, both in the number of members and in the characteristics of the individual members Probably one of the most famous showers on record is the Leonid shower of November 12, 1833, during which the number of meteors observed from some stations was estimated as 200,000 per hour for several hours

Many of the showers occur year after year with definite regularity of date Such periodic showers may be explained by huge numbers of meteors traveling about the **sun** in an **orbit** which intersects the orbit of the earth. Such a phenomenon has been referred to as a "flying gravel bank," but such a descriptive term is misleading because of the fact that few, if any, of the meteors are large enough to be considered as gravel pebbles In some cases, the meteors are distributed with fair uniformity all along the orbit, in which case the showers will recur on successive years with approximately the same frequency and appearance Such is the case with the Perseid shower, which may be observed during the latter part of July and the early part of August each year In other cases the meteors are concentrated in one or more large swarms with a few scattered members in between along the orbit This is the case with the Leonid shower

In a number of cases the orbits of meteor radiant points have been found to agree with orbits of comets In some cases the comets are still observed as comets, and in other cases the comet itself no longer appears At present, a large amount of work is being done in this interesting and important field. (W K G)

RADIATION. Electromagnetic Radiation; Thermal Radiation.

RADIATION PRESSURE. That **electromagnetic radiation** exerts a pressure upon any surface exposed to it was deduced theoretically by Maxwell in 1871, and proved experimentally by Lebedew in 1900 and by Nichols and Hull in 1901 The pressure is very feeble, but can be detected by allowing the radiation to fall upon a delicately poised vane of polished metal (See

Nichols' Radiometer.) It may be shown by the electromagnetic theory, by the **quantum theory**, or by **thermodynamic** reasoning making no assumption as to the nature of radiation, that the pressure against a surface exposed in a space traversed by radiation uniformly in all directions is equal to one-third the total radiant energy per unit volume within that space For **black-body** radiation, in equilibrium with the exposed surface, the energy density is, in accordance with the **Stefan-Boltzmann law**, equal to $\frac{4\sigma}{c}T^4$, in which σ is the Stefan-Boltzmann constant, c is the **electromagnetic constant**, and T is the absolute temperature of the space One-third of this energy density is equal to $2\,549 \times 10^{-15}\ T^4$ (ergs/cm^3), which is therefore the pressure in bars For example, at the boiling point of water ($T = 373\ 2°$), the pressure amounts to only 0 00005 dynes/cm^2 or about 3 pounds per square mile Such feeble pressures are, nevertheless, able to produce marked effects upon minute particles like gas ions and electrons, and are of importance in the theory of electron emissions from the sun, **cometary** matter, etc (L D W)

RADIATION PYROMETER. This instrument, of which there are several commercial designs, is based upon the fact that the intensity of the thermal radiation from a heated body depends in a systematic way upon the temperature of its surface The essential principle involves the focusing of the radiation upon a thermocouple or some other sensitive thermometric detector by means of a suitable mirror In one form the mirror is concave, producing a real image of a portion of the heated surface, in another it is a hollow cone, in which the radiation converges in an opening at the apex, where the thermocouple is placed All instruments of this type must be experimentally calibrated, as temperatures computed theoretically from the **Stefan-Boltzmann law** are, for various reasons, found to be in error A fundamental difficulty arises from the fact that no actual radiator is an ideal **black body**, and the emissive power of one surface differs from that of another at the same temperature This gives rise to the term "radiation temperature" as different from the actual temperature of the body under examination

In addition to the foregoing type, sometimes called the "total radiation pyrometer," the **spectrophotometer** or the spectroradiometer (an infrared spectrophotometer) is used in the case of very high temperatures, and the temperature deduced from the "peak" wave length in accordance with the Wien displacement law (See **Wien's Laws.**) In this way the surface temperature of the sun, giving out radiation with a maximum at a wave length of about 5,000 angstroms, has been found to be about 5750° C (L D W)

RADIATOR. A radiator is a surface especially heated for the emission of heat energy by radiation Most persons are familiar with the cast iron sectional type radiators which are associated with steam and hot air building-**heating systems** The hot water or steam on the inside of these sections produces, by **conduction**, a heated outer surface from which the heat is discharged to the air by radiation, aided by **convection** currents which rise over the heated surfaces It is possible that the greater part of the heat emission from such radiators is by convection rather than radiation Less artistic in appearance, but equally suitable for heating, are banks of steam pipes, in which the separate pipes are joined at the ends by U bends These are usually hung on the wall or suspended from the ceiling in industrial type buildings. More truly deserving of the name radiator is a domestic electrical appliance consisting of a heater element mounted at the focus of a parabolic reflector Practically all the heat delivered by this type of radiator is radiant in character Another type of radiator is the radiant type gas heater having a number of gas jets producing a flame which heats especially formed fire-clay elements held in it. As a result of the excellent combustion obtained, the fire-clay is heated to incandescence, and emits, radiantly, a great deal of heat **energy** Of course the products of combustion rising from the heater may deliver a considerable amount of heat by convection, but such heaters are essentially radiators

On the other hand, there are many devices called radiators in which radiation plays an insignificant part. Outstanding among these, perhaps, is the so-called automobile radiator, by means of which the heat absorbed by the cooling water is dissipated to the atmosphere If at any time there has been an appreciable amount of heat transfer accomplished by radiation, that is eliminated by recent trends towards enclosed, or nearly enclosed, radiators, in which the radiator core itself is concealed behind polished louvres The heat transfer in this case takes place mainly by convection, and the design incorporating cellular structure and forced draft is directed towards aiding this type of **heat transfer.** (F T M)

RADICAL AXIS OF TWO CIRCLES. Circle.

RADICAL CENTER OF THREE CIRCLES. Circle.

RADICAL EQUATIONS. A radical equation (or irrational equation) is an **equation** in which the unknown appears under a **radical** sign or with a **fractional exponent.**

Such an equation may usually be solved by squaring both sides of the equation one or more times, or raising both sides to the same other power one or more times, to remove the radicals (or fractional exponents), thus reducing the equation to a **polynomial equation.** Usually one radical should be isolated on one side of the equation before raising to the power

In this process of solution, **extraneous roots** may be introduced, hence the solution of each radical equation should be checked by substitution in the original equation, and any values not satisfying the equation should be rejected (L L S)

RADICALS. For chemical radicals, see **Chemical Composition.**

In mathematics, a radical is an indicated **root of a number**, usually a principal root, thus, the radical symbol $\sqrt[n]{a}$ means the principal n^{th} root of a

Operations with radicals are expressed by the formulas.

$$\sqrt[n]{a\,b} = \sqrt[n]{a}\cdot\sqrt[n]{b},$$

$$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}},$$

if a and b are positive (L L S)

'RADICLE. Seed.

RADIOACTINIUM Symbol RdAc A radioactive element of the **actinium** series See **Radioactive Changes.** (R K S)

RADIO. Radio Communication.

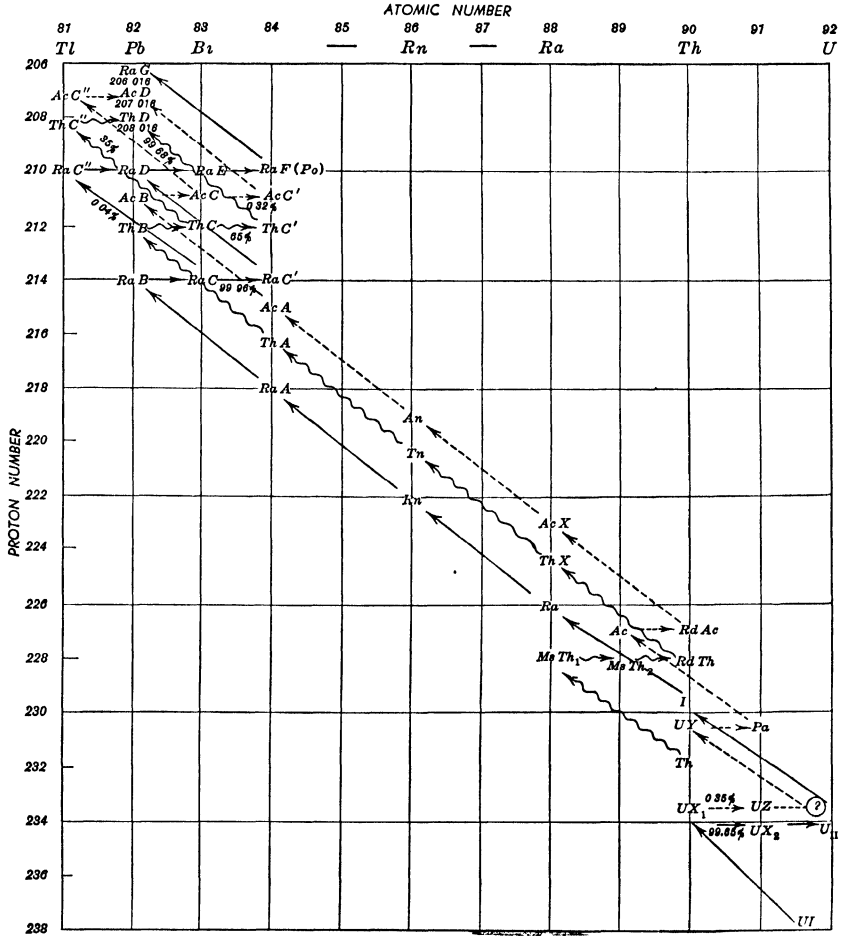
RADIOACTIVE CHANGES The phenomenon of radioactivity was discovered by Becquerel in 1896 by the effect produced on a photographic plate by **pitchblende** (**uranium** containing mineral) while wrapped in black paper in the dark. Soon after this, it was found that uranium minerals and uranium chemicals are radioactive, and strangely the minerals showed more radioactivity than could be accounted for by the uranium content About the same time there was discovered radioactivity of **thorium** minerals and thorium chemicals Uranium and thorium are the previously known chemical elements to which is attributable the phenomenon of radioactivity Later, it was found that **potassium** and **rubidium** possess a mild degree of radioactivity There is sufficient thorium element in the oxide of a gas mantle so that, if it is treated as Becquerel treated pitchblende, an image of the mantle web is obtained on the photographic plate.

The excess radioactivity of mineral over chemical uranium led P and Mme Curie to experiment with the mineral. For detecting the presence of radioactive substance a method was found in the discharge of a charged gold-leaf electroscope, which method also serves for the quantitative estimation of radioactivity by observation of the rate of drop of the gold-leaf. By separating into fractions and examination of each fraction by the electroscope, they found in the **bismuth** element fraction the first new radioactive element to be discovered. It was named **polonium** (1898). They found that polonium disappeared rapidly, half of its radioactivity vanished in about six months. The fraction containing **barium** element was also found by them to be radioactive. Repeated fractional crystallizations of the chloride and bromide solutions made possible the recovery by them of practically pure salt of the second new radioactive element. It was named **radium** (1898).

Radium is chemically similar to barium, displays a characteristic **spectrum**; its salts exhibit **phosphorescence** in the dark, a continual evolution of heat taking place sufficient in amount to raise the temperature of 100 times its own weight of water one degree C every hour, and many remarkable physical and physiological changes have been produced. Radium shows radioactivity a million times greater than an equal weight of uranium, and unlike polonium, suffers no measurable loss of radioactivity over a short period of time (in 1600 years the activity diminishes to one-half of the original). From solutions of radium salts, there is separable a radioactive gas, radium emanation, **radon**, which is a chemical element similar to **xenon** and disappears at a characteristic rate (in 3.8 days the activity diminishes to one-half of the original) with the simultaneous formation of another radioactive element, Radium A.

The series of radioactive transformations are displayed in graphical form below, and the constants of the radioactive elements in tabular form on page 922.

TRANSFORMATIONS OF RADIOACTIVE ELEMENTS



SOME CONSTANTS OF RADIOACTIVE ELEMENTS

Radioactive Element	Symbol	Type of Decay	Range (R) of Alpha Particle in Air at 15° C 760 mm pres	Absorption Coefficient (μ) of Beta Rays $cm^{-1}Al$	Number of Gamma Lines	Half-period (T)	
						Seconds	Equals
Actinium	Ac	β				$4\ 23 \times 10^8$	13 5 yr
" A	AcA	α	6 58			$2\ 10 \times 10^{-3}$	
" B	AcB	β		1000 (approx)		$2\ 16 \times 10^3$	36 0 min.
" C	AcC	α	5 51 5 09			130	2 16 min
" C'	AcC'	α(?)	(6 5?)			5×10^{-3} (approx)	
" C''	AcC''	β			3	286 283	4 76 min 4 71 min
" C' + C''		$\alpha + \beta$		29			
" D	AcD						
" lead	AcD						
" , prot- (below)	Pa						
" , radio-	RdAc						
" uranium	AcV						10^8 to 10^9 yr. (approx)
" X	AcX	α	4 37		5	$9\ 7 \times 10^5$	11 2 d
Actinon	An	α	5 79			3 92	
Ionium	Io	α	3 19			$2\ 6 \times 10^{12}$	$8\ 3 \times 10^4$ yr
Mesothorium 1	$MsTh_1$	β				$2\ 1 \times 10^8$	6 7 yr
" 2	$MsTh_2$	β		40 to 20	8	$2\ 21 \times 10^4$	6 13 hr
Polonium (Po)	RaF	α	3 87				
Potassium	K	β		74 49			
Protactinium	Pa	α	3 67	126	3	$1\ 01 \times 10^{12}$	$3\ 2 \times 10^4$ yr
Radio actinium	RdAc	α	4 68 4 34	175	10	$1\ 63 \times 10^8$	18 9 yr
Radiothorium	RdTh	α			2	$6\ 0 \times 10^7$	1 90 yr
Radium	Ra	α	3 39	312	1	$5\ 02 \times 10^{10}$	1590 yr
" A	RaA	α	4 72	420		183	3 05 min
" B	RaB	β		890 80 13	10	$1\ 61 \times 10^3$	26 8 min
" C	RaC	α	4 1			$1\ 18 \times 10^3$	19 7 min
" C'	RaC'	α	6 96			10^{-6} (approx)	
" C''	RaC''	β				79 2	1 32 min.
" C' + C''		$\alpha + \beta$		50 13	11		
" D	RaD	β		5500	1	$6\ 94 \times 10^8$	22 yr
" E	RaE	β		45 5		$4\ 26 \times 10^5$	4 9 d
" F	RaF	α				$1\ 21 \times 10^7$	140 d.
" G	RaG						
Radon	Rn	α	4 12			$3\ 305 \times 10^5$	3 825 d.
Rubidium	Rb	β		700 190 900			
Samarium	Sm	α	1 2			$3\ 8 \times 10^{19}$	$1\ 2 \times 10^{12}$ yr
Thorium	Th					$5\ 6 \times 10^{17}$	$1\ 8 \times 10^{10}$ yr.
" A	ThA			153	3	0 14	
" B	ThB	β		14 4		$3\ 82 \times 10^4$	10 6 hr
" C	ThC	$\alpha + \beta$				$3\ 63 \times 10^3$	60 5 min.
" C'	ThC'					10^{-9} (?) $< 10^{-6}$	
" C''	ThC''	β		21 6	11	186	3 1 min.
" D	ThD						
" , meso-1 (above)	$MsTh_1$						
" , meso-2 (above)	$MsTh_2$						
" lead	ThD						
" , radio-	RdTh						
" X	ThX	α			2	$3\ 14 \times 10^5$	3 64 d.
Thoron	Tn					54 5	
Uranium I	UI	α	2 67 2 73 3 12 3 28			$1\ 4 \times 10^{17}$	$4\ 4 \times 10^9$ yr
" II	UII	α				$9\ 4 \times 10^{12}$	3×10^5 yr.
" X_1	UX_1	β		460	1	$2\ 12 \times 10^6$	24 5 d
" X_2	UX_2	β		18		68 4	1 14 min.
" Y	UY	β		300 (approx)		$8\ 88 \times 10^4$	24 6 hr.
" Z	UZ	β		270 to 36		$2\ 4 \times 10^4$	6 7 hr.
" lead	RaG						

Of the various properties possessed by radioactive substances, the emitted radiations merit special attention. The radiations are of three types, alpha, beta, and gamma In kind they resemble **anode rays, cathode rays, x-rays,** respectively In this behavior towards **electrical** and **magnetic fields,** the resemblance is qualitatively complete (1) alpha rays are positively charged particles of mass 4 and slightly deflected by electrical and magnetic fields, (2) beta rays are negatively charged **electrons** of mass 1/1800 of that of the **hydrogen atom,** and largely deflected by electrical and magnetic fields, (3) gamma rays are undeflected by electrical and magnetic fields, and of **wave length** of the order of 10^{-8} to 10^{-9} centimeter

Alpha rays consist of particles shot off from the interior of the atoms of certain **elements** with a definite velocity and a definite range for each element The velocity is from 5 to 7 percent of that of **light.** The range is the distance traversed in a homogeneous medium before **absorption,** and is proportional to the cube of the velocity (Geiger and Nuttall, 1911) The penetrating power is the smallest of the three kinds of rays, the beta being of the order of 100 times, and the gamma rays 10,000 times more penetrating The alpha rays are particles of **helium** carrying two unit positive charges (He^{++}) Ramsay and Royds (1909) experimentally demonstrated that accumulated alpha particles, quite independently of the matter from which they have been expelled, consist of helium They sealed radon in a glass tube with wall so thin that the alpha particles passed through the wall into a surrounding vessel and after six days the whole spectrum of helium was observed Helium itself does not diffuse through such a wall Therefore alpha particles on losing their charge become ordinary helium This is the first instance of the *production of a known element* during radioactive transformation The loss of a single alpha particle by an atom leaves the residual atom four units less in **atomic weight** and two positive charges less in **valence** (Fajans, 1913) The shooting of alpha particles may be visibly registered by Crookes' spinthariscope, in which the tip of a wire, coated by a tiny amount of radium salt, is placed near a screen coated with **zinc** blende Viewed in the dark with a magnifying eyepiece, each alpha particle striking the zinc blende target emits a visible scintillation It is *as if* one were seeing atoms The detection and counting of single alpha particles was accomplished by Rutherford and Geiger (1908) by the deflection of an electrometer needle upon the arrival of each alpha particle in a gas at low pressure in an electric field somewhat below the sparking point

Beta rays are electrons shot off from the interior of the atom of certain elements with velocities varying almost up to that of light The loss of a single beta particle by an atom leaves the residual atom the same in atomic weight and one negative unit less in valence (Fajans, 1913)

Gamma rays are like x-rays but more penetrating The presence of gamma rays from 30 milligrams of radium can be observed in an **electroscope** after passing through 30 centimeters of iron (Rutherford) For the protection of the operator, radium is kept in **lead** outer containers or screened by lead sheets Gamma and beta rays usually accompany each other, and seem to be related in much the same ways as x-rays and cathode rays The wave length of gamma rays has been determined by diffraction through crystals, and ranges from about 10^{-8} centimeters for the *soft* gamma rays of radium B to 0.7×10^{-9} centimeters for the *hard* penetrating rays of radium C

The end-product of the uranium series indicates lead of atomic weight 206 Actually, uranium lead (RaG) has an atomic weight of 206.016 (from uranium I, 238.14, by loss of 8 alpha particles) The end point of the thorium series indicates lead of atomic weight 208. Actually thorium lead (ThD) has an atomic weight of 208.016 (from thorium 232.12, by loss of 6 alpha particles). The end point of the actinium series indicates lead of atomic weight 207 (stated as 207.016) Atomic weight determinations by Richards (1916) showed lead of North Carolina uranite of atomic weight 206.40, from Colorado carnotite 206.59, and from Joachimsthal pitchblende 206.57.

Radioactive Isotopes Mesothorium I and radium are chemically identical. It is possible to distinguish by chemical methods only 10 different radioactive elements, numbers 81, 82, 83, 84, 86, 88, 89, 90, 91, 92, while from radioactive evidence it appears that there are about 39 All of the elements in each of the 92 possible places of the Mendeleeff-Moseley classification of elements exhibit identical chemical properties Such elements—isotopic elements—are abundant among the radioactive elements

Artificial Disintegration of the Elements In 1919, Rutherford disintegrated the atom of nitrogen by bombardment with alpha particles fired off from Radium-C

Projectiles that have been used in atomic bombardment are·

1 Alpha Particles (mass 4, positive charge 2, helium).
2 **Protons** (mass 1, positive charge 1, hydrogen)
3 **Neutrons** (mass 1, no charge, hydrogen)
4 **Deuterons** (mass 2, positive charge 1, deuterium—heavy hydrogen)

In 1933, F and Mme Joliot produced artificially radioactive substances by bombardment of aluminum and boron by alpha particles, and observed protons, neutrons, and positive electrons (mass of electron, positive charge 1) (R K S)

RADIOACTIVE MINERALS. Strutt, one of the earliest workers in radioactive minerals, discovered that a specimen of **thorianite** which he tested contained two hundred and eighty million times as much helium as the same mineral could generate in a year, thus he assumed that the **igneous** rock in which thorianite formed must be two hundred eighty million years old **Uranium,** another radioactive substance, has been found to break up into **helium** and lead, one atom of uranium yielding eight atoms of helium and one atom of lead Since these stable atoms of helium and lead can be measured and compared with the amount of uranium which has not disintegrated, it is possible to determine how long it has been since the mineral was formed Analysis of radioactive minerals, by this method, collected from the oldest known granites of the **Archeozoic** intimate that the age of these rocks is approximately one billion eight hundred million years old One of the chief arguments in favor of the "radioactive method" for determining the age of the earth is that it checks when applied to the radioactive minerals collected from successively younger formations (R M F)

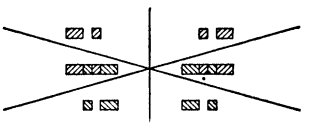
RADIO AIDS TO NAVIGATION. With the decrease in cost of equipment and the increase in reliability, effectiveness, and ease of operation, radio has become an important aid to navigation There are certain fundamental principles underlying all of the various applications of radio to increasing the safety of navigation, not only of the seas, but also of the air.

The fundamental principle of radio is that so-called **Hertzian waves** may be sent out from a sending station and received at a distant receiving station By using at the receiving station a certain particular type of antenna, known as the loop antenna, in connection with the ordinary receiving set, the direction from which signals are being received may be determined with an accuracy of one or two degrees of angle The use of the loop antenna in connection with the sending station will confine the transmitted signals to an **azimuthal** sector which increases in width by about ten miles for every hundred miles of distance from the transmitter

The particular uses of these basic principles in connection with problems of navigation will be found dis-

cussed under **radio bearings, radio compass,** and **radio beacons.** (W K G)

RADIO BEACON. The radio beacon is one of the **radio aids to navigation** which serves the purpose of guiding a vessel directly toward or away from a given sending station The sending station sends out, by a system of loop antennas, a series of "a's" (dot dash) and "n's" (dash dot) in such a manner that they blend into a continual long dash or code letter "T" along certain fundamental directions The system of sector sending is



Radio beacon.

illustrated in the accompanying figure The direction along which the long dash is received (the "T sector") is selected in the case of ocean navigation with reference to dangers to safe navigation, and, in the case of aircraft, with reference to nearby beacons

In case a vessel is approaching a radio beacon, so long as a series of long dashes are heard in the receiver, the navigator knows that he is approaching along the true course If a series of a's (dot dash) is heard, he knows he is to the right of the true course (in the "a sector"), or if a series of n's (dash dot) is heard, he knows that he is to the left In case there is a slight wavering in the long dash the navigator knows that he is within the true course sector, but is slightly off the central line

The intensity of the radio signals and the narrowness of the true course sector are indications of the distance of the vessel from the beacon For further assistance to navigators in determining the distance of the beacon, many stations send out both submarine and audible signals simultaneously with the sending of a radio signal The difference in velocity between the radio and either the submarine or audible signal may be used to determine with considerable precision the distance between the receiver and sending station Instruments have been constructed which will automatically convert the difference in time of reception of the various signals into distance

The direction of the radio beacon beam is a **great circle** distance and, while it is the shortest distance from the sender to the receiver, it may not be a practical course for a navigator to follow, because of intervening land, etc When following a radio beacon course close to land a navigator must exert great care not to be led into danger Furthermore, care must be taken not to follow the beacon for too long a period In the case of the sinking of the Nantucket Light vessel by an incoming steamer, the navigating officer of the steamer followed the radio beacon directly into the sending station itself (W K G)

RADIO BEARINGS. A radio bearing is the direction from which any radio signal is received Radio bearings may be taken by any ship equipped with the **radio aid to navigation** known as the loop antenna All that is necessary is to adjust the loop antenna until the signal is of maximum, or minimum, intensity and then from a direction circle attached to the loop determine the direction from which the signal is coming There is, at times, an ambiguity of 180° in direction thus determined, but the circumstances of the problem usually will remove the difficulty In case a real ambiguity exists the vessel may change course to head along the determined line and the increase or decrease in intensity of the signals will tell the true direction of the sending station

In determining a **line of position** from a radio bearing care must be taken on account of the fact that the radio wave travels along a great circle If the line of position is to be plotted on a **chart,** either a **great circle chart** must be used, or a table used to convert great circle bearings to **mercator** values In case the bearing is taken of a station which is well inland, caution must also be exercised because of the fact that the direction of the radio beam will frequently be distorted by local conditions in the vicinity of the sending station (W K G)

RADIO COMMUNICATION. Communication between distant points not directly connected by an electrical conductor may be accomplished by electromagnetic waves radiated through space Thus radio communication utilizes radiated energy instead of the conducted energy of the wired methods Obvious benefits of the radio method are the elimination of the expense of installation and upkeep of a wire communication system, and the communication between points difficult of access by wired systems Furthermore, since energy may be radiated in all directions in space, broadcasting to large numbers of persons is simpler Radiated electro-magnetic waves can be used for communication purposes in three ways First, they may be used to create a monotone signal of dots and dashes comprising a code This is **wireless telegraphy** It has certain important commercial and governmental uses, but is not suitable for broadcasting, as it must be interpreted by trained operators Secondly, electro-magnetic waves may be modulated so that they carry the electrical equivalent of sound waves At the receiver they are caused to reproduce the original sound, whether it was voice or music This is the field of radio telephony and broadcasting, one which more than any other has entered intimately into the life of the average citizen Thirdly, it is possible to transmit, by means of these waves, electrical pulses which will recreate at the point of reception, a scene which originated at the transmitter This **television** process is now the subject of considerable experimentation, and its present approach to commercially satisfactory perfection indicates that it may, in the future, be expected to become an important phase of radio.

There are three essentials to radio communication These are, first, **transmitter,** or source of electro-magnetic radiation second, the radio waves themselves, travelling between the transmitter and receiver, and thirdly, the **receiver,** which can receive and interpret the electrical pulses either as code, sound, or scene A requisite to radiation of electro-magnetic waves is a source of alternating current of extremely high frequency The radiation of energy from power lines which carry alternating current at 60 cycles per second is negligible because of the comparatively low frequency When, however, a current oscillates in a wire suitably arranged for radiation (antenna) at a frequency of, say, 1,000 kilocycles (one "kilocycle," by common usage, is 1,000 cycles per second), it is possible to radiate considerable power into space in the form of electro-magnetic waves, because radiated power increases as the square of its frequency Furthermore, since at the higher frequencies a smaller antenna is suitable for radiating the energy, it is natural to expect high frequencies to be employed for all radio communication In any transmitter there must be this source of high frequency current Originally rotary spark gaps and vibrator coils were employed, but at present the vacuum tube is generally used as an **oscillator** The frequency of the oscillator is kept under close control by adjusting the characteristics of the circuit incorporating it, so that there may be little or no interference between the waves sent out by different transmitting systems That is, at the receiving station the electrical circuit employed may be "tuned" to the frequency of one particular transmitter, thus excluding all other wave trains Between the oscillator and the radiating **antenna,** the

transmitter must have a signalling system. For code this might be as simple as a means for interrupting at will the oscillating current In telephony, there will be provided some way of securing **modulation** of the high frequency carrier wave with the sound wave. The strength of the electric currents created in a microphone by the direct action of the sound waves may be amplified and strengthened before being used to modulate the carrier wave, and the modulated wave itself may be strengthened by amplifying These **amplifiers** are generally **vacuum tubes**, and, depending on the position relative to the modulator, are designated as **audio frequency** or **radio frequency** amplifiers Ultimately the intensified high frequency currents are sent into the antenna system where they produce the radio waves For broadcasting purposes these waves flash off into space in all directions, but for commercial telephony or telegraphy, some degree of directional control is possible by special arrangements of the antenna

Radio wave propagation from a simple antenna is an action which is similar to the waves created by dropping a pebble into a quiet pool Concentric waves travel outwards from the antenna, decreasing in intensity, very rapidly at first, then more slowly, as they travel further from the antenna Their speed of travel is probably the same as the speed of light, and they possess the property of being able to pass through and around most obstacles Atmospheric conditions, however, can affect their travel, as can also sunlight and water But while the waves may become successively ever more attenuated, they retain their original frequency

The third essential to radio communication mentioned above, is the receiver A receiver consists of an antenna suitably arranged to receive the impressed voltages of the electro-magnetic waves which reach it from the transmitting antenna Then, since the receiver must be selective, so that it will receive the output of one only of several possible transmitters, means must be provided to "tune" it to the frequency of the selected transmitter The received signal is very weak, and it must be strengthened by being passed through one or more stages of radio and audio frequency amplification Between the radio and audio amplification occurs the action of **detection**, or demodulation, **separating** the carrier wave from the electrical wave which mirrors the original voice or sound wave Finally, the amplified voice current is fed into a **speaker** which recreates the original sound Since the velocity of propagation of electro-magnetic waves is of the order of 186,000 miles per second, radio broadcasting creates peculiar situations such as the following If a certain public concert is being broadcast, an individual sitting at home, say one hundred miles away, listening to his radio, may receive the music before members of the direct audience This is because the latter are receiving music entirely by the relatively slow moving sound waves

The above discussion, and the related cross-references, can convey only a faint idea of the electrical complexity of modern radio circuits, and give no hint at all of the problems which have arisen from the wide-spread commercialization of this form of communication Although in recent years radio has become an important feature of marine and naval operations (See **Radio Beacon**) and it is being relied on to an ever increasing extent to secure safety in aerial transportation (See **Blind Flight**), and although there has been developed for public use commercial telephonic service between ship and shore, and between continent and continent, and although radio has been employed for many other interesting and useful services, it is proposed here to dwell only on some of the problems associated with the commercialization of radio broadcasting

The rise of radio broadcasting in the early 1920's was phenomenal. An important new industry mushroomed into existence in this country almost overnight following the initiation of radio broadcasting service by station KDKA in 1920 Hundreds of firms began the manufacture of receiving sets, thousands of retailers opened up stores for sale and distribution of the product, broadcasting stations were set up everywhere, and the principal chain networks were organized People everywhere purchased receiving sets, and, with adoption by station WEAF of the toll broadcasting policy, the introductory phase of broadcasting by manufacturers of radio equipment in order to stimulate sales was over, and the sponsored program appeared The commercial possibilities of the radio broadcasting station as an advertising medium attracted a large amount of capital into the field, and soon there was a chaotic condition of interference between stations

Radio broadcasting developed using long waves, that is, waves having frequencies between 550 and 1500 kilocycles To avoid interference between stations, a clear channel of a **band of frequencies** of 10 kilocycles should be provided each station However, in the broadcast range there are only 96 such channels, and by 1927 there were several hundred broadcasting stations attempting to use them. At that time the situation obviously required governmental control, and since all radio communication may well be considered intra-state, the Government created the Federal Radio Commission to remedy the serious interference which existed among the 600 or more stations In order to accommodate the large number of stations to the available channels in such a way as to reduce interference, so that the owner of a receiver could obtain satisfactory use from it the Commission had to assign definitely the frequency and power to be used by the different stations, and rigidly control the number of new stations which could be put in service from time to time Furthermore, it was found necessary where the facilities offered by a station duplicated that of another to cause them to divide their broadcasting time Also, low power stations for local broadcasting were frequently required to terminate their activities at sundown

During the period of rapid growth of broadcasting, the band of frequencies mentioned above was considered to be not only the most suitable, but also the only practical frequency range for general broadcasting Since that time more information as to peculiarities or virtues of short wave or high frequency radio waves has been accumulated, and it has been found that the high frequency waves are more suitable for certain purposes Nevertheless relief of the crowded broadcast channels is apparently not to be obtained through extension of the broadcast band of frequencies, because of the need of the available channels, both above 1500 kilocycles and below 550, for numerous other important services, i e, radio telegraph, police systems, radio amateur work, television, and experimentation Also, at the present time there are many sets already marketed and in use whose capacity is limited to the ordinary broadcast band That limits the commercial incentive for investing in stations to broadcast outside of the ordinary channels

RADIO COMPASS. The term radio compass is one which is loosely applied to all of the various **radio aids to navigation** which employ the directional characteristics of the loop antenna Many navigators refer to the loop antenna itself as the radio compass

Before loop antennas were carried by vessels themselves the term radio compass was employed in connection with the determination of the direction of a vessel from a shore station The various governments of the world maintain along the coast a number of so-called radio compass stations which are prepared to give, on request, the direction of any calling vessel from the station If a navigator obtains radio compass directions from two or more radio compass stations, he has at his disposal two **lines of position**, the **fix**, or point of intersection, of which will give him his position The usual precautions relative to the use of **radio bearings** must be taken.

Many governmental radio compass stations are equipped, not only to give the direction of a ship from the station, but also to give the true position of the ship calling for information At such stations a number of receiving stations are employed, scattered for a considerable distance along the coast line Each of these substations is equipped with a loop antenna and is connected with a central station by private telephone The radio bearing of the ship calling for information is taken at each one of the substations and telephoned to the central station At the central station a large plotting board is located and on this board the various bearings of the ship, after being properly corrected, are laid off and the true position of the calling ship determined and sent out to the vessel (W K G)

RADIO FREQUENCY. The frequency of the **electromagnetic** waves used as the carrier of wireless communication is known as radio frequency This frequency is very high, as compared to audible frequencies, ranging, usually, between 500,000 and 1,600,000 cycles per second for commercial broadcasting Lower frequencies than these are used for amateur wireless telephony and commercial code communication (F T M)

RADIOLARIA. Plasmodroma.

RADIOLARIAN OOZE. Oceanic Deposits.

RADIOMETER. Thermal Radiation: Crookes Radiometer; Nichols Radiometer.

RADIOMICROMETER. A very sensitive **thermel,** adapted to the detection of feeble thermal radiation, devised by C V Boys (1889) It consists of a small bismuth-antimony thermocouple short-circuited by a narrow, oblong loop of copper wire and suspended by a quartz fiber between the poles of a strong permanent magnet The couple is surrounded by a thick housing of soft iron to shield it from magnetic disturbances and stray radiation The radiation to be measured is admitted through an opening in this shield and falls on a tiny copper disk soldered to the couple A very small amount of radiation communicates heat enough to generate a current in the loop and cause it to turn in the magnetic field The deflection is observed by means of a mirror attached to the loop, which reads on a scale like a **galvanometer** By using a large lens to concentrate the rays, Boys was able to detect the radiation from a candle more than two miles distant. (L D.W)

RADIO RECEIVER. See **Receiver.**

RADIOTHORIUM. Symbol RdTh A radioactive element of the **thorium** series See **Radioactive Changes.** (R K S)

RADIUM. Symbol Ra Atomic number 88 Atomic weight 225 97 Melting point 960° C

Radium metal is white, rapidly oxidized in air, decomposes water, and in the metallic state is a curiosity. Radium is usually handled as the chloride or bromide, either as solid or in solution Its most remarkable property is its radioactivity, which decreases about 1 per cent in 25 years Radium element evolves heat continuously, 0 132 calories per hour per milligram of radium when the decomposition products are retained, and the temperature of radium salts remains about 5° C. above the surroundings Discovered by P and Mme Curie in 1898 (See **Radioactive Changes.**)

Radium occurs in **pitchblende,** and in **carnotite** along with **uranium.** Radium was first obtained from the uranium residues of pitchblende of Joachimsthal, Czechoslovakia, later from carnotite of southwestern Colorado and eastern Utah. Richer ores have been found more recently in Belgian Congo, and in the Great Bear region of north-western **Canada.**

Radium is formed by the radioactive transformation of uranium—about 3,000,000 parts of uranium being accompanied in nature by 1 part of radium—, and spontaneously generates **radon** gas—about 100 cubic millimeters of radon per day per gram of radium

Chemically related to **barium,** radium is recovered from its ores by addition of barium salt, followed by treatment as for recovery of barium, usually as the sulfate The sulfates of barium and of radium are insoluble in most chemicals, so they are transformed into **carbonate** or **sulfide,** both of which are readily soluble in **hydrochloric acid.** Separation from barium is accomplished by fractional crystallization of the chlorides (or bromides, or hydroxides) Dry, concentrated radium salts are preserved in sealed glass tubes, which are periodically opened by experienced workers to relieve the pressure The glass tubes are kept in lead shields

Radium chloride ($RaCl_2$) and radium bromide ($RaBr_2$) are less soluble and radium hydroxide ($Ra(OH)_2$) more soluble than the corresponding barium compounds

Radium causes serious flesh burns due to its radioactivity, but under proper control is used in the treatment of certain forms of **cancer** (R K S)

RADIUS. In zoology, the term radius has two common meanings 1 It is a principal radiating division of the body of an **echinoderm.** In the starfishes and other forms with projecting arms, the arm or ray is the most conspicuous part of a radius In more compact forms like the sea urchins each radius is a segment of the body 2 It also denotes a bone of the forearm or lower foreleg of **vertebrates.**

For the use of the term radius in mathematics, see **Circle** and **Polar Coördinates.** (A W.L)

RADIUS OF CURVATURE. In mathematical terms the radius of curvature of a curve is the reciprocal of the curvature k, that is $\frac{1}{k}$, in which k is equal to the change in the direction of a curve per unit length of arc The radius of curvature of a straight line is infinite The radius of a **circle** is the radius of curvature of the circular curve The radius of curvature of an **ellipse, parabola, hyperbola,** etc (all mathematical curves), is a variable which depends upon the sharpness (curvature) at a particular point on a curve If these curves are assumed to be made up of a number of infinitely short, connected, circular arcs, the radius of curvature might be defined, in simple terms, as the radius of an infinitely short, circular arc located at the point where the radius of curvature is desired (See also **Curvature of a Plane Curve.**) (C W C)

RADIUS OF GYRATION. The radius of gyration of an area in respect to a particular axis is the square root of the quotient of the **moment of inertia** divided by the area It is the distance at which the entire area must be assumed to be concentrated in order that the product of the area and the square of this distance will equal the moment of inertia of the actual area about the given axis The numerical value of the radius of gyration, k, is given by the following formula in which I is the moment of inertia and A, the area.

$$k = \sqrt{\frac{I}{A}}.$$

The radius of gyration of a **mass** is similar except that the moment of inertia of the mass is involved (C W C)

RADIUS VECTOR OF A POINT. Polar Coordinates in a Plane.

RADON. Symbol Rn. Atomic number 86. Atomic weight 222. Density 9 72 grams per liter, 0° C, 760 mm, or 7 5 when air equals 1 00 Melting point. —110° C.

Radon is a colorless gas, radioactive, and formed by **radioactive** transformation of radium Radon, **thoron** and actinon are isotopes Discovered by Dorn in 1900 in the radioactive transformation of **radium,** and thoron by Rutherford in 1900 in the radioactive transformation of thorium Radon decays to one-half its radioactivity in about 4 days. Radon is obtained by bubbling air through a radium salt solution, and collecting the gas plus air See **Radioactive Changes** (R K S)

RADULA. A horny strip in the floor of the mouth of a **snail.** It bears many rows of minute teeth and is used for scraping up food The radula is developed in a ventral pouch of the oral cavity known as the radula sac. (A W L)

RAFFIA. *Raphia Ruffia* Palmae This African **palm** tree has leaves of great length, sometimes as much as 25 feet The leaf epidermis may be removed in strips. These strips, known as raffia, have been used in basket-work and for tying up plants. (R M W)

RAFINESQUINA. Invertebrate Paleontology.

RAGLANITE. A term proposed by Adams and Barlow, in 1910, for a **facies** of **nepheline-syenite** also containing aboundant **oligoclase feldspar** and the accessory minerals, **mica, calcite, apatite and magnetite.** (R M F)

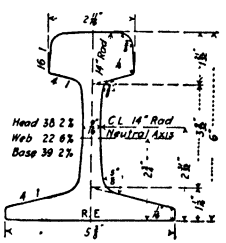
RAGWEED. *Ambrosia artemisiaefolia* **Composite Family.**

RAIL. Aves, Gruiformes Long-legged marsh birds (**Aves**) of wide distribution They have moderate to long and slender beaks, rather small wings, and a short tail North America has several species, including the clapper, *Rallus longirostris,* Virginia, *R limicola,* and sora rail, *Porzana porzana* The corncrake, *Crex crex,* is a Eurasian species which reaches North America occasionally In New Zealand the group is represented by the large weka rails which do not fly, although they have wings (A W L)

RAILWAY. The railway is a transportation agency which, in spite of the growing importance of other transportation systems (bus, truck, aircraft), is the principal method of transporting goods over long distances The activities connected with the operation of railways constitute one of the leading industries of the United States by virtue of the services rendered, the capital invested, and the personnel employed The operation of the railway, furthermore, may and does affect practically all persons living in its sphere of influence, because of the dependence upon transportation for the distribution of goods under the system of manufacture used in a progressive and mechanized civilization such as ours The services of the railway consist of the movement, for a price as expressed by the current rate, of freight or passenger traffic From the standpoint of total receipts, freight is the more important The speed with which a railway can transport goods with a small expenditure of energy means that manufacture can be specialized geographically Large scale production, and a considerable division of labor, are possible These things have contributed in a large degree to making many commodities available at costs which would not be possible under any other system of production The carrying of passengers is of greater importance to the nation than the net receipts of passenger traffic to the railway would indicate The availability of definite scheduled transportation to the people as a whole, which transportation is rarely affected by season or weather, has an important economic and political connotation. Suburban passenger railway facilities have grown to be essential to the life of a metropolis, the housing facilities of which are entirely inadequate to its workers, who therefore, by necessity or choice, reside in suburbs which are swiftly and surely connected with the metropolis by the railway Mobility of labor, rapid transportation of the mail, and carrying of commodities at a premium rate by the express business, are further important branches of railway activity. The railways of the United States are privately owned under the supervision of the Federal body for the control of interstate commerce Although there are nearly 2,000 separate companies divided into three classes by the range of their annual revenue, practically all of the transportation based on ton or passenger mileage is controlled by the class 1 companies, of which there are about 175 organizations A class 1 railway is that having an annual revenue in excess of one million dollars

The railway proper consists of a continuous strip of ground called the right of way, varying from 60 to 150 feet in width, which extends, with a minimum of curves and departures, in a direct course between centers of population, business, or industry which it serves. On this right of way there is a smooth graded base called the subgrade, upon which is laid **ballast** consisting of cinders or crushed stone The cross ties which support the rails are usually laid on the subgrade, and afterwards lifted into position when the ballast has been placed. The gradient employed in rolling or mountainous country is, of necessity, a compromise between cost of construction and cost of operation The steeper the ruling gradient of a line, the more powerful the tractive equipment must be, or the smaller the train size On the other hand, the cost of reducing the gradient may, in rugged country, become extremely high One cut-off constructed by a railway company which was able to reduce its ruling gradient from 1 2 percent to 0 7 percent is said to have cost approximately $300,000 per mile. This expenditure was justified since it reduced the grade and distance between termini on a trunk line which carried heavy traffic

The wooden cross tie has become standard in this country, although substitutes in the form of concrete or stone have been tried New wooden ties are usually creosoted to lengthen their life, and are approximately 7 inches x 9 inches x 8 feet 6 inches long They are spaced a little under 2 feet on centers, and on them are laid two parallel steel rails which are firmly spiked to each tie The hard smooth way provided by the steel rail and the minimum rolling friction of steel wheels on these rails accounts for the extremely low haulage costs per ton mile on railways The T-rail is the standard for open track work These rails are rolled in steel rolling mills to standard sections the size of which is denoted by the weight per yard of run A 60-lb rail is a relatively light one, and most of the trackage of this country will be found from this weight upwards to 150 lbs The present standards of the American Railway Engineering Association are 100, 110, and 131 pound rails The rails are manufactured in lengths of between 30 and 40 feet, and are coupled together by splice plates of several different designs At regular intervals these couplings must permit **expansion** and contraction Where the rails bear on the cross ties, there will be wear When treated ties having a long life expectancy are used, steel tie plates are installed to relieve the cross tie of rail wear The plate is held securely to the tie and the relative motion, caused by traction or expansion and contraction of the rails, is taken up between the plate and rail



Rail section.

Principal routes are nearly all double tracked The rapid movement of trains, operation of automatic **block**

signalling, and freedom from collision hazards, are so superior with the double tracked arrangement that the additional expense is justified where a large amount of traffic is carried over the railway. Feeder and branch lines are largely single track, although in many cases where it is thought that a large traffic will eventually develop, the subgrade of the right of way is prepared in sufficient width for double tracking Standard practice on double tracked roads is for the train to advance on the right-hand track In a few instances trunk lines have triple or quadruple tracks.

Necessary features of the right of way are those structures which are required to carry the railway over obstacles or depressions such as highways, rivers, streams, valleys The use of **bridges** and trestles, tunnels, **culverts**, and other auxiliary structures, is inevitable in a railway having the trackage implied by membership in the class I railway group Such structures are independently treated in this work

The railway just described is served by terminal facilities and intermediate stations The facilities of the intermediate stations will depend upon the importance of the stop Usually this may be gaged roughly by the population of the locale The facilities provided consist ordinarily of a station house and side track to which cars may be shunted for unloading or loading of bulk freight, such as sand, lumber, coal, etc Packaged and crated commodities are handled in a portion of the station set aside for that purpose, or in a separate freight warehouse The intermediate station contains a waiting room for passengers, and an office from which passenger tickets are dispensed, and which often serves as the base for freight, express, and telegraph services, all of which are concentrated in the hands of one station agent in the small, unimportant stops, but which may be divided among a larger personnel in the case of a city. Express and mail handling facilities and conveniences for passenger loading are also part of the station equipment Under the head of terminal facilities come also those mentioned for the intermediate stops, although greatly increased and amplified in service to the general public Larger passenger stations offering diversified services, greater division of labor, and more attention to architectural embellishment, characterize the terminal passenger station Space is provided also for the executive branch Long railways are subdivided into divisions with termini intermediate between the divisions as well as at the ends of the line These termini are important servicing points for the mobile equipment From the standpoint of the rolling stock, the railway terminal is a "yard" in which the passenger and freight cars may be stored, and an engine house to perform a similar function for the locomotives The yard is an area of ground covered by long parallel lines of track as close together as is possible, and equipped with switches and cross-overs so that all tracks may be connected with the main railway The rolling stock not in use, or awaiting use, can be shunted to these yards Car maintenance and overhaul shops are located alongside The engine house is provided with stalls for the locomotives and shop facilities for normal repair work and servicing facilities for coaling, cleaning, inspection, and oiling These houses are either rectangular in form, having a transfer table which rolls the entire length of the house and thus can serve a long line of parallel stalls More frequently they are constructed in circular form, hence the name roundhouse In a roundhouse the stalls are ranged radially from a central point at which is located a turntable The incoming **locomotive** is rolled onto this turntable, which is then turned until the turntable track aligns with the short section of track leading to the stall.

The economic operation of a railway system is a very complex affair, reaching into practically all walks of life. The technical maintenance and operation is a subject more appropriate to the nature of this work. This activity consists of the scheduling of trains, and the maintenance of them on schedule; servicing of the equipment, both stationary and mobile, so that it will be available for use when needed; and the operation of the physical system, safely and reliably, yet with train speeds as high as possible, for one of the essentials of the service rendered by the railway is fast transportation, whether it be that of freight or of passengers. The activities of technical maintenance must be carried out in a manner to maintain the system against the continuous tendency to deteriorate through such factors as floods, washouts, rust, dirt, rot, snow, friction, wear It also will include the installation and operation of signalling systems, which have been found necessary, even on double tracked roads, if heavy traffic schedules are to be maintained The subject is discussed in more detail under **railway signalling.** Rolling stock must be periodically serviced, at which time work like greasing of bearings, cleaning of upholstery, repair and cleaning of box cars, painting of steel cars, replacement of wheels and brakes, etc, is done A steam **locomotive,** consisting, as it does, of an entire steam power plant on wheels, is a complicated piece of equipment having many points of wear, and many requirements of adjustment The vibratory nature of its motion when in use, coupled with the presence of high temperatures, high pressures, ash, and smoke, make for expensive but necessary periodic overhauls, and for close inspections at the end of every run The constant pounding of heavy loads over the track may loosen spikes, crack rail joints, loosen bonds, and these defects can, if unattended, lead directly and rapidly to a serious accident Hence it is necessary to have a large force going over the right of way constantly, for inspection and repairs Certain auxiliary services of a special nature are exemplified by the special ballast cleaner trains and by cars fitted with apparatus to detect "rail cancer" Special snow handling equipment is necessary on railways which are not located in a southern climate. (F T M)

RAILWAY SIGNALLING. The **momentum** arising from the **velocity** and **mass** of a train requires a signalling system for the safety and convenience of operation of a railway train Railway signalling, which displays signals designed to prevent more than one train occupying a certain section of track at a time, permits the operation of rolling stock at much higher speeds than would be possible, with safety, if the presence of other trains had to be detected visually by the engineman Furthermore, passenger trains may be operated more smoothly if the engineman has the information given by the signalling system The railway automatic block signal system has become standard equipment on the railways of this country

Railway signalling embodies many functions besides the automatic block, but except for the following brief mention, these other classes of signalling are not treated here A railway system employs signals for advising the engineman when orders from train dispatchers are ready for him Special signals are employed for controlling railway traffic at junctions, grade crossings, drawbridges, etc, and other fixed or manually operated signals, such as signs along the right of way, indicate yard limits or speed limits The trainmen make use of torpedoes, flags, or lanterns as signalling devices Block signals are not always automatic, since many street car systems have used manually operated block signals for suburban lines With the disappearance of these extended street railways before the competition of buses, the examples of manually operated block signals have dwindled.

The block signal itself is the physical mechanism employed to signal the condition of the track ahead to the engineman. This it does by a mechanism which conveys the information visually. An apparatus having a semaphore arm and lights is mounted alongside the track on the right of way, in clear view of the engineman. The trackage of the railway is divided electrically into blocks of from 1 to 5 miles in length. On de-

scending grades the blocks are made longer than on rising grades, since a greater distance is required in which to stop a train The shorter the block the more trains the system can handle, but the signalling system becomes more expensive, and the average speed of operation may

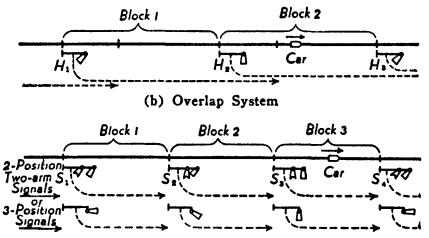


Figure 1 Block signal systems

be curtailed The system used for dividing the line into blocks may be (a) simple blocks (not shown), one beginning where the other ends, each block covered by one block signal, (b) an overlap system, in which the blocks overlap by a distance equal to the space required for a train to stop after application of brakes, (c) the double semaphore system, in which the condition not only of the block being entered is being shown, but that of the one next ahead The semaphores in this system are known as the home and distant signals They are distinguished during the daytime by the position and painting of the semaphore arm, and at night by the relative position of the lights on the pole The double

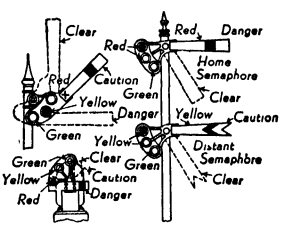


Figure 2

semaphore is replaceable by a single semaphore which operates at three positions, clear, caution, and stop, shown by vertical, 45°, and horizontal positions of the semaphore These systems are shown in Figures 1 and 2 The basis of the automatic block signal system is the track circuit, by means of which the train automatically operates the signals by electricity As shown in Figure 3, the block is a section of track in which the rails are insulated from those in the adjoining block by insulating track joints The rail joints within the block are bonded electrically by bridging them with galvanized wire For steam roads the track circuit is low voltage direct current, but in the case of electric railways, in which the track forms a return circuit for the power current, it is not possible to insulate the blocks, and alternating track circuits must be used for automatic block signalling In the case of alternating current electric railways, the blocks must be laid out with the use of alternating current track circuits of much higher frequency than the power current. Figure 3 illustrates

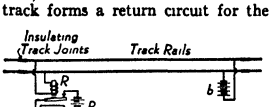


Figure 3.

automatic block signal connections for a steam road A track circuit battery *B* maintains a current through the track relay *R* The armature of this relay closes the semaphore circuit so that the battery *B* holds the semaphore arm clear When a train enters the block the wheels and axle short circuit the relay coil and the battery *B* is disconnected from the semaphore holding solenoid, causing it to drop to horizontal position Electrically the track circuits are more complicated when the home and distant signalling is used, and polarized relays are used to distinguish between the impulses received from the two blocks (F T M)

RAINBOW. Looking into a spray or mist which is illuminated by strong white light from behind his own back, an observer sees one and sometimes two sets of concentric, spectrally colored rings, called a rainbow. If two are visible, the inner, called the "primary bow," is brighter and narrower than the outer or "secondary bow" In the primary, the red is on the outside edge and violet on the inside, the order in the secondary being the reverse of this The colors are not so pure as in a spectrum, because each wave length extends over a wide radial range, the rainbow itself being made up of the fairly pronounced intensity maxima

The colors of the rainbow are caused by the refractive dispersion of the spherical water drops Figures 1 and 2 show, respectively, the dispersion composing the primary

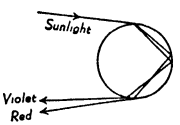


Figure 1.

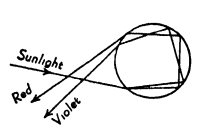


Figure 2.

Formation of primary bow (left) and secondary bow (right) Circles represent raindrops

and the secondary bow. The figures also explain why the order of colors is reversed, and show that only the highest drops in the primary and the lowest in the secondary refract red light to the eye The two internal reflections, with consequently greater loss of light, explain why the secondary bow is fainter The center of the ring system is exactly opposite the source of light; so that natural rainbows are seen only when the sun is near the horizon, unless the observer is elevated high above the surrounding country and can look obliquely downward into the rain. (L D W.)

RAM. The male **sheep.**

RAMAN EFFECT. A phenomenon involved in the scattering of light from the molecules of transparent gases, liquids, and solids, discovered by the Indian physicist, C V Raman, in 1928 It consists in the appearance of extra spectrum lines in the vicinity of each prominent line of the spectrum of the incident light For example, if light from a **mercury arc** shines into carbon tetrachloride (CCl_4, a liquid), some of the violet lines in the scattered light, especially the one at 4358 angstroms, have associated with them a fairly distinct "Raman spectrum," consisting of several lines, some of which are of longer, some of shorter, wave length than the much brighter, unaltered line The shorter, usually faint, are called "anti-Stokes" lines, because they violate the law of Stokes (See **Luminescence**)

The Raman spectrum for a given line is characteristic of the scattering substance, and is made up of lines somewhat more diffuse, or "broader," than the corresponding incident line Water gives broad bands The phenomenon extends into the x-ray region, and is somewhat analogous to the **Compton effect,** in which, however, the scattering particles are electrons instead of molecules The Raman effect is explained as due to the absorption or contribution of energy from or to the quantum

of incident radiation by the scattering molecule, the result being a decrease or an increase in the frequency of the quantum, with corresponding change of wave length The phenomenon was predicted by Kramer four years prior to its discovery. (L D W)

RAMIE. Boehmeria nivea.

RANG. The term for a sub-division of the **igneous rocks** according to their classification by Cross, Iddings, Pirrson and Washington (R M F)

RANKINE CYCLE Rankine's modification of the Carnot cycle is the basis of the modern steam plant cycle even though the Rankine cycle itself has been

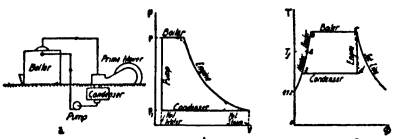


Figure 1

modified and changed with the passing of time The elements of the Rankine vapor cycle are shown in Figure 1(a) It consists essentially of a **boiler** which receives **feed water** from a **pump**, a prime mover to expand the steam **adiabatically**, a **condenser** to receive the exhaust steam from the **engine** and reduce it to water, and a pump to overcome the pressure difference between boiler and condenser In Figure 2 is shown a common form of application of the Rankine vapor cycle This plant is characterized by atmospheric exhaust, use of a portion

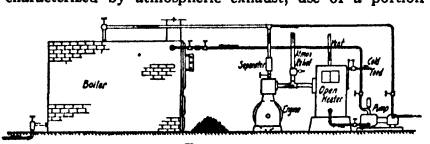


Figure 2

of the exhaust for feed water heating in an open heater, and a reciprocating steam-driven boiler feed pump, also exhausting to atmosphere The efficiency of such a plant is necessarily very poor, yet for small amounts of power it represents a type of plant that has the advantage of a minimum investment and can be operated by the non-technical man in a semi-successful manner

The Rankine vapor cycle efficiency is (see Figure 1(c))

$$E_{rv} = \frac{H_c - H_d}{H'_c - ha'} \quad \text{or} \quad \frac{2545}{S(H'_c - ha')}.$$

where H_c = heat per pound of steam entering prime mover.
H'_c = heat per pound of steam leaving boiler
ha' = heat per pound of boiler feed water
S = the steam rate in pounds per horsepower hour.
(F T M)

RANULA. A ceptic **tumor** beneath the tongue due to obstruction of the sublingual or submaxillary gland ducts. The obstruction is usually due to stone formation in the duct The treatment is usually surgical. (R S M)

RAOULT'S LAW. The **vapor pressure** of a substance in **solution** is proportional to its **mole fraction.** (R K S)

RAPFEN. Pisces, Teleostei A fish (**Pisces**) of northern and eastern Europe, related to the carps It lives in quiet waters in lakes and slow streams. (A.W.L)

RARE EARTH METALS. Cerium; Yttrium.

RASH. An eruption of temporary nature which may be caused by sensitivity to **drugs**, to protein substances (**allergic**) or to chemicals A rash frequently accompanies certain fevers, especially **scarlet fever** and **measles.** (R S M.)

RASPBERRY. Rose Family.

RASPBERRY-CANE BORER. Insecta, Coleoptera. The **larva** of a **beetle** which bores in the canes of raspberry plants, ultimately killing them The adults girdle the tender growth and cause it to wilt If wilted canes are removed to a few inches below the girdling the development of the larvae is prevented (A W L.)

RASPBERRY FRUIT-WORM. Insecta, Coleoptera. The **larva** of a small **beetle**, *Byturus unicolor*, which lives on the inside of the fruit on raspberries It eats the receptacle but is often found in the fruit itself Since the adults eat the foliage and buds the pest can be held in check by spraying with **lead** arsenate (A.W L)

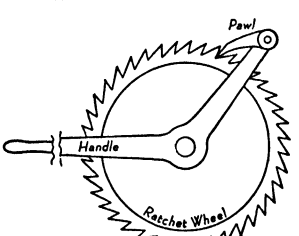
RASSE. Mammalia, Carnivora. A **civet** of the Oriental region (A W L)

RAT. Mammalia, Rodentia In the strict sense an animal of the genus *Rattus*, this term is much more widely applied to many small gnawing animals The true rats are dull colored animals with long scaly tails, short legs, small ears, and a pointed muzzle The common brown rat, *R norvegicus*, is a typical example This species was introduced from Europe in Colonial times and has since become a troublesome and sometimes dangerous pest over the entire country It is much more aggressive than the related black rat, *R rattus*, and has almost crowded the latter out The roof rat, *R alexandrinus*, is a third species found in the southern United States Still other species of the genus are found in other continents

Some of the closely related genera include the bandicoot rats, bush rats, bamboo rats, kangaroo rats and cane rats The name American pouched rats is sometimes applied to a group containing the pocket **gopher.**

Less closely related members of the order are the **Philippine rats, fish-eating rats, wood rats, African crested rat,** and **muskrat.** (A W L)

RATCHET AND PAWL. The ratchet and pawl together comprise an intermittent type of mechanism in which motion derived from a reciprocation or oscillation is converted into intermittent circular motion, constant in direction This mechanism finds considerable use in lifting **jacks, windlasses,** and similar mechanisms The ratchet wheel has a circumference covered with ratchet



Ratchet and pawl.

teeth. As shown in the accompanying figure, these are designed to receive a forceful pressure in the counter-clockwise direction only When a ratchet must be reversible, the shape of the teeth necessarily must be modified from that shown in the diagram The pawl on the oscillating arm slips freely over the teeth in the clockwise direction, but engages and rotates the ratchet when

it moves in the anti-clockwise direction If the ratchet wheel is under a torque it will rotate backwards when the pressure of the driving pawl is released unless a holding pawl is provided The pawls are held against the ratchet wheel either by dead weight or by spring pressure. (F T M)

RATE OF CHANGE OF A FUNCTION. Derivative of a Function of one Variable.

RATEL. Mammalia, Carnivora A short-legged animal, *Mellivora ratel,* with a broad depressed body and head, resembling the badgers in form The ratels live in India and Africa They are nocturnal burrowing animals which eat other animals and insects From their love of honey they have received the name honey badger (A W L)

RATING. Mechanical and electrical apparatus is rated on different bases, the particular method being associated with the conditions of usage, or with the historical development of the apparatus The rating of electrical apparatus is almost always based upon the temperature at which the apparatus may be operated continuously Usually the limiting condition is the temperature to which the **insulation** may be continuously subjected without its rapid deterioration The rated horsepower of an electric motor, then, would be the power at which the current which was drawn caused the maximum permissible temperature rise in the windings A very common basis of rating where rubber insulation is employed is a 40° C temperature rise above room temperature

A few examples of the determination of rating in the mechanical field will show how varied the picture is, and explain the statement that technical equipment is not subject to uniform systems of rating Steam **boilers** are rated by a unit based on their heating surface, but progress in the art of generating steam in boilers, and in the field of combustion engineering, has so increased the steam production possible from a given area of heating surface that the actual performance of steam boilers can nowadays be related to their ratings only by the use of a term "per cent rating" A boiler operating at 300 per cent rating would not necessarily be considered overloaded

The power rating of a **steam engine** depends upon the extent to which steam is used expansively in the engine The less the expansion, the greater the power rating of a given cylinder volume, and the less economical the engine is of steam Common practice rates the power as that derived when the **ratio of expansion** is 4, but an engine may, by advancing the cut-off, derive more than this rating, at the expense of steam consumption A steam turbine has its nozzles, blades, and passages designed for a certain full load at which steam consumption will be minimum Loads above this can be carried by admitting some high pressure steam into low pressure sections of the casing by overload valves Naturally the **generator** to which the **turbine** is connected is provided with sufficient capacity to absorb this power Since the turbo-generator unit is rated on the basis of electrical output the rating given is that carried by the turbine in its overload condition, and its most economical or designed condition is possibly only 80% of its rating (F T M)

RATIO. The ratio of two numbers is their indicated **quotient,** frequently expressed as a **fraction.** The ratio of a to b is indicated by the notation $a : b$, or frequently a/b or $a \div b$ (L L S)

RATIO OF EXPANSION. This ratio of certain volumes in the **piston** and **cylinder** engine is of considerable importance, since it is indicative of power output, and other important characteristics of engines This is also the same as "compression ratio," a term frequently used in describing the modern **Otto cycle engine.** However, ratio of expansion will first be defined for the **steam engine.** In a steam engine, when the piston is at the inner end of its stroke and ready to do work on an outward stroke, there is a small clearance volume created by the necessity for avoiding mechanical contact between piston and cylinder head As the piston moves under the influence of inflowing steam, the pressure remains nearly constant until the steam is cut off by the valve action Beyond this point the steam expands with decreasing pressure The ratio of expansion is the number of times steam is expanded in volume after the point of cutoff. It is equal to the ratio,

$$\frac{\text{volume of the cylinder at the conclusion of a stroke}}{\text{the volume at point of cutoff}}$$

The greater the ratio of expansion, the smaller the amount of power developed by a cylinder of given size, but the power produced is obtained more efficiently than with small ratios A common ratio of expansion for steam engines is four

The cycle of the gasoline engine includes a compression of the charge from maximum cylinder volume into the clearance volume, with a corresponding rise of pressure After an explosion, the charge re-expands to the maximum volume, so that whether we consider the ratio taken along the compression or expansion portion of the cycle, numerically it will be the same In the Otto cycle, the ratio of expansion is

$$\frac{\text{The piston displacement} + \text{the clearance volume}}{\text{the clearance volume}}$$

Since the efficiency of the Otto engine is dependent to a great extent on the ratio of expansion, it is seen that the clearance volume is an important dimension in these engines Modern engines have "compression ratios" of six or slightly over, as compared to ratios of four obtained in earlier engines The use of high compression ratios has incurred the problems and results discussed under the head of **detonation.** (F T M)

RATIONAL FUNCTION. A rational function is a **function** which involves the **variable** in only the rational operations of addition, subtraction, multiplication, division and raising to powers with constant integral exponents

Rational functions are divided into two sub-classes: rational integral functions or **polynomial functions,** and rational **fractional functions.** (L L S)

RATIONAL INTEGRAL EQUATIONS. Polynomial Equations

RATIONAL INTEGRAL FUNCTION. Polynomial Function.

RATIONAL NUMBERS. Number.

RATIONAL ROOTS OF POLYNOMIAL EQUATIONS. Polynomial Equations.

RATTANS. Species of *Calamus* Palmae The various **palms** known as rattans are all climbing plants of the Old World tropics. The genus *Calamus,* with its 280 species, contains the greater number of these palms, especially those of commercial importance As a group the rattans are found in low altitudes, growing in the forests Many are leaf-climbers, in which the main axis or outer ends of the **pinnae** of the pinnately compound leaves bear stout downward projecting spines These spines prevent the plants from sliding from any support on which they may rest The stems are slender (from an eighth of an inch to two and a half inches in diameter) and very long Many are from 250 to 600 feet in length, and of uniform diameter throughout this

length. The outer portion of the stem is very hard and tough; the inner, softer and rather porous.

In gathering, these stems are cut off close to the base and pulled from their supports. The leaves are then removed and the stem cut into sections 10–20 feet long. These may be bent double and thus bundled for shipment Sometimes they are split before shipping. The outer layer, removed in long narrow strips, is used in weaving mats, making baskets, and for the cane-seats of chairs. The central portion remaining after the cane is stripped off is used in making reed furniture. Coarse brushes are also made from this central portion. Many other minor uses are made of these plants in the eastern countries and islands where they are native. (R.M.W.)

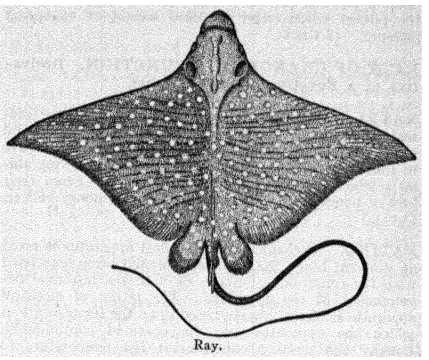
RATTLESNAKE. Reptilia, Sauria. A poisonous **snake** with a series of loosely attached horny rings at the tip of the tail which constitute the rattle. When aroused the snake vibrates its tail, producing a sound between a rattle and a buzz. These snakes have a thick body, tapering at the neck toward the broad triangular head. They are **pit vipers.**

Rattlesnakes occur only in the New World, chiefly in North America. They are most abundant in the warmer parts of the United States. The little massasauga, *Sistrurus catenatus*, which reaches a length of only thirty inches, is the most widely distributed species, ranging from New York to South Dakota and southward into Mexico. It still persists in wild spots, especially swamps, even in heavily settled areas. The ground rattler, *S. miliarius*, of the southeastern coastal area and southern Mississippi Valley is still smaller. These small species are less dangerous than the large rattlesnakes, but even they are not to be disregarded. The common rattlesnake, *Crotalus horridus*, is distributed from Maine to Florida, east of the plains. Another eastern species, the diamond-back rattlesnake, *C. adamanteus*, is found on wet ground from the Carolinas to Louisiana. It is the largest species, with a length of six feet, and is correspondingly dangerous. In the western United States several species are found in the plains area and the deserts. Of these the sidewinder, *C. cerastes*, and prairie rattler, *C. confluentus*, are the best known. The latter is found from Canada to Texas over the entire western half of the United States.

These snakes have been ruthlessly destroyed and are now rare except in wild country. Their virulent poison has been the chief cause of economic importance, but the skins and rattles have been attractive as curios in some parts of the country, and in Florida one enterprising snake fancier makes canes of the spinal column and cans the flesh for the market It is more than probable that filets of rattlesnake will also remain in the class of curios. (A.W.L.)

RAVEN. Aves, Passeriformes. Large **black birds** with more or less iridescent luster. They are closely related to the common crow. The common raven, *Corvus corax* is found in Europe, Asia, and North America. One variety, the American raven, extends from Canada to Guatemala and from the Rockies to the Pacific. Another, the northern raven, is found from Alaska to Greenland, southward into the northern tier of states, and in the mountains to Carolina. Two species of white-necked ravens are known, one in the southwestern deserts of the United States and the other in Africa. All of these birds eat carrion, eggs, insects, small animals, and to a limited extent vegetable matter. (A.W.L.)

RAY. Pisces, Plagiostomi. Fishes (**Pisces**) related to the sharks. The body is flattened and the pectoral fins are highly developed to form broad lateral lobes. The tail is slender. Rays are typically marine, but some species ascend rivers and some fresh-water species occur in tropical America. Among the different forms the electric rays (*Torpedo*) and eagle rays (*Myliabatis*) or devil-fishes are noteworthy. The former have electric organs formed of modified muscle tissue and are said to kill their prey by electrocution. The latter attain



Ray.

great **size**, up to a weight of 800 pounds, and are said to be dangerous to divers. Some of the rays are also known as skates. (A.W.L.)

RAYNAUD'S DISEASE. A disorder of the nervous mechanism of blood vessels that especially affects fingers, toes, ears, lips, chin, etc. The cause of the disease is not known. The disease begins suddenly with attacks of severe pain, numbness, and pallor of the affected parts. The attack may last for minutes or hours. In more advanced stages the involved parts become dark blue or black, with excruciating pain. This stage may last for months, but finally **gangrene** is complete and the parts may fall off. Treatment is not very satisfactory, although the disease may occur in a mild chronic form, never progressing to the gangrene stage. (R.S.M.)

RAYON. Carbohydrates; and **Cotton.**

RAZORBACK. 1. Pisces, Teleostei. One of the less common species, *Xyrauchen texanus*, of **buffalo fishes** of the Mississippi basin. 2. Mammalia, Artiodactyla. Feral hogs of the southern states. (A.W.L.)

RAZORBILL. Aves, Charadriiformes. A moderately large ocean bird (**Aves**), *Alca torda*, found on both sides of the northern Atlantic. It has a large compressed beak with deep furrows. The species is related to the extinct great auk and to the murres, puffins, and guillemots, and is also known as the razor-billed auk. A number of other vernacular names are indiscriminately applied to various members of this group. (A.W.L.)

REACTANCE. Alternating Currents.

REACTION. Apart from the chemical usage of this term (See various **Reactions**; and **Chemistry**), its technical meaning is associated with mechanical action. The reaction force is that which is produced as the result of an **acceleration** of some **mass**, be it a solid or fluid. The recoil of a gun is a reaction force set up by the acceleration of the projectile. In a certain class of **turbine**—both hydraulic and steam—the machines obtain the principal part of their actuating forces by the reaction created when, in the one case, water, and in the other, steam, is accelerated under conditions controlled by the mechanism of the turbine.

In structural engineering the term reaction refers to the forces exerted by the supports of a **structure** to counteract the effects of applied loads. (F.T.M.)

REACTIONS INVOLVING OXIDATION-REDUCTION. Originally oxidation referred to the reac-

tion of a substance with **oxygen gas** The elucidation by Lavoisier of the burning of substances with oxygen is considered by some to mark the beginning of chemistry as a science When **carbon** burns in excess of oxygen or air, **carbon dioxide** is formed with the accompanying liberation of a definite amount of heat When **hydrogen** and oxygen of air are burned or subjected to an electric spark, water is formed with the accompanying liberation of a definite amount of heat When substances containing carbon and hydrogen are similarly burned, carbon dioxide and water are formed with accompanying liberation of a characteristic amount of heat in each case **Fuels** are burned for the sake of the heat liberated upon oxidation. **Foods** are consumed in part for the sake of the heat liberated in the oxidation reactions of digestion **Iron** rusts in moist air or oxygen, forming hydrated forms of ferric oxide by oxidation **Magnesium**, when ignited, burns in air with the formation of white magnesium oxide solid and the liberation of heat and an intense light of high actinic value and used for this purpose in photography

In all cases, the weight (**mass**) of the substance burned plus the weight of oxygen consumed equals the weight of the products of oxidation This was demonstrated by Lavoisier in the case of the substances with which he experimented

Oxidation is a reciprocal process Oxygen is the oxidizing agent, the substance reacting with oxygen is called the reducing agent Besides the kinds of simple reactions given in the examples above, there are many others more complex But the reciprocal principle of oxidation-reduction applies in all cases Oxidation-reduction, as now understood, includes

I Reactions involving oxygen, **chlorine**, and substances supplying such elements on the one hand, with carbon, hydrogen, metals, and other similar substances on the other hand

II Reactions taking place in an **electrolyte** wherein a change of electronic charge of an **ion** occurs Compare **Reactions Involving Recombination of Ions.**

Reactions involving oxygen, etc , with carbon, etc , are illustrated as follows

Reducing Agent	Oxidizing Agent	Resultant	
carbon, hydrogen, sulfur, phosphorus	oxygen, excess	carbon dioxide, water, sulfur dioxide, phosphorus pentoxide	
hydrogen, excess	copper oxides, lead oxides, tin oxides, iron oxides (but not magnesium oxide, aluminum oxide, zinc oxide)	copper, lead, tin, iron	water
magnesium, aluminum, zinc, iron, tin, lead, copper (but not mercury, silver, gold, platinum)	oxygen-furnishing substance	magnesium oxide, aluminum oxide, zinc oxide, ferric oxide or ferroferric oxide, stannic oxide, lead monoxide, cupric oxide	
arsenic, antimony, aluminum, iron, copper	chlorine	arsenic trichloride, antimony trichloride, aluminum chloride, ferric chloride, cupric chloride or cuprous chloride	
carbon monoxide, carbon	copper oxides, lead oxides, tin oxides, iron oxides	copper, lead, tin, iron	carbon dioxide or carbon monoxide or both
aluminum*	iron oxides, silicon oxide, boron oxide, manganese oxides, chromic oxide	iron, silicon, boron, manganese, chromium	aluminum oxide, glass
silicon	iron oxides	iron	silicon oxide
magnesium, zinc, iron, lead	sulfur	magnesium sulfide, zinc sulfide, ferrous sulfide, lead sulfide	
	Other oxidizing agents		
	Metallic nitrates		
	Metallic chlorates		
	Metallic perchlorates		
	Metallic bromates		
Magnesium (in ether, Grignard's reaction)	Aldehydes	Secondary alcohols	
	Ketones	Tertiary alcohols	

*Goldschmidt thermit reaction

II Reactions taking place in an **electrolyte**, wherein a change of electronic charge of an **ion** occurs, are brought about (A) by an impressed electric **direct current** in an electrolyte, (B) by the transfer of **electrons** between ions, either (1) where spatially separated *and* electrically connected, or (2) by contact in an electrolyte See **Electrochemistry** for (A) and (B) (2) in more detail

(A) *Oxidation-Reduction Reactions Due to Impressed Direct Current*

In an Electrolyte In the electrolytic refining of **copper** a **cell** is arranged containing the impure copper casting as **anode**, copper sulfate as **electrolyte**, and a thin pure copper sheet as **cathode**. Upon the impression of a direct current of low **electromotive force** in the proper direction, copper of the anode passes into the electrolyte as cupric ion (Cu^{2+}) and pure copper is deposited from the electrolyte onto the cathode. The reaction may be represented thus.

Copper (Cu^0) of anode $\rightarrow$ Cupric ions (Cu^{2+})
of electrolyte $\rightarrow$ copper (Cu^0) of cathode

In a similar manner, the electrolysis of fused **sodium** chloride yields sodium metal at the cathode and **chlorine** gas at the anode (Downs process for sodium, 1920) The reaction may be represented thus

Sodium cation (Na^+) of electrolyte $\rightarrow$ (Na^0) at cathode
Chlorine (Cl_2^0) at anode $\leftarrow$ Chlorine anion ($2Cl^-$) of electrolyte

In all such reactions, there is a *change of charge*, that is, oxidation or reduction, of ions *at* cathode *and* anode The electrolysis of sodium sulfate solution will clarify this, thus.

Hydrogen ions ($2H^+$) (turning litmus red) plus oxygen gas (O_2^0) 1 volume, at anode	Sodium cations ($2Na^+$) of electrolyte / Sulfate anions (SO_4^{--}) of electrolyte	Hydroxyl ions ($2OH^-$) (turning litmus blue) plus hydrogen gas (H_2^0) 2 volumes at cathode

Sodium ions and sulfate ions when discharged react with water at the cathode and anode, respectively, yielding the above products The total amount of sodium and sulfate ions in the electrolyte remains the same after as before passing the current, the *net* effect (upon stirring the electrolyte) being the decomposition of water to form 1 volume of oxygen at the anode and 2 volumes of hydrogen at the cathode

Sodium chloride solution electrolyzed with accompanying stirring of the electrolyte yields sodium **hypochlorite** (NaOCl)

Aluminum metal is produced by electrolysis of aluminum oxide dissolved in fused **cryolite** (Na_3AlF_6), and **magnesium** metal by electrolysis of fused magnesium chloride anhydrous ($MgCl_2$).

The charging of a lead storage cell (**Accumulator**) involves reactions in this category, thus.

Lead sulfate ($Pb^{2+}SO_4^{--}$) paste of the anode, in contact with the electrolyte, is changed into lead dioxide ($Pb^{4+}O_2^0$), brown solid *in situ* Sulfate ion (SO_4^{--}) passes into electrolyte

←Sulfuric acid-water electrolyte (concentration of sulfuric acid increases with the amount of charging→

Lead sulfate ($Pb^{2+}SO_4^{--}$) paste of the cathode, in contact with the electrolyte is changed into lead metal (Pb^0) *in situ* Sulfate ion (SO_4^{--}) passes into electrolyte

(B) (1) *Oxidation Reduction Reactions by the Transfer of Electrons Between Ions*, where the latter are spatially separated *and* electrically connected In the Daniell cell, one of the oldest known wet batteries, the chemical set-up is

Zinc metal (Zn^0) in zinc sulfate ($Zn^{2+}SO_4^{--}$) electrolyte

Copper sulfate ($Cu^{2+}SO_4^{--}$) electrolyte containing copper metal (Cu^0)

The two electrolytes in contact *in the cell*

The two metals electrically connected *outside the cell* by a metallic conductor

Results (1) An electromotive force (1 1 volts) is generated

(2) Simultaneously, chemical reaction occurs

Zinc metal is dissolved into the electrolyte as zinc ions at the electrode

Copper ions are precipitated from the electrolyte as copper metal at the electrode

$Zn^0 \rightarrow Zn^{2+}$ ⟶ $Cu^{2} \rightarrow Cu^0$

Direction of positive current *in* the cell

As thus arranged, (1) the chemical reaction generates a definite **electromotive force**, namely, 1 1 volts The direction of the positive current is from zinc to copper *in* the cell, through the electrolyte, and from copper to zinc *outside* the cell through the metallic conductor (2) The *amount* of electric current generated is proportional to the *amount* of chemical reaction taking place, namely, 96,500 coulombs per equivalent weight (See **Chemical Composition**) of change Of zinc, $\frac{65\ 38}{2} = 32\ 69$ grams changed from metallic to ionic, and of copper, $\frac{63\ 57}{2} = 31\ 79$ grams changed from ionic to metallic in generating 96,500 coulombs of electricity

The discharging of a lead storage cell involves reactions in this category, thus

Lead dioxide (PbO_2) electrode in **sulfuric acid** electrolyte

Sulfuric acid electrolyte containing lead metal (Pb^0) electrode

The two electrodes electrically connected *outside* the cell by a metallic conductor

Results. (1) An electromotive force (about 2 2 volts) is generated

(2) Simultaneously, chemical reaction occurs.

Lead dioxide transformed into lead sulfate ($Pb^{2+}SO_4^{--}$) at the electrode

Lead sulfate ($Pb^{2+}SO_4^{--}$) formed from lead at the electrode

$Pb^{4+} \rightarrow Pb^{2+}$ ⟵ $Pb^{2+} \leftarrow Pb^0$

Direction of positive current *in* the cell

As thus arranged, (1) the chemical reaction generates a definite electromotive force, namely, about 2 2 volts when fully charged to about 1 9 volts when almost discharged, the concentration of sulfuric acid *decreases* with the amount of discharging. The direction of the positive current is from lead to lead dioxide *in* the cell through the electrolyte, and from lead dioxide to lead *outside* the cell through the metallic conductor (2) The amount of electric current generated is proportional to the *amount* of chemical reaction taking place, namely, 96,500 coulombs per equivalent weight (See **Chemical Composition**) of change Of lead dioxide, $\frac{239}{2} = 120$ grams changed to lead sulfate, $\frac{303}{2} = 152$ grams; of lead, $\frac{207}{2} = 104$ grams changed to lead sulfate, $\frac{303}{2} = 152$ grams; and of sulfuric acid $\frac{98}{2} \times 2 = 98$ grams removed from electrolyte as lead sulfate in generating 96,500 coulombs of electricity.

SINGLE POTENTIAL DIFFERENCES, 25° C, OF CERTAIN ELEMENTS IN SOLUTIONS OF THEIR IONS WITH REFERENCE TO HYDROGEN GAS AT 1 ATMOSPHERE—PLATINUM—1 00 NORMAL HYDROGEN ION EQUALS 0 00 VOLT

Element	Ion	Potential Difference (In volts, for 1 00 *N* solution)
Mg	Mg^{++}	+2 40
Al	Al^{+++}	+1 7
Be	Be^{++}	+1 69
Mn	Mn^{++}	+1 1
H_2(Pt)	OH^-	+0 83
Zn	Zn^{++}	+0 76
Cr	Cr^{++}	+0 6
S	S^{--}	+0 51
Fe	Fe^{++}	+0 44
Cd	Cd^{++}	+0 40
Co	Co^{++}	+0 29
Ni	Ni^{++}	+0 22
Sn	Sn^{++}	+0 13
Pb	Pb^{++}	+0 12
H_2(Pt)	H^+	**0.00**
Bi	Bi^{+++}	−0 2
Cu	Cu^{++}	−0 34
Cu	Cu^+	−0 51
Hg	Hg^+	−0 80
Ag	Ag^+	−0 80
Hg	Hg^{++}	−0 86
O_2(Pt)	OH^-	−0 40
I_2	I^-	−0 54
Br_2	Br^-	−1 07
O_2(Pt)	H^+	−1 23
Cl_2	Cl^-	−1 36

Reading down Each **element** *above loses* **electrons** more readily than any element below Accordingly, each element above has a higher *reducing* power than any element below

Reading up Each element *below gains* electrons more readily than any element above Accordingly, each element below has a higher oxidizing power than any element above

Therefore, any *metal above* will displace, from the salt solution of any metal below, the metal of the latter from its own cation

ADDITIONAL SINGLE POTENTIAL DIFFERENCES, 25° C WITH REFERENCE TO HYDROGEN GAS AT 1 ATMOSPHERE—PLATINUM—1 00 NORMAL HYDROGEN ION EQUALS 0 00 VOLT

From	To	No Electrons Liberated	Volts
$Fe(OH)_2 + OH^-$	$Fe(OH)_3$	1	0 65
Ti^{++}	Ti^{+++}	1	0 37
$Pb^0 + SO_4^{--}$	$PbSO_4$	2	0 31
$P^0 + 4H_2O$	$5H^+ + H_3PO_4$	5	0 3
V^{++}	V^{+++}	1	0 2
$Cu_2O + 2OH^-$	$2CuO + H_2O$	2	0 15
Sn^{++}	Sn^{++++}	2	−0 13
$H_2SO_3 + H_2O$	$4H^+ + SO_4^{--}$	2	−0 14
Cu^+	Cu^{++}	1	−0 17
H_2S	$2H^+ + S^0$	2	−0 17
$PbO + 2OH^-$	$PbO_2 + H_2O$	2	−0 3
$S^0 + 3H_2O$	$4H^+ + H_2SO_3$	4	−0 47
$Fe(CN)_4^{----}$	$Fe(CN)_6^{---}$	1	−0 49
$H_3AsO_3 + H_2O$	$2H^+ + H_3AsO_4$	2	−0 49
$Ni(OH)_2 + 2OH^-$	$NiO_2 \cdot 2H_2O$	2	−0 49
MnO_4^{--}	MnO_4^-	1	−0 66
H_2O_2	$2H^+ + O_2$	2	−0 68
$C_6H_4(OH)_2$ (Hydroquinone)	$2H^+ + C_6H_4O_2$ (Quinone)	2	−0 70
$MnO_2 + 4OH^-$	$MnO_4^{--} + 2H_2O$	2	−0 71
Fe^{++}	Fe^{+++}	1	−0 74
$Cl^- + 2OH^-$	$OCl^- + H_2O$	2	−0 94
$NO + 2H_2O$	$4H^+ + NO_3^-$	3	−0 94
$Cr^{+++} + 4H_2O$	$7H^+ + HCrO_4^-$	3	−1 3

From	To	No Electrons Liberated	Volts
$Br^- + H_2O$	$H^+ + HOBr$	2	−1 33
$Mn^{++} + 2H_2O$	$4H^+ + MnO_2$	2	−1 33
$Pb^{++} + 2H_2O$	$4H^+ + PbO_2$	2	−1 44
$Cl^- + 3H_2O$	$6H^+ + ClO_3^-$	6	−1 45
$Cl^- + H_2O$	$H^+ + HOCl$	2	−1 50
Mn^{++}	Mn^{+++}	1	−1 5
$Mn^{++} + 4H_2O$	$8H^+ + MnO_4^-$	5	−1 52
$MnO_2 + 2H_2O$	$4H^+ + MnO_4^-$	3	−1 63
$PbSO_4 + 2H_2O$	$4H^+ + SO_4^{--} + PbO_2$	2	−1 7
$2H_2O$	$2H^+ + H_2O_2$	2	−1 78

Latimer and Hildebrand "Ref Book of Inorg Chem," Macmillan

(B) (2) *Oxdation-Reduction Reactions by the Transfer of Electrons Between Ions*, where the latter are in contact in an electrolyte. Instead of arranging the electrodes and electrolytes of the Daniell cell described above wherein the electrode compartments are separated in space and electrically connected through the electrolyte *in* the cell and through the metallic conductor *outside* the cell, the materials may be placed in direct contact To make it still simpler, when zinc metal is placed in copper sulfate solution, a reaction occurs—copper metal is displaced from the solution and an equivalent amount of zinc metals goes into solution as zinc ions This part of the reaction is identical with

VARIOUS ELECTRONIC STATES OF OXIDATION-REDUCTION OF SOME OF THE ELEMENTS

Element	Periodic Group	Valence											
		−4	−3	−2	−1	0	+1	+2	+3	+4	+5	+6	+7
Chlorine	7				HCl	Cl_2	NaOCl		$KClO_2$		$HClO_3$		$KClO_4$
Bromine	7				HBr	Br_2	NaOBr				$KBrO_3$		
Iodine	7				HI	I_2	NaOI				KIO_3		KIO_4
Fluorine	7				H_2F_2	F_2							
Sulfur	6			H_2S		S				H_2SO_3		H_2SO_4	
Selenium	6			H_2Se		Se				SeO_2		H_2SeO_4	
Tellurium	6			H_2Te		Te		$TeCl_2$		TeO_2		H_2TeO_4	
Nitrogen	5		NH_3			N_2		NO	HNO_2		HNO_3		
Phosphorus	5		PH_3			P	H_3PO_2		H_3PO_3		H_3PO_4		
Arsenic	5		AsH_3			As			$NaAsO_2$		Na_3AsO_4		
Antimony	5		SbH_3			Sb			$SbCl_3$		Sb_2O_5		
Bismuth	5					Bi			$BiCl_3$		$HBiO_3$		
Carbon	4	CH_4		HCH_2OH		C		CO		CO_2			
						HCHO		HCOOH		HOCOOH			
Silicon	4					Si				SiO_2			
										$SiCl_4$			
Tin	4					Sn		SnO		SnO_2			
								$SnCl_2$		$SnCl_4$			
Lead	4					Pb	Pb_2O	PbO		PbO_2			
								$PbCl_2$					
Boron	3					B			H_3BO_3				
Aluminum	3					Al			$AlCl_3$				
Zinc	2B					Zn		$ZnSO_4$					
Cadmium	2B					Cd		$CdSO_4$					
Mercury	2B					Hg	HgCl	$HgCl_2$					
Copper	1B					Cu	CuCl	$CuCl_2$					
Silver	1B					Ag	$AgNO_3$	AgO					
Gold	1B					Au	AuCl		$AuCl_3$				
Nickel	8					Ni		NiO		NiO_2H_2O			
Cobalt	8					Co		CoO	$Co(OH)_3$	CoO_2			
Iron	8					Fe		$FeCl_2$	$FeCl_3$			K_2FeO_4	
Manganese	7B					Mn		$MnCl_2$	$Mn(OH)_3$	MnO_2		K_2MnO_4	$KMnO_4$
Chromium	6B					Cr		$CrCl_2$	$CrCl_3$			K_2CrO_4	
Molybdenum	6B					Mo		$MoCl_2$	$MoCl_3$	MoO_2	$MoCl_5$	MoO_3	
										$MoCl_4$			
Tungsten	6B					W		WCl_2		WO_2	WCl_5	WO_3	
										WCl_4		WCl_6	
Uranium	6B					U			UCl_3	UO_2	UCl_5	UO_3	
										UCl_4			
Vanadium	5B					V		VCl_2	VCl_3	VCl_4	$VOCl_3$		
Titanium	4B					Ti			$TiCl_3$	TiO_2			
										$TiCl_4$			
Zirconium	4B					Zr				$Zr(SO_4)_2$			
Thorium	4B					Th				$Th(SO_4)_2$			
Cerium	3B					Ce			$Ce_2(SO_4)_3$	$Ce(SO_4)_2$			
Other elements of	3					M			MCl_3				
Elements of	2					M		MCl_2					
Elements of	1					M	MCl						
Elements of	0					E							

that in the Daniell cell But to generate an electromotive force the conditions laid down for the Daniell cell must be followed

Reactions of this type may, therefore, be brought about either (1) by the cell method, wherein the electromotive force of each half-cell may be measured by balancing against the electromotive force of a standard half-cell, e g , a hydrogen electrode, or a calomel (mercurous chloride) electrode, or (2) by placing the substances in contact, as in a test-tube or a beaker The resulting transformation of materials, that is, the chemical reaction, is the same in each case. The difference in the electromotive force of the component half-cells is a measure of the tendency to react

Reactions not in solutions of electrolytes but oxidation-reduction in character are of wide scope and of fundamental importance in organic chemistry They comprise such reactions as transformations (horizontally, not vertically) among the following typical groups of compounds

Methane	Methyl alcohol	Formaldehyde	Formic Acid	Carbonic Acid
			Carbon Monoxide $C{=}O$	Carbon Dioxide $O{=}C{=}O$

Hydrocarbons, primary	Alcohols, primary	Aldehydes	Acids, carboxylic
" secondary	" secondary	Ketones	
" tertiary	" tertiary		
" quaternary			

See **Hydrocarbons, Alcohols; Aldehydes** (ketones included), **Acids, Carboxylic.**

Benzene	Phenol		
C_6H_6	C_6H_5OH		
	Hydroquinone	Benzoquinone	
	$C_6H_4(OH)_2(1,4)$	$C_6H_4(O)_2(1,4)$	

See **Phenols and Quinones**

Ethane	Ethyl amine	Acetamide	Urea
$CH_3 \cdot CH_3$	$CH_3CH_2NH_2$	$CH_3 \cdot CONH_2$	
		Methyl cyanide CH_3CN	

See **Amines and Amides**

Benzene	Phenylamine (aniline)	Phenylhydrazine	Beta-Phenyl-hydroxylamine	Nitrosobenzene	Nitrobenzene
C_6H_6	$C_6H_5NH_2$	$C_6H_5NHNH_2$	C_6H_5NHOH	C_6H_5NO	$C_6H_5NO_2$

See **Hydrazines; Hydroxylamines; Nitro and Nitroso Compounds.**

Benzene	Phenylamine	Hydrazobenzene	Azobenzene	Azoxybenzene	Nitrobenzene
C_6H_6	$C_6H_5 \cdot NH_2$	$C_6H_5NHNH \cdot C_6H_5$	$C_6H_5N \cdot N \cdot C_6H_5$	$C_6H_5N{:}N \cdot C_6H_5$ (O above)	$C_6H_5 \cdot NO_2$
		Benzidine $(4)H_2N\,C_6H_4\,C_6H_4\,NH_2(4)$			

See **Azo- and Related Compounds.**

Benzene	Thiophenol	Benzene sulfinic acid	Benzene sulfonic acid
C_6H_6	C_6H_5SH	C_6H_5SOOH	$C_6H_5 \cdot SO_2OH$
	Carbon disulfide	Carbonyl sulfide	
	CS_2	COS	
	Diphenyl sulfide	Phenyl sulfinyl benzene	Phenyl sulfonyl benzene
	$(C_6H_5)_2S$	$(C_6H_5)_2SO$	$(C_6H_5)_2SO_2$

See **Thioalcohols and Related Compounds.**

Methane	Methyl chloride	Methylene chloride	Chloroform	Carbon tetrachloride
H_4C	$H_3C\,Cl$	$H_2C\,Cl_2$	$HCCl_3$	CCl_4

See **Chlorine, Organic Compounds**

Methyl phosphine CH_3PH_2	Methyl phosphinic acid $CH_3PO(OH)_2$
Dimethyl phosphine $(CH_3)_2PH$	Dimethyl phosphinic acid $(CH_3)_2POOH$
Trimethyl phosphine $(CH_3)_3P$	Trimethyl phosphine oxide $(CH_3)_3PO$
Tetramethyl phosphonium hydroxide $(CH_3)_4POH$	

See **Phosphines and Related Compounds.**

pH OF VARIOUS MATERIALS

Material	pH
Sea water	7 75 to 8 25
Soils	3 to 10
Plant tissues and fluids	About 5 2
Animal tissues and fluids	About 7 0 to 7 5
Blood	7 35–7 5
Urine	5 0–7 0
Milk	6 5–7 0
Gastric juice	1 7
Pancreatic juice	7 8
Intestinal juice	7 7
Internal tissue fluids	
Minimum, below which acidosis ensues	7 0
Maximum, above which tetany ensues	7 8

SOIL FOR SPECIFIC CROPS

Crop	pH Desired	Crop	pH Desired
Wheat	6 0–8 0	Onion	6 0–8 0
Corn	6 0–8 0	Spinach	6 0–8 0
Oats	6 0–7 0	Apple, pear, cherry, peach, plum	6 0–8 0
Barley	6 0–8 0	Orange, lemon	5 0–7 0
Rye	6 0–8 0	Grape	6 0–8 0
Potato	6 0–8 0	Strawberry, raspberry	5 0–6 0
Peanut	5 0–6 0	Tomato	6 0–8 0
Cotton	6 0–8 0	Rose	6 0–8 0
Flax	6 0–7 0	Pea, sweet	6 0 8 0
Tobacco	5 0–8 0	Hydrangea	6 0 8 0
Clover	6 0–8 0	Hollyhock	6 0–8 0
Alfalfa	6 0–8 0	Foxglove	6 0–8 0
Red top	6 0–7 0	Tulip ..	6 0–8 0
Timothy	6 0–8 0	Rhododendron	5 0–6 0
Bluegrass	6 0–8 0	Oak	5 0–8 0
Pea	6 0–8 0	Maple	5 0–8 0
Bean	6 0–8 0	Elm	6 0–8 0
Sugar cane	6 0–8 0	Holly	4 0–6 0
Beet, common and sugar	6 0–8 0	Spruce, pine, fir	5 0–6 0
Carrot	6 0–8 0	Douglas fir	6 0–7 0

VARIOUS SUBSTANCES HAVING (IN 0 01M SOLUTION) A pH VALUE WITHIN THE COLOR TRANSITION RANGE OF INDICATORS

0 01 Molar Solution	pH Approximate	Indicator	Color Point Acidic-Basic
Hydrochloric acid	2	Thymol blue	Red–yellow
Acetic acid	3	2,6-Dinitrophenol	Colorless–yellow
Ammonium chloride	5	Methyl orange	Red–yellow
		Congo red	Blue–red
Sodium chloride	7	Bromthymol blue	Yellow–blue
Sodium acetate	10	Phenolphthalein	Colorless–pink
Ammonium hydroxide	11	Orange II	Amber–red
Sodium hydroxide	12	Sodium indigo sulfonate	Blue–yellow

Titration of Acids and Bases An indicator does not change color from the purely acidic to the purely basic side at a point, but rather, it will be noted, over a narrow measurable band or range of pH—the color change interval The selection of an indicator for the titration of a given slightly ionized acid or slightly ionized base depends upon the **ionization constants** The ionization constant is, for slightly ionized acids, practically the product of the hydrogen ion concentration and of the anion concentration The following data are in all cases stated for the *first* hydrogen ion dissociation only, thus:

$$\frac{[H^+] \times [Anion^-]}{[Non\text{-}ionized\ acid]} = \text{Ion product constant of acid.}$$

IONIZATION CONSTANTS OF ACIDS

(first hydrogen ionization)

AT 25° C, EXCEPT AS OTHERWISE STATED

Acid	Ionization Constant
Acetic	2×10^{-5}
Arsenic	5×10^{-3}
Benzoic	6.5×10^{-5}
Boric	6.5×10^{-10}
Carbonic (18° C)	3×10^{-7}
Chloroacetic	1.5×10^{-3}
Citric	8×10^{-4}
Dichloroacetic	5×10^{-2}
Formic	2×10^{-4}
Fumaric	1×10^{-3}
Hydrocyanic	7×10^{-10}
Hydroquinone (18° C)	1×10^{-12}
Hydrosulfuric (18° C)	9×10^{-8}
Hydrazoic	2×10^{-5}
Hypochlorous (17° C)	4×10^{-8}
Iodic	2×10^{-1}
Lactic	1.5×10^{-4}
Maleic	1.5×10^{-2}
Malic	4×10^{-4}
Malonic	1.5×10^{-3}
Nitrous (18° C)	4×10^{-4}
Oxalic	4×10^{-2}
Periodic	2×10^{-2}
Phenol	1×10^{-10}
Phosphoric (18° C)	1×10^{-2}
Phosphorous	5×10^{-2}
Phenolphthalein	2×10^{-10}
Phthalic	1×10^{-3}
Picric (18° C)	1.5×10^{-1}
Propionic	1.5×10^{-5}
Pyrophosphoric (18° C)	1.5×10^{-1}
Salicylic	1×10^{-3}
Succinic	7×10^{-5}
Sulfanilic	6×10^{-4}
Sulfuric	4×10^{-1}
Sulfurous	2×10^{-2}
Tartaric	1×10^{-3}
Thiosulfuric	1×10^{-2}
Trichloroacetic (18° C)	2×10^{-1}
Uric	1.5×10^{-4}

For ionization constants of **nitrogen** bases and nitrogen acids see Amines

$$\frac{[Cation^+] \times [OH^-]}{[non\text{-}ionized\ base]} = \text{Ionization product of base}$$

Common Ion Effect When **sodium** acetate (Na^+Ac^-, ionization large) solution is added to **acetic acid** (H^+Ac^-, ionization small) solution, the concentration of acetate ion is greatly increased with equivalent decrease of hydrogen ion When **ammonium** chloride ($NH_4 + Cl^-$, ionization large) solution is added to ammonium hydroxide ($NH_4^+OH^-$, ionization small) solution, the concentration of ammonium ion is greatly increased with equivalent decrease of hydroxyl ion This may be demonstrated in such cases by the use of the proper indicator, e g, methyl orange in the case of acetic acid, phenolphthalein in the case of ammonium hydroxide The principle is not confined to cases of acids and bases, but is of general application to **electrolytes** This may be visibly demonstrated by the use of **cupric** bromide solution The addition of either cupric chloride solution on the one hand, or **potassium** bromide solution on the other hand, causes increase in the cupric and bromide ions, respectively, with resultant color change from the predominant blue of cupric ion to predominant green to brown of non-ionized cupric bromide

(b) Those reactions in which there is *a change of state* involved, that is, a gas or a solid separates from or enters into the solution

Of these reactions, the most common is the precipitation or the solution of a solid and the evolution or the solution of a gas. In principle, precipitation of **solid**

and evolution of gas are the same, in that in each case the given substance is insoluble (more or less) in the medium (Examples 3 and 4, below). Solution of a solid or of a gas in the medium is the converse of the above in simple cases (Examples 5 and 6, below).

Example 3 Taken 100 mols M/20 $AgNO_3$
100 mols M/20 HCl

$$\begin{array}{ccccc} AgNO_3 & \rightleftarrows & Ag^+ & + & NO_3^- \\ o/ & & 100/o\ 0013 & & 100/100 \\ & & + & & + \\ HCl & \rightleftarrows & Cl^- & + & H^+ \\ o/ & & 100/o\ 0013 & & 100/100 \\ & & \Downarrow & & \Downarrow \\ & & AgCl & & HNO_3 \\ & & /o & & /o \\ & & \Downarrow & & \\ & & AgCl & & \\ & & (Solid) & & \\ & & /100 & & \end{array}$$

Result AgCl solid separates as precipitate.

Example 4 Taken 100 mols M/20 Na_2CO_3
200 mols M/20 HCl

$$\begin{array}{ccccc} & & H_2O & + & CO_2\ (gas) \\ & & /large\ prop & & /large\ prop. \\ & & \Downarrow & & \\ & 2NaCl & H_2CO_3 & & \\ & /o & /small\ prop. & & \\ & \Downarrow & \Downarrow & & \\ Na_2CO_3 \rightleftarrows & 2Na^+ & + & CO_3^{--} & \\ o/ & 200/200 & & 100/small\ prop. & \\ & + & & + & \\ 2HCl \rightleftarrows & 2Cl^- & + & 2H^+ & \\ o/ & 200/200 & & 200/small\ prop & \end{array}$$

Result Na_2CO_3 decomposed, CO_2 gas given off

Example 5. Taken 100 mols $BaCrO_4$ solid
200 mols M/20 HCl

$$\begin{array}{ccccc} BaCrO_4 \rightleftarrows & BaCrO_4 \rightleftarrows & Ba^{++} & + & CrO_4^{--} \\ (solid) & & & & \\ 100/ & o/ & o\ 015/100 & & o\ 015/100 \\ & & + & & + \\ & 2HCl \rightleftarrows & 2Cl^- & + & 2H^- \\ & o/ & 200/200 & & 200/200 \\ & & \Downarrow & & \Downarrow \\ & & BaCl_2 & & H_2CrO_4 \\ & & /o & & /o \end{array}$$

Result. $BaCrO_4$ dissolved.

Example 6 Taken 100 mols CO_2 gas passed into NaOH solution
100 mols M/20 NaOH

$$\begin{array}{ccccc} CO_2 \rightleftarrows & H_2CO_3 \rightleftarrows & H^+ & + & HCO_3^- \\ (gas) & & & & \\ Large/ & Small/ & Small/Small & & Small/Large \\ prop/ & prop/ & prop/prop. & & prop/prop \\ & NaOH \rightleftarrows & OH^- & + & Na^+ \\ & o/ & 100/Small\ prop. & & 100/Large\ prop. \\ & & \Downarrow & & \Downarrow \\ & & H_2O & & NaHCO_3 \\ & & /100 & & /Small\ prop. \end{array}$$

Result CO_2 dissolved, and $NaHCO_3$ formed.

II Formation of Complex Anions or Cations

The formation or disappearance of complex ions is similar in principle New combinations are formed without change of electronic charge of the fundamental element.

Example 7. Taken $Zn(OH)_2$ Solid
Excess NaOH Solution

$$\begin{array}{ccccc} Zn(OH)_2 & \rightleftarrows & Zn(OH)_2 & \rightleftarrows & Zn^{++} + 2OH^- \\ (solid) & & & & \rightleftarrows 2H^+ + ZnO_2^{--} \\ & & & & + \quad + \\ & 2NaOH & \rightleftarrows & & 2OH^- \quad 2Na^+ \\ & & & & \Downarrow \quad \Downarrow \\ & & & & 2H_2O \quad Na_2ZnO_2 \\ & & & & (solution) \end{array}$$

Result $Zn(OH)_2$ dissolved Similar cases $Na_2Pb^{2+}O_2$, $Na_2Sn^{2+}O^2$, $NaAl^{3+}O_2$, complex zincate anion (ZnO_2^{--}) containing Zn^{2+} formed.

Example 8 Taken $Zn(OH)_2$ solid
Excess NH_4OH solution.

$$\begin{array}{ccccc} Zn(OH)_2 & \rightleftarrows & Zn(OH)_2 & \rightleftarrows & 2H^+ + ZnO_2^{--} \\ (solid) & & & & \rightleftarrows Zn^{++} \} + 2OH^- \\ & & & & + \quad + \\ & 4NH_4OH & \rightleftarrows & & 4NH_3 \} + 4H_2O \\ & & & & \rightleftarrows 4OH^- + 4NH_4^+ \\ & & & & \Downarrow \quad \Downarrow \\ & & & & (NH_3)_4Zn^{++} + 2OH^- \end{array}$$

Result $Zn(OH)_2$ dissolved, complex ammonio-zinc cation ($(NH_3)_4Zn^{++}$) containing Zn^{2+} formed
Similar cases $(NH_3)_2Ag^{1+}OH$, $(NH_3)_4Cu^{2+}(OH)_2$, $(NH_3)_2Cu^{1+}OH$, $(NH_3)_4Cd^{2+}(OH)_2$ (R K S)

REACTIONS INVOLVING WATER. The length of the present discussion is not in proportion to the importance of the subject for the reason that several aspects have conveniently and necessarily been discussed elsewhere The following articles should be consulted **Chemical Changes, Reactions Involving Recombination of Ions.**

Reactions involving water are classified as follows

I Consumption of water
II. Production of water
III Water as catalyzer

I *Consumption of Water.* This topic is concerned with all reactions in which water is a reactant—hydrolytic and hydration reactions

(a) **Salts** are hydrolyzed in solution to an extent depending upon the strength of the acid of the **anion** and the strength of the base of the **cation** **Sodium** chloride, a salt of a highly ionized base and a highly ionized acid, is, practically, not hydrolyzed in solution **Ammonium** acetate, a salt of a slightly ionized base and a slightly ionized acid, is hydrolyzed in solution with the consequent presence of some ammonium hydroxide and some **acetic acid.** One-sided hydrolysis is frequently encountered, e g, **sodium** carbonate, a salt of a highly ionized base and a slightly ionized acid, is basic (contains excess hydroxyl ions (OH^-)) in solution, **aluminum** chloride, a salt of a slightly ionized base and a highly ionized acid, is acidic (contains excess hydrogen ions (H^+)) in solution

(b) Some salts crystallize from water solution with definite ratios of water called water of **crystallization,** composing the crystal. Water of crystallization is an integral part of such crystals Spontaneous evolution of water (in cases of efflorescent crystals) or loss of water upon heating, causes change in the crystal form and composition.

(c) Some salt crystals, those containing water of crystallization and where the salt is of a slightly ionized nonvolatile base and a highly ionized volatile acid (e g, HCl), are hydrolyzed upon heating, e g, **magnesium** chloride crystals ($MgCl_2\ 6H_2O$) when heated yield hy-

drogen chloride (HCl) gas and basic magnesium chloride $\left(Mg\begin{matrix}Cl\\OH\end{matrix}\right)$ or, at higher temperature, magnesium oxide (MgO)

(d) The hydrolysis of ethyl acetate ester is discussed elsewhere in detail (See **Chemical Changes**). Many classes of organic compounds are hydrolyzable, some preferably in acidic, some in basic, and some in either media Such compounds include **esters, acetals, acid anhydrides,** polysaccharides (See **Carbohydrates**), **glucosides, tannins, amides** (to form ammonium compounds), **cyanides** (to form **carboxylic acids**), **proteins, oximes, phenylhydrazones,** osazones, semicarbazones, non-benzenoid halogen compounds

(e) **Acetylene** reacts with water in the presence of a **catalyzer,** e g , **mercuric** salt, to form **acetaldehyde** This is a reaction of great importance

II *Production of Water* This topic is concerned with all reactions in which water is a resultant

(a) In the field of inorganic chemistry, neutralization of acids and bases is a common instance of the production of water Also, the reduction of oxides, such as **copper, lead, iron** oxides, by heating them in a current of **hydrogen** gas, the burning of hydrogen gas in air or oxygen; and the loss of water of crystallization of crystals

(b) In the field of organic chemistry, the combustion of organic hydrogen compounds (rapid, as in burning, or slow) results in the formation of water from the contained hydrogen

(c) The reaction of **alcohols** plus **acids** to form **esters** (esterification) results in the accompanying formation of water Esterification is a special case of a general reaction, namely, loss of **hydroxyl** by a compound and loss of **hydrogen** by the same or another compound (chemical dehydration) Examples, ethyl alcohol, 1 molecule, into ethylene (CH_2 CH_2) plus water, thus $H_2C\begin{matrix}H\\OH\end{matrix}$, ethyl alcohol, 2 molecules, into ethyl ether ($(C_2H_5)_2O$), thus, $\begin{matrix}CH_2CH_2O\ H\\CH_2CH_2OH\end{matrix}$, ethyl alcohol, 1 molecule, plus acetic acid, 1 molecule, into ethyl acetate ($CH_3COOC_2H_5$) thus, $\begin{matrix}CH_2CH_2O\ H\\CH_3CO\ OH\end{matrix}$

(d) Another group of reactions of frequent occurrence in organic chemistry belongs in this category The reactions are illustrated by the behavior of **nitric** or **sulfuric acid** with benzenoid compounds These processes, known as nitration and sulfonation, respectively, result in the formation of water and a **nitro-compound** or a sulfonic acid compound

III *Water as Catalyzer* In some reactions water plays the role of **catalyzer**

A mixture of extremely dry hydrogen and oxygen gases is ignited with difficulty, if at all, although water is a resultant when the reaction occurs, and in the presence of water **ignition** is easily accomplished by flame or electric spark Dixon found that the rate of explosion of **carbon monoxide**-oxygen gas mixtures was definitely affected by the presence of water vapor, thus, when the mixture was saturated with water vapor at 28° C (3 7% water vapor) the rate of explosion is 1713 meters per second, when moderately dry, 1305 meters per second, and when dried with phosphorus pentoxide, 1264 meters per second

Baker (1902) showed that extremely dry hydrogen (2 volumes) plus oxygen (1 volume) does not explode even when heated to redness No combination of the gases occurs when heated below 960° C (although an electric spark induces an explosion) Previously, it had been demonstrated that extremely dry **ammonia** and **hydrogen chloride** gases do not unite to form ammonium chloride as ordinarily occurs. Burk and Hinshelwood (1927) admitted the dried gases into a glass receiver that had been heated at 200° C. in vacuum to remove all water *except* a film of **adsorbed** water on the interior surface of the glass receiver They showed that no ammonium chloride smoke was formed in the gas upon admitting extremely dried ammonia and hydrogen chloride gases, but that solid ammonium chloride was formed on the surface of the receiver *beginning* at the place of entrance of the gases The reaction probably takes place between ammonium ions (NH_4^+) and chloride ions (Cl^-) in water solution

An extremely dried mixture of hydrogen and chlorine does not explode in sunlight (as does the moist mixture) Similarly, dried **nitric oxide** and oxygen mixture does not yield **nitrogen** dioxide, **carbon,** when heated to bright redness in dried oxygen, does not burn, **sulfur,** when distilled in dried oxygen, does not burn, **potassium,** when vaporized in dried oxygen, does not burn, **sodium,** burning freely in air, is extinguished when lowered into a jar of dried oxygen Baker (1922) reported remarkable elevations of the boiling point of liquids that had been subjected to drying for several years by means of phosphorus pentoxide, e g , bromine, dried 8 years, original boiling point 63° C , new boiling point 118° C , elevation of boiling point 55° C , benzene, 8 5 years, 80°, 106°, 26° C , respectively, ethyl alcohol, 9 years, 78 5°, 138°, 60° C , respectively (R K S)

REACTOR The effect of a short circuit upon any portion of the electrical system is immediately reflected throughout the whole system In order to minimize the disturbance, and localize it as much as possible, extensive use is made of current limiting reactors The reactor, as the name implies, is a coil introducing a certain amount of **reactance** into the circuit The coils have an air or concrete core In use, they choke the current rush on short circuit, preventing overheating or excessive mechanical strains, and permitting the use of circuit breakers of smaller capacity

Reactors are used in **alternator** leads if the alternator reactance is insufficient to limit short circuit current to a safe value, they are used in sectionalizing a bus to localize disturbances, and in feeder lines to prevent a serious drop in voltage on feeders other than the short circuited one, thereby reducing the probability of synchronous apparatus falling out of step The percentage reactance of generators varies from 8% to 30%, and of transformers from 3% to 15% Reactors are rated on the per cent reactance drop they will give at rated frequency

$$\text{The per cent reactance is the } \frac{\text{voltage drop across reactor}}{\text{voltage to neutral}}$$

at the rated capacity (in kilovolt amperes) of the reactor (F T M)

REALGAR. The mineral realgar is a **monosulfide of arsenic** corresponding to the formula AsS. It is **monoclinic,** showing short prismatic crystals, or may be in granular or compact masses It is a soft sectile mineral, hardness, 1 5–2, specific gravity, 3 5, luster, resinous, color, red to orange yellow, transparent to translucent Realgar occurs associated with other arsenic minerals and with **gold, silver,** and **lead** ores, although not in great quantities It has been found as a hot spring deposit and in volcanic sublimations Realgar has been found in Macedonia, Japan, Switzerland, and in the United States in Yellowstone National Park, as a hot spring deposit, and in Utah and Nevada The name realgar is derived from the Arabic words *rahj al ghar,* which means the powder of the mine. (E S C S)

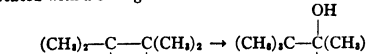
REARRANGEMENTS. These are reactions in organic chemistry which involve the transfer of an **atom** or group from one part of the **molecule** to another **Tautomerism** is a special case of rearrangements in which the two forms are in dynamic **equilibrium** When such reactions take place the establishment of structural formulae is complicated, since such reactions

do not serve as proof for the establishment of structural formulae (**Chemical Formulae**) The following is a list of the more important cases of rearrangements.

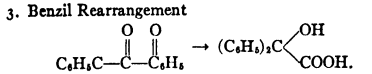
1. Allyl Rearrangement

$$CH_3CH\ CHCH_2Br \rightarrow CH_2\ CHCHBrCH_3$$

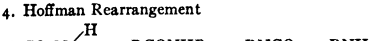
2. Pinacol Rearrangement takes place when pinacol is treated with a strong acid



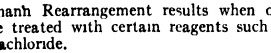
3. Benzil Rearrangement



4. Hoffman Rearrangement

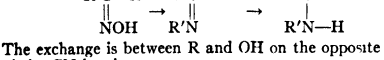


5. Beckmann Rearrangement results when oximes of ketones are treated with certain reagents such as phosphorus pentachloride.

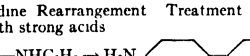


The exchange is between R and OH on the opposite sides of the CN bond

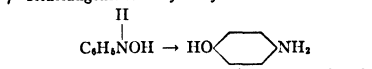
6 Benzidine Rearrangement Treatment of hydrazobenzene with strong acids



7 Rearrangement of hydroxylamine derivatives



8 Rearrangement in reaction of nitrous acid and alkyl amines



9 Walden Inversion A rearrangement takes place in the reaction of optically active substances The structural formula does not change but the configuration changes due to the interchange of two groups attached to the asymmetrical carbon atom during the course of the reaction (R K S)

REAUMUR SCALE. Temperature Scales.

RECALESCENCE. A singular phenomenon exhibited by iron and some other ferromagnetic metals If iron is heated white hot and allowed to cool, it will, at a certain temperature, suddenly evolve enough heat to halt the cooling and even produce a momentary heating This is easily exhibited by stretching an iron wire against the tension of a spring and arranging a lever index to show slight changes in length The wire is first heated by an electric current As it cools and contracts, the index will at a certain point give a perceptible jerk, and then resume its steady motion of contraction The effect is thought to be due to some exothermic change in the crystalline structure The reverse phenomenon, exhibited on heating, is called "decalescence" For cast iron the recalescence point is a little below 700° C Pure iron has two such points, at 780° C. and 880° C

A somewhat analogous effect is exhibited by some amorphous solids upon "devitrification," which takes place when the temperature becomes high enough for the substance to crystallize Non-crystalline sodium silicate, for example, has such a transition point near 500° C., where it suddenly begins to glow. (L D.W)

RECEIVER. The radio receiving system consists of an **antenna** to receive the broadcast waves, **vacuum tubes** of different types for amplification, demodulation, power output, etc, a **loud speaker** for the final delivery of the audio frequency impulses back to the air for the creation of speech or music, and numerous condensers, resistors, inductances, and transformers for the purpose of tuning, adjusting voltages, and generally providing the proper electrical circuit characteristics between tubes Radio receivers have been based on many different special circuits, amongst which the more important have been

1. Regenerative
2. Tuned radio frequency.
3 Superheterodyne

Regenerative receivers, in addition to having poor selectivity, tended to produce interference in nearby receivers tuned to the same frequency, and, as a result of these defects, are but little used today as broadcast receivers Tuned **radio frequency** receivers use three or more tuning circuits, all of which are under a single operating control This system consists of an antenna and antenna coupling to transfer the signal wave to the grid of the first tube in the receiver This is usually followed by one or more stages of radio frequency amplification, then by a **detector** which will detect variations of amplitude in a train of **audio frequency** waves, and which, acting as a rectifier, produces an audio frequency wave which is then picked up and amplified by audio frequency amplifiers to give sufficient power to operate a loud speaker The selectivity of the tuned radio receiver is superior to that of the regenerative set, but inferior to the superheterodyne, and it is being superseded by the latter

The superheterodyne is very much like a tuned radio frequency receiver, but has, in addition, a frequency converter and intermediate frequency amplifier It is this intermediate frequency amplifier which provides the special characteristics of the superheterodyne principle Its selectivity, coupled with other desirable characteristics, has resulted in the adoption of the superheterodyne circuit by most manufacturers, even though it is patented and manufacture of it must be under license Briefly, the superheterodyne circuit receives the signal from the antenna through the radio frequency amplification stage, after which the signal is demodulated and combined with a local oscillator signal which is maintained at a definite frequency above it, usually between 400 and 500 kilocycles The combination produces a beat frequency which is called the intermediate frequency This frequency is fixed, regardless of the frequency of the signal received by the antenna This intermediate frequency is then put into an intermediate frequency amplifier, where the **electromotive force** is greatly amplified The next stage is the second detector, which separates the intermediate frequency from the audio frequency The electromotive force at audio frequency is then amplified through one or more stages of audio frequency amplification, including power output, and is ready to actuate the loud speaker The functions of the first detector and oscillator are combined in a single tube called the converter-oscillator tube The simplest superheterodyne circuit would be one in which the signal from the antenna was supplied to the convertor-oscillator tube through the radio frequency inductance coil, followed by one stage of intermediate frequency amplification, by detector tube, and by power output tube These, with the addition of a power rectifier tube, in the case of A C sets, would give a minimum of five tubes for a superheterodyne circuit.

The common telephone receiver operates by an electromagnetic action An iron diaphragm is placed in the

magnetic field of a permanent steel magnet of U shape, having soft iron extensions on the pole pieces When the receiver is not in use, the iron diaphragm is at rest under a constant pull from the permanent **magnet**. On the soft iron extensions are wound coils carrying the receiver current, and which, by electro-magnetic action, modulate the constant magnetic **flux** provided by the permanent magnet The resultant variable magnetic flux vibrates the diaphragm in accordance with the variation of receiver current until it produces sound waves which duplicate those used to vary the carrier current at the **transmitter** (F T M)

RECEPTACULUM SEMINIS. A reservoir associated with the genital ducts of the female The seminal fluid received from the male during coitus is stored in this organ The term spermatheca is also applied to such reservoirs

In some of the **insects** a pouch of independent origin receives the seminal fluid In some species it is connected with the vagina and in others its external opening is independent, but in both forms it is called the bursa copulatrix It may be associated with a true spermatheca or may itself be the storage reservoir (A W L)

RECESSIONAL MORAINE. Terminal moraine.

RECIPROCAL OF NUMBER. Division

RECIPROCAL SYSTEMS OF VECTORS From the **quadruple vector product** formula, we obtain

$$\mathbf{r}[\mathbf{abc}] = [\mathbf{rbc}]\mathbf{a} + [\mathbf{rca}]\mathbf{b} + [\mathbf{rab}]\mathbf{c}$$

where $[\mathbf{abc}] = (\mathbf{a}\times\mathbf{b})\cdot\mathbf{c}$, or

$$\mathbf{r} = \mathbf{r}\cdot\frac{\mathbf{b}\times\mathbf{c}}{[\mathbf{abc}]} + \mathbf{r}\,\frac{\mathbf{c}\times\mathbf{a}}{[\mathbf{abc}]} + \mathbf{r}\,\frac{\mathbf{a}\times\mathbf{b}}{[\mathbf{abc}]}.$$

The three **vectors**

$$\frac{\mathbf{b}\times\mathbf{c}}{[\mathbf{abc}]}, \quad \frac{\mathbf{c}\times\mathbf{a}}{[\mathbf{abc}]}, \quad \frac{\mathbf{a}\times\mathbf{b}}{[\mathbf{abc}]},$$

which are perpendicular, respectively, to the planes of **b** and **c**, **c** and **a**, **a** and **b**, are said to form the system reciprocal to the vectors **a**, **b**, **c**

It is found that if we denote this system of reciprocal vectors by **a′**, **b′**, **c′**, then

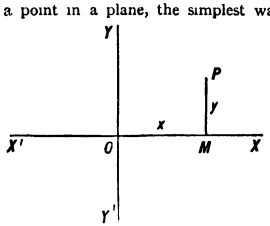
$$\mathbf{a} = \frac{\mathbf{b}'\times\mathbf{c}'}{[\mathbf{a}'\mathbf{b}'\mathbf{c}']}, \quad \mathbf{b} = \frac{\mathbf{c}'\times\mathbf{a}'}{[\mathbf{a}'\mathbf{b}'\mathbf{c}']}, \quad \mathbf{c} = \frac{\mathbf{a}'\times\mathbf{b}'}{[\mathbf{a}'\mathbf{b}'\mathbf{c}']}$$

We also find that

$$[\mathbf{abc}]\ [\mathbf{a}'\mathbf{b}'\mathbf{c}'] = 1$$

The system $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, $\hat{\mathbf{k}}$ of unit vectors is reciprocal to itself (L L S)

RECTANGULAR COORDINATES IN A PLANE. In most mathematical investigations involving geometrical figures, it is necessary to fix the positions of points by means of some system of coordinates, which consists of a set of numbers referred to a framework of reference For a point in a plane, the simplest way to fix its position is by means of a pair of numbers called its rectangular coordinates



Rectangular coordinates

Let $X'X$ and $Y'Y$ be two straight lines perpendicular to each other These lines are to be used as a framework of reference, and are called rectangular coordinate axes, and their intersection O is called the origin, $X'X$ is called the X-axis and $Y'Y$ the Y-axis The X-axis is usually drawn horizontally

Let P be any point in the plane; draw line PM perpendicular to the X-axis Let the distance OM be regarded as positive when M is to the right of the origin and negative when M is to the left of the origin, let the distance MP be regarded as positive when P is above the X-axis and negative when P is below the X-axis These distances with the associated algebraic signs are called directed distances.

The rectangular coordinates of the point P are the directed distances OM and MP The directed distance OM is called the abscissa of P and is usually denoted by x, and the directed distance MP is called the ordinate of P and is usually denoted by y. Together the abscissa x and the ordinate y are the rectangular coordinates of point P. A point whose rectangular coordinates are x and y is commonly denoted by the symbol (x, y).

Every point in a plane has a single pair of rectangular coordinates, and conversely, every pair of rectangular coordinates determines a single point

Rectangular coordinate paper (or squared paper) is paper ruled into small squares, and is very useful for plotting points given by rectangular coordinates in the plane

The distance between the points whose rectangular coordinates are (x_1, y_1) and (x_2, y_2) is given by the formula

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

A point of division P which divides the line-segment P_1P_2 joining the points whose rectangular coordinates are $P_1(x_1, y_1)$ and $P_2(x_2, y_2)$ so that $P_1P/P_1P_2 = r$ has rectangular coordinates given by the formulas

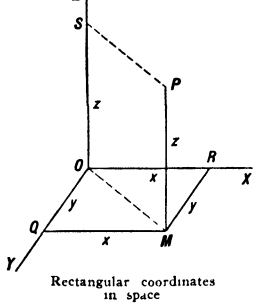
$$x = x_1 + r(x_2 - x_1), \quad y = y_1 + r(y_2 - y_1)$$

In particular, the mid-point is given by

$$x = \tfrac{1}{2}(x_1 + x_2), \quad y = \tfrac{1}{2}(y_1 + y_2) \qquad \text{(L L S)}$$

RECTANGULAR COORDINATES IN SPACE. The simplest method for determining the position of a point in space is by means of a set of three numbers called the rectangular coordinates

Let three mutually perpendicular **planes** be chosen, intersecting in lines $X'X$, $Y'Y$ and $Z'Z$, these lines are also mutually perpendicular These planes are called rectangular coordinate planes, and are labeled the XY, YZ and ZX planes, the intersection lines $X'X$, $Y'Y$ and $Z'Z$ are called coordinate axes and are labeled the X-axis, Y-axis and Z-axis respectively The point of intersection of the planes and of the axes is called the origin



Rectangular coordinates in space

Let us suppose the XY-plane to be horizontal, with the X-axis in the plane of the paper, the ZX-plane to coincide with the plane of the paper and in vertical position, and the YZ-plane therefore perpendicular to the plane of the paper and in vertical position This is sometimes called a left-handed system Frequently the X- and Y-axes are interchanged from the preceding position, and we then have a right-handed system

In the above left-handed system, let P be any point and draw PM perpendicular to the XY-plane, then MR perpendicular to the X-axis and MQ perpendicular to the Y-axis Let the directed distance MP be regarded as positive when P is above the XY-plane and negative when below, let the directed distance QM (or

OR) be considered positive when *P* is to the right of the *YZ*-plane and negative when to the left, let the directed distance *RM* (or *OQ*) be considered positive when *P* is in front of the *ZX*-plane and negative when behind

The rectangular coordinates of the point P are the directed distances QM (or *OR*), *RM* (or *OQ*) and *MP* (or *OS*), and are usually denoted by *x, y, z* respectively. These rectangular coordinates of a point are therefore the directed perpendicular distances of the point from the coordinate planes

The distance between the points whose rectangular coordinates are (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2}$$

A point of division *P* of a segment joining the points in space whose rectangular coordinates are $P_1(x_1, y_1, z_1)$ and $P_2(x_2, y_2, z_2)$ so that $P_1P/P_1P_2 = r$ has coordinates given by

$$x = x_1 + r(x_2 - x_1), \quad y = y_1 + r(y_2 - y_1), \quad z = z_1 + r(z_2 - z_1).$$

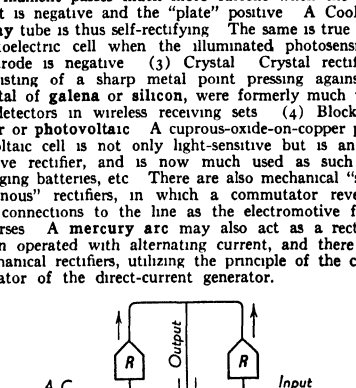
In particular, the mid-point is given by

$$x = \tfrac{1}{2}(x_1 + x_2), \quad y = \tfrac{1}{2}(y_1 + y_2), \quad z = \tfrac{1}{2}(z_1 + z_2).$$

(L.L.S)

RECTANGULAR HYPERBOLA. Hyperbola.

RECTIFIERS. It is often desired to draw a direct current from an alternating-current source, a rectifier or "current valve" is a device for accomplishing this Four principal types have been extensively used (1) Electrolytic. Certain electrolytic cells present a high resistance to the current in one direction, for example, one with lead and aluminum electrodes and an electrolyte of sodium bicarbonate conducts readily only when the aluminum is the cathode (2) Thermionic or photoelectric A thermionic vacuum tube with a white-hot filament passes much more current when the filament is negative and the "plate" positive A Coolidge **x-ray** tube is thus self-rectifying The same is true of a photoelectric cell when the illuminated photosensitive electrode is negative (3) Crystal Crystal rectifiers, consisting of a sharp metal point pressing against a crystal of **galena** or **silicon**, were formerly much used as detectors in wireless receiving sets (4) Blocking-layer or **photovoltaic** A cuprous-oxide-on-copper photovoltaic cell is not only light-sensitive but is an effective rectifier, and is now much used as such for charging batteries, etc There are also mechanical "synchronous" rectifiers, in which a commutator reverses the connections to the line as the electromotive force reverses A **mercury arc** may also act as a rectifier when operated with alternating current, and there are mechanical rectifiers, utilizing the principle of the commutator of the direct-current generator.



A four-part rectifier circuit for utilizing both halves of the current cycle

Rectifiers are often coupled in such a way as to utilize both halves of the current cycle The figure shows a set of four rectifiers (R) arrayed for this purpose. (L D W)

RECTIGRADATION. Aristogenesis.

RECTUM. A terminal portion of the alimentary tract (**digestive system**) (**intestine**) in which the feces accumulate, pending their periodical discharge It may be a part of the true gut, lined with endodermal tissue, or a part of the **proctodaeum**, lined with ectoderm. (A W L)

RED BELLY. Pisces, Teleostei A **sunfish** of olive color with red belly and lower fins It is found from Maine to Louisiana (A W L)

RED CLAY. The most common of deep sea sediments A ferruginous clay formed from the alteration products of volcanic ash and other **aeolian** sediments, including **meteoric** material **Manganese** concretions develop in these muds which are deposited exceedingly slowly and contain little or no organic or **calcareous** matter, due to the solvent power of the sea water under great pressure (R M F)

REDFIN Pisces, Teleostei The common shiner or **dace**, *Luxilus cornutus*, and another species of the same group which becomes red below during the breeding season Both are small fishes which are abundant in small streams (A W L)

REDFISH. Pisces, Teleostei 1 The Tahoe **trout**, *Trutta henshawi*, found in streams and lakes on the eastern slope of the Sierras 2 The channel **bass**, *Sciaenops ocellata*, an important marine food fish taken along the Atlantic and Gulf coasts of the United States 3 A species of **salmon**, *Oncorhynchus nerka*, second only to the king salmon in the fisheries of the Pacific Coast Also called the blueback Its flesh is deep red (A W L)

REDHORSE. Pisces, Teleostei Fresh-water fishes (**Pisces**) of the genus *Moxostoma* found in rivers and lakes of the eastern half of the United States The common redhorse is a good food fish, also called the white sucker or mullet (A W L)

RED MUD. A reddish-brown deep-sea mud composed of **aeolian** terrigenous dust or **loess** which is deposited off the seaward end of a large delta or off desert coast lines (R M F)

REDPOLL. Aves, Passeriformes A small bird (**Aves**) related to the finches Named for its red crown One species nests in the northern parts of the northern hemisphere and is known in Europe as the mealy redpoll Europe has another species, the lesser redpoll, and Asia and North America have the related hoary redpoll, *Acanthis hornemanni*, which only occasionally enters the northern United States (A W L)

REDSHANK. Aves, Charadriiformes A Eurasian bird (**Aves**), *Tringa totanus*, related to the snipes and sandpipers, named from the red color of the bare part of the legs The name is also applied to a larger related species of Europe, *T erythropus* (A W L)

RED SHIFT. Spirals; Doppler Effects.

REDSTART. Aves, Passeriformes 1 Birds (**Aves**) of Europe, northern Africa, and palaearctic Asia The common redstart, *Phoenicurus phoenicurus*, also called the firetail, has the tail and rump chestnut above This and the allied species are related to the thrushes 2 The American (*Setophagea ruticella*) and painted (*S picta*) redstarts of North America are **warblers** Both are variable in color according to age and sex, adult males showing black and white with red or orange markings The painted redstart extends into Mexico (A W L)

REDTAIL. Aves, Falconiformes. The red-tailed **hawk**, *Buteo borealis* (A W L)

REDUCING MOTION. A reducing motion is one in which a given displacement of rectilinear, rotary, or

curvilinear character is converted by the apparatus to a similar motion in which the displacements are at all times proportional to the original motion, but on a smaller scale The multiplying lever, the large and small pulley, and the inclined plane, are a few examples of the many common elements of mechanisms which may be adapted to reducing motions These are not necessarily exact reducing motions, for frequently very close approximations serve just as well as exactly similar motion The pantograph, which is described in the article on **parallel mechanisms**, is typical of another group of reducing motions, in which the apparatus is of a more specialized character, and not merely some adaptation of a general element of mechanism (F T M)

REDUCTION. Reactions Involving Oxidation-Reduction.

REDUNDANCY. In a structure of the type of a **truss**, redundancy refers to the condition in which there are more members than would be needed to produce stability if the joints act as hinges Redundant members may be used for the purpose of producing a more rigid structure than that which would be obtained with just enough members to satisfy the conditions for static equilibrium A flag pole held in a vertical position by four guy wires which are spaced equi-distant around the pole is not a redundant system, since the wires are incapable of carrying **compression** and only two wires act at one time If the guy wires were replaced by stiff members capable of carrying either **tension** or compression the system would be redundant, as but two are necessary A truly redundant structure is incapable of analysis by statical mechanics because the distribution of load between the redundant members and the other members depends upon the elastic properties of the members The distribution of stress between the stiff members in the above example would depend upon their size and elastic properties The analysis of such structures can be made by the method of **least work** or other recognized methods for the solution of **indeterminate structures** (C W C, F T M)

REDWING. Aves, Passeriformes 1 A European **thrush**, *Turdus musicus*, named from the red markings of the sides and under surface of the wings 2 The American red-winged **blackbird**, *Agelaius phoeniceus* The species is black with a conspicuous red patch on the shoulder, margined with whitish or yellowish (A W L)

REDWOODS. Conifers.

REEDBUCK Mammalia, Artiodactyla *Redunca* A small African **antelope** The male has relatively small horns which turn forward Also known by the Dutch equivalent, reitbok (A W L)

REEVE. Ruff.

REFLECTION. When an emission, such as radiation or sound, traveling in one medium encounters a different medium, part of it in general passes on and undergoes **refraction**, while part is reflected. Even water waves exhibit reflection upon meeting an obstacle, and some of the characteristics of the process are conveniently observed by watching surface ripples In all cases of "regular" reflection, in which the direction of propagation is sharply defined after reflection, the change takes place in accordance with a very simple law, viz · The reflected and incident wave trains travel in directions making equal angles with the normal to the reflecting surface and lie in the same plane with it. These angles are called, respectively, the angle of reflection and the angle of incidence. For normal incidence, both of these angles are zero. Rough surfaces reflect in a multitude of directions, and such reflection is said to be "diffuse" Only part of the emission or of the energy associated with it is reflected, the ratio of that part to the whole incident emission is called the "reflectivity" of the surface

Various phenomena may accompany reflection under appropriate circumstances Sometimes there is a change or even a reversal of phase (See **Vibrations and Waves**), the reflected wave-train may be polarized (See **Polarized Light**), or the incident and reflected waves may, through their **interference**, produce stationary waves If the incident waves are of complex character, the reflection may be selective, due to the difference in reflectivity for the different components See **Mirrors and Lenses**, and **Total Reflection** (L D W)

REFLECTIVITY. Reflection; Thermal Radiation.

REFLEX. An involuntary secretory or motor response to any external or efferent impulse (See **Nervous System**) Examples of motor reflexes are as follows If a light is flashed before the eyes the pupil contracts If a painful stimulus is given the hand, the hand is jerked away Secretory reflex occurs when appetizing food is seen, smelled or tasted (The stomach begins to secrete gastric juice) These actions or reflexes do not occur unless the proper stimulus is supplied Ordinarily reflex actions are purposeful or protective, and the same response appears regularly for the same stimulus The impulse transmitted along the nerves finds the proper motor cells in the spinal chord to produce the desired muscular action—in other words, it follows a set pathway and only this reflex pathway is open to the impulse, other alternate pathways being closed

New pathways are first formed by habit or training and voluntary will is necessary to produce motor responses Hitting the keys of a typewriter may be used as an example After the proper training these voluntary actions become reflex actions and as soon as the eye sees the letter the proper key is struck without voluntary thought Piano playing is another example of acquired reflex motor response

Reflexes are of three kinds (1) Simple, involving only one muscle as in winking, (2) Coordinated, involving several or many muscles, some of which contract to varying degrees while opposing muscles relax, (3) Convulsive, where there is no coordination—all the muscles are stimulated—and only the action of the stronger muscles predominate This type is purposeless and harmful and is due to opening up of all the pathways, so that main motor cells are stimulated (R S M)

REFRACTION. The term refraction properly applies to the change of direction which light or other wave emission experiences on passing obliquely from one medium to another in which its velocity of propagation is different The physical nature of the effect can be visualized by considering a regiment marching in column of platoons across a boundary between smooth turf and freshly plowed ground If the line of march is perpendicular to the boundary, the platoons are simply slowed up and thus crowded more closely together, but if it is oblique, one end of each platoon is retarded sooner than the other, and the file swings around to a direction nearer the normal (Fig 1) A train of waves is similarly affected as it passes into a new medium with change of velocity

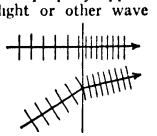


Figure 1 Change of wave length and (in general) of direction of wave train upon entering new medium

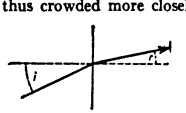


Figure 2 Angles of incidence (i) and refraction (r)

It is easy to show that if i is the angle of incidence and r the angle of refraction

at such a boundary (Fig 2), the refraction is governed by a simple relation known as Snell's law.

$$\sin i = n \sin r,$$

in which n has the same value for various angles of incidence and refraction This constant n, known as the **refractive index**, depends upon the character of the wave train and of the two media Physically it represents the ratio of the velocity of the disturbance in the first medium to that in the second For light passing from one medium to another in which its velocity is greater, so that $n < 1$, we may, for a sufficiently large angle of incidence, encounter the curious phenomenon known as **total reflection** (L D W)

REFRACTIVE INDEX. When light passes from one medium into another, it in general changes velocity. The ratio of the velocity in the first medium to that in the second is the "relative index of refraction" for the two media It is the constant of proportionality which appears in Snell's law of **refraction** If light enters a medium from a vacuum, the ratio is called the "absolute index" for that medium Let the absolute indices for two media A and B be respectively n_A and n_B Then it is easy to show that the relative index for light passing from A to B is $n_{AB} = n_B/n_A$ If, for example, the absolute indices of water and of glass are respectively 4/3 and 3/2, then the relative index from water to glass is $3/2 - 4/3 = 9/8$, while from glass to water it is 8/9

The absolute index for all ordinary transparent substances is greater than 1, but there are some metals (e g, silver) for which it is less than 1 Since the absolute index for air exceeds unity by less than 0 0003, the relative indices for solids and liquids in air are practically equal to their absolute indices It should be noted that since the refractive index varies with the wave length (See **Dispersion**), any exact statement of its value must specify the wave length to which it refers, in tables it is usually given for sodium light (5893 angstroms)

Measurements of refractive index may be made by using a **prism** of the substance at minimum deviation; by the **interferometer**, or by observing the "critical angle" of **total reflection**, as with a **refractometer** Some typical values are given below (for 5893 angstroms).

Substance	Absolute Index	Substance	Absolute Index
Air	1 00029	Glycerine	1 47
Bromine	1 66	Helium	1 00007
Carbon dioxide	1 00097	Ice	1 3
Diamond	2 419	Rock salt	1 54
Glass	1 5 to 1 7	Water.	1 33

(L D.W)

REFRACTOMETERS. Several types of instruments, called refractometers, have been devised for measuring the **refractive index** of any substance Special forms are used for solids, liquids, and gases Solid and liquid refractometers usually depend upon the principle of **total reflection** and the fact that the sine of the critical angle is equal to the refractive index for light passing from the more to the less refractive medium The critical angle is what is measured, or deduced from other measured angles.

Suppose that a specimen of the solid or liquid to be tested is brought into optical contact with one face of a glass prism (or "block") of known, higher refractive index and known angle, and that a slightly convergent pencil of light, entering the test substance, is directed at grazing incidence upon the interface between it and

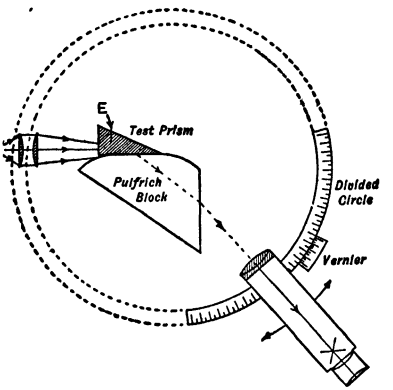


Figure 1 Pulfrich refractometer (diagrammatic).

the prism Those rays incident at less than 90° to the normal of the interface enter the prism, the others do not, and the boundary between is sharply defined. The resulting half-pencil traverses the prism and emerges from the other face where the direction of its cut-off edge can be observed (Fig 1) The angle between the cut-off boundary of the pencil and the first prism face,

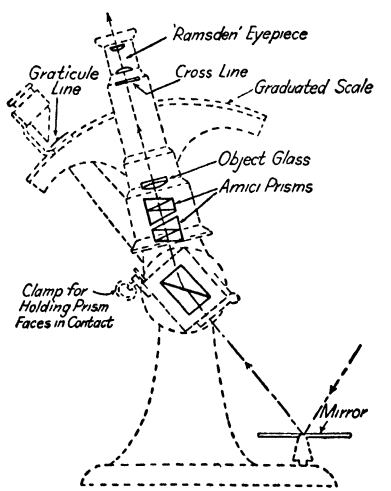


Figure 2 Optical system of Abbe refractometer.

inside the prism, is the critical angle, and can be easily calculated from the observations and the known data. This is the principle of the Pulfrich refractometer.

Another form, due to Abbe, is used for liquids. A film of the liquid is enclosed between two similar glass prisms (Fig 2), and the total reflection at the inter-

face observed Any spectrometer, with a pair of good prisms (preferably right-angled) mounted on the prism table, can be used in this way.

Rayleigh utilized an **interference** method for measuring the indices of gases Using a **collimator** to render the rays parallel, the stream of light entering one of the slits of the apparatus for **Young's experiment** is passed through a tube of the gas to be tested The resulting retardation in phase causes a shift of the interference fringes, the amount of which gives the retardation and hence the refractive index of the gas relative to the air outside the tube (L D W)

REFRACTORY. Materials which will resist change of shape, weight, or physical properties at high temperatures are known as refractories The materials which are chiefly used for refractories are fire-clay, silica (See **Silicon**), kaolin, diaspore, alumina (See **Aluminum**), and certain products of the electric furnace, such as silicon carbide Refractories are used most often in the form of bricks Refractories are chiefly used to line regions in which **combustion** creates a very high temperature Also, they are needed to line passages or chambers remote from the combustion region, but which contain high temperature gases When refractories are used to line a vessel in which a fluid such as molten steel or molten glass is to be contained, the chemical reaction of the refractory is important Basic and acid refractory brick have their industrial uses The bulk of refractory is used in **furnaces** Fire-clay brick are preferred wherever they give satisfactory service, because of their low cost Fire-clay brick are classified for temperature duty on the basis of the pyrometric cone scale (See **Seger Cone**) High temperature duty fire brick is classed as that which possesses a pyrometric cone rating equivalent to a temperature about 3,056° F, whereas low duty fire-clay must have refractoriness at not less than 2,876° F Between these two limits, the American Society for Testing Materials recognizes two intermediate classifications Extremely high temperature service is so severe that material of more refractoriness than fire-clay is often specified Silicon carbide and high alumina brick containing as much as 70% of alumina, with the remainder principally silica, are refractory at a temperature 300° F higher than the best fire-clay It is important that the refractory have certain other desirable features besides its refractoriness, for resistance to melting is only one of several requirements to be met by furnace linings Among other requirements are absence of tendency to spall under rapid fluctuations of temperature, resistance to erosion by ash-laden gases, resistance to fluxing action, and, as already mentioned, in certain cases, chemical reactions suitable for the service (F T M)

REFRIGERANT. A refrigerant is a substance which is suitable as the working medium of a cycle of operations wherein refrigeration is accomplished To be satisfactory for this service, the refrigerant should be capable of absorbing heat at a low temperature (i e, the temperatures associated with ice making, cold storage, and other forms of refrigeration) and release it at a higher temperature This may be accomplished only by a suitable expenditure of energy, in accordance with the second law of **thermodynamics**, and through processes involving expansion, evaporation, or chemical change (The last method is not used) Refrigerants in actual use can be either gases or vapors

The use of a gas is but little favored in refrigeration, due to the bulk of the equipment necessary in the cycle, however, refrigeration systems using air as a working medium are entirely successful Most refrigeration equipment operates with a vaporizable liquid as a working medium Those refrigerants which are or might be used are as follows·

REFRIGERANTS

Refrigerant	Chemical Formula	Boiling Point (atmospheric pressure)	Minimum Pressure Required (80° F cooling water)	Melting Point	Latent Heat of Vaporization
Ammonia	NH_3	− 28° F	140 lbs gage	−107° F	589 4 B T U per lb
Carbon dioxide	CO_2	Not liquid at atmospheric pressure	960 lbs. gage	−161° F.	158.6 B T U. per lb
Sulfur dioxide	SO_2	+ 14° F.	45 lbs. gage	−102° F.	172 3 B T U per lb
Ethyl chloride	C_2H_5Cl	+ 54° F	10 lbs. gage	−244 5° F	168 6 B T U per lb
Methyl chloride ..	CH_3Cl	− 10 6° F.	73 lbs gage	−132 5° F.	180 6 B T U per lb
Butane .	C_4H_{10}	+ 32° F.	25 lbs gage	−211° F.	165 2 B T U per lb
Propane .	C_3H_8	− 48° F.	130 lbs gage	−310° F	182 6 B T U per lb
Ethane	C_2H_6	−127° F	615 lbs gage	−277° F.	234 B T U per lb
Isobutane	C_4H_{10}	+ 13 6° F.	40 lbs. gage	−229° F.	158 B T U per lb
Nitrous oxide .	N_2O	−128° F.	880 lbs gage	−152° F	163 B T U per lb
Ether	$(C_2H_5)_2O$	+ 94° F	7 in. vac.	−177° F.	162 B T U per lb
Carbon bisulfide .	CS_2	+115° F.	15 in vac.	−169° F.	153 B T U per lb.
Chloroform	$CHCl_3$	+142° F	21 in vac	− 82° F.	109 B T U per lb
Carbon tetrachloride	CCl_4	+170° F	25 in. vac.	− 9° F.	83 B T U per lb
Dichlorodifluoromethane	CF_2Cl_2	+ 21° F	85 lbs. gage	−247° F	72 B T U per lb

The above data are compiled by W. R Wǒolrich, who also states that the properties that the most suitable refrigerant should possess are:

1 It should be readily obtainable.
2 It should condense at normal cooling water temperatures at relatively low pressures.
3 Its boiling point should be sufficiently low not to require vacuum operation.
4. It should have a high latent heat of vaporization
5 For the service desired the odor should not be objectionable.
6 It should not seriously interfere with lubrication (F.T M.)..

REFRIGERATION CYCLE. A refrigeration cycle is any that takes heat at a lower temperature and rejects it at a higher To do this, the cycle must receive a power input from an external source, and the amount of heat rejected is more than that taken in by the amount of work required to effect the cycle Theoretically, any power cycle which is reversible could be reversed to create a refrigeration cycle Actually, practical considerations have caused modification of the power cycle for refrigeration use Nevertheless, the ordinary vapor compression refrigerating cycle resembles the **Rankine** power cycle to a close degree In the power cycle, work is done by an **engine**, and in the refrigerating cycle work must be supplied to a reversed engine, which then becomes a pump to pump heat from a lower to a higher temperature In actual practice this heat pump is a **compressor** Most refrigeration cycles make use of a vaporous **refrigerant**, and the following discussion will be confined to that type In a power cycle the efficiency is the work done divided by the heat supplied In the refrigeration cycle the efficiency expression is replaced by "coefficient of performance," which is the reciprocal of efficiency A coefficient of performance is the heat energy extracted at the low temperature divided by the work which must be supplied to operate the cycle It measures the cycle performance in that it is an expression of the refrigeration obtained per unit of work supplied to the cycle.

$$\text{Coefficient of performance} = \frac{778Q}{W}$$

Q = heat in B T U absorbed from the ice tank, cold storage room, etc , per pound refrigerant

W = work in foot pounds supplied to the compressor per pound refrigerant

The unit of refrigeration corresponding to the absorption of heat equivalent to the production of 1 ton of ice per day of 24 hours is called a "ton" Normally, about 144 B T U must be abstracted to convert a pound of water to ice Using this value, together with the proper conversion factors, a ton of refrigeration is found to be equivalent to a heat abstraction of 200 B T U. per minute This rate of heat flow is 4 715 H P As the coefficient of performance measures the ratio of heat abstraction to input, the horsepower which would theoretically be necessary per ton of refrigeration capacity is

$$\frac{4\ 715}{\text{coefficient of performance}}$$

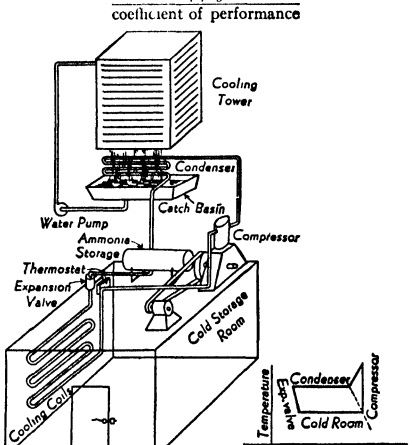


Diagram of refrigerating plant. Refrigerating cycle.

An elementary cycle of refrigeration can be operated with a minimum of four pieces of equipment These are shown in an accompanying figure Beginning the description with the refrigerating coils, note the bank of pipes in a cold storage room In these pipes is a liquid whose boiling temperature is lower than the temperature of the cold storage room, so heat is passed through the pipes into this liquid, which absorbs it as heat of vaporization, changing the liquid to a vapor. The vapor is withdrawn from the cooling coils by a motor driven compressor which increases its pressure, adiabatically, until, at the discharge pressure from the compressor, the refrigerant has a saturation temperature high enough so that it may be condensed by some available cooling source such as water The compressed vapor is discharged into a condenser This is usually a bank of tubes over which cool water trickles The heat of vaporization is passed from the vapor to the water, condensing the former to a liquid The warmed water is then either wasted, or cooled (by spray pond or cooling tower) and recirculated The liquid refrigerant then is passed through an expansion valve to the lower pressure of the cooling coils This is a throttling process The condition of the refrigerant as it emerges from the expansion valve is liquid, a very small portion of which has been flashed into vapor The delivery of the refrigerant from the cooling coils to the compressor takes place under the action of natural flow of a vapor in the direction of lowest pressure

The vapor entering the compressor is dry, or nearly so, and an **adiabatic** compression raises it to a superheated state This is shown on the cycle diagram. Known as dry compression, this entails considerably more work from the compressor than is needed merely to raise the vapor to the higher pressure If the vapor could be brought back along the saturation line instead of the adiabatic line, a large amount of work would be saved, and the coefficient of performance increased. In practice this is sometimes done by

1 Spraying a small amount of liquid ammonia into the compressor cylinder (wet compression system)
2 Jacketing the compressor cylinder with cold water
3 Cooling the refrigerant in coolers located between the cylinders of a multi-stage compressor

Control of a refrigerating system of this type is exercised thermostatically on the expansion valve, allowing it to discharge more or less liquid ammonia into the cooling coils There are important differences between the system just described, which resembles that employed in central refrigeration or ice making plants, and the small domestic refrigerator Whereas ammonia is the refrigerant chiefly used in the central palnt, domestic refrigerators operate on a variety of **refrigerants**, among which sulfur dioxide has been very popular. Air is used as the condensing medium in a domestic refrigerator, and variable load operation is secured, not by operating the compressor at constant speed and controlling the expansion valve, but by a fixed setting of expansion valve and on-off operation of the compressor The larger the refrigerating load, the smaller the off intervals of time for the compressor motor In one leading make, sulfur dioxide vapor is compressed in a small cylinder by a piston whose connecting rod is driven from a crankshaft attached directly to the motor shaft The compressed vapor is delivered at around 60 pounds per square inch pressure to a condenser which resembles an automobile radiator Air is drawn by a fan through the openings in the condenser core, and sulfur dioxide vapor is reduced to a liquid The liquid flows to a float chamber where a constant level is maintained by a float valve As more liquid flows into this chamber, the valve passes it into the freezing unit, where it absorbs heat from the refrigerator box and is vaporized The pressure there is a few pounds above atmospheric The vapor is drawn by the suction of the compressor into the compressor chamber,

where it is ready to begin the cycle again Despite the small sizes, the coefficient of performance of the domestic refrigerators is not markedly inferior to the large scale central plant. (F T M)

REGELATION. This curious phenomenon is a direct consequence of the fact that the melting point of ice is measurably lowered by intense pressure Ice at the normal melting point will, if subjected to great pressure, become liquid, and will "regelate" or refreeze when the pressure is removed Crushed ice or snow may thus be molded into clear blocks of any desired shape A small, heavy object placed on a cake of ice not too far below the melting point will gradually bury itself in the ice, the water which results from the pressure escaping from under it and refreezing above it. In the same way a cake of ice resting on a metal grid will hook itself around the bars of the grid Ice is slippery even when below the freezing point, because the pressure of any hard object, as a skate blade, produces a film of water at the surface of contact Water extruded under pressure from the terminal wall of ice at the foot of a **glacier** sometimes freezes into snake-like spirals of ice Regelation is believed to explain the flowing motion of the glacier itself Only substances which, like water, expand on freezing are capable of exhibiting regelation (L D W)

REGENERATION. In zoology, regeneration is the development of a tissue or part of the living body to replace a similar structure that has been damaged or destroyed

A conspicuous degree of regeneration is possible in some of the simpler animals, including sponges, **coelenterates**, and **worms** When cut into pieces, the fragments undergo a reorganization of their materials to form complete individuals of smaller size The process is not unlimited, however, for abnormalities of regeneration take place in some groups when the mutilation is of a certain type In experiments with flatworms (**Platyhelminthes**), for example, C M Child has found that halves of worms or a segment from the middle of the body develop into complete animals, but a head produces only another head and so perishes T H Morgan, in experiments with a species of **earthworm**, found that the amputation of a limited part of the anterior end was followed by complete regeneration but that the removal of more segments resulted in the formation of a minimum number like the original extreme anterior end Starfishes undergo the regeneration of amputated arms very readily and **mollusks** and **arthropods** are capable of some restoration of lost parts Insects and crustaceans develop new appendages if the loss occurs before the completion of their growth

Among the most remarkable cases of regeneration are those of the **bryozoans** and sea cucumbers The animal (polypide) breaks down within the body wall (zooecium) in the former group to become a disorganized mass called the brown body From the zooecium a new animal is formed. Sea cucumbers, under extremely irritating stimuli, sometimes discharge the entire intestine, along with the defensive Cuvierian organs The tract is later replaced.

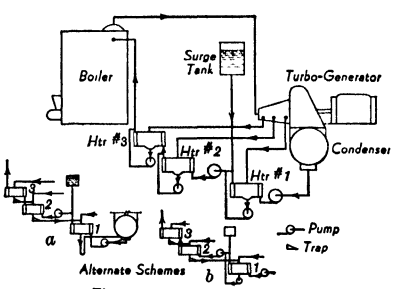
In complex animals, including man, regeneration is limited to the replacement of parts subject to wear and easy loss, such as hair and nails, and to the renewal of damaged tissues, such as skin Even the renewal of tissues is limited, some kinds undergoing normal and complete regeneration while others are repaired by the formation of scar tissue of different origin but cannot be replaced.

In engineering, regeneration is the restoration of a property or quantity to some original state In any cycle where some medium is carried through a series of processes which eventually restore it to its original condition, there is, at some point, regeneration Ordinarily, it is not thought of as regeneration, but in two specific cases this term is frequently used

A furnace so arranged that heat from the flue gases is restored to the furnace by being imparted to incoming air is frequently termed a regenerative furnace For an example of this, see **Open Hearth.**

Most of the large central power stations of the present time operate on a cycle known as the regenerative cycle, so called because of the method of regenerating the thermal potential of the working medium (feed water) in order to condition it for the boiler. Nearly fifty years ago Cotterill perceived that the extraction of some of the steam from an **engine** for the purpose of bringing the boiler **feed water** nearer to the saturation temperature of the boiler, would result in considerable **thermodynamic** gain over the simple **Rankine cycle** This idea was first applied to reciprocating steam engine plants, but did not enjoy its present widespread use until the advent of the high capacity steam central station The reason for this is to be sought in the expense of the regenerative equipment, which could not be justified in small plants

When refinements in the design of steam turbines and condensers brought the Rankine cycle to a state of perfection, but little improvement could be hoped for because increase of boiler pressure and steam temperature were the only available means of raising thermal efficiency This condition was dissipated by the application of regenerative feed water heating, using a **turbine** arranged for bleeding a portion of the steam flow from suitable intermediate points between throttle and condenser pressures The reason for the efficiency gain of the regenerative over the Rankine cycle lies in the fact that the steam, as extracted from the turbine, has performed a certain amount of work, but whereas the percentage of the available heat converted into work before extraction is considerable, the percentage decrease in the total heat of the steam is small, and hence, by extracting it before it reaches a low thermal potential, it has remaining in it a high degree of availability as a feed water heating medium This factor becomes of more and more importance as boiler pressure increases The elements of the regenerative



The regenerative vapor cycle

vapor cycle, shown in the figure, consist of the boiler-turbine-condenser combination, and one or more heaters to which steam is extracted, and through which the water flows on its way back to the boiler Plants using this cycle differ, of course, in the number of heaters employed, and in the manner of handling the heater condensate The usual arrangement is to employ from two to four extraction heaters, which heat the water to about 80% of the saturation temperature There is an attempt made to divide the heating nearly equally among the different heaters, although exact division of the heating is unnecessary About 10% of the throttle flow will need to be extracted The cycle may show 5 to 15% improvement over the plain Rankine cycle.

Regeneration in a vacuum tube may be usefully employed, as in an **oscillator,** or may be undesirable, as in an amplifier The undesirable regenerative features of the "regenerator **receiver**" have caused it to be superseded by other circuits Regeneration by the vacuum tube is caused by a feedback of some of the output voltage into the input circuit through the grid-to-plate electrostatic coupling The action of even a small portion of the amplified output energy when fed back into the tube may cause continuous oscillation In receiving sets it is necessary to balance out this electrostatic capacity and to combat oscillation by such methods as high grid resistances and carefully shielded circuits (F T M, A W L)

REGIONAL METAMORPHISM. Metamorphism.

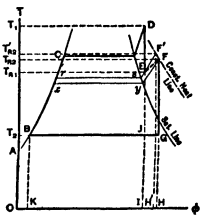
REGOLITH. Soil.

REGULUS. Regulus (α **Leonis**) has long been a famous star in all ages According to the best authority the present name was given to the star by Copernicus Among the ancients a great variety of different names were used Regulus has always been regarded as a royal star and among the Persians was considered one of the four rulers of the heavens As one of the royal stars, Regulus was considered by the **astrologers** as portending the greatest of good fortune (W K C)

REHEATING. A material, having once been heated, may be found to have undergone important changes, and it may be still further modified when subjected to reheating In some cases the reheating may have been carried out until the original state was restored, in others to some different temperature Many industrial processes in which heat plays a part, employ reheating, sometimes to the extent of several "reheats" In annealing, steel is subjected to several reheating processes, which are controlled as to temperature reached, length of time, and cooling, so that treated steels of desired characteristics are produced When air is compressed to be used in air power tools, it usually cools off between the time it is compressed and the time it is used Often it is found economical to reheat this air with fuel in order to increase its volume This is especially true in cases where the air is used expansively in the appliance

A very interesting application of reheating is to be found in the dozen or so extremely high-pressure (1200 pounds per square inch and up) steam plants operating in this country An adiabatic heat drop, such as is approximated in steam nozzles, engines, and turbines, implies that the mechanical energy which appears has been produced at the expense of the heat in the steam The physical properties of steam are such that superheated steam will lose its superheat and become more and more wet as the expansion proceeds to lower pressures It is found by experience that moisture in expanding steam is undesirable

The present trend of advanced central station design is unquestionably towards higher pressures and temperatures on account of the larger heat drop they permit Unfortunately, the increase of temperature has been checked prematurely by having reached the working temperature limits of the available metals, with the result that pressure increases have left temperatures behind Now since higher pressure means also an increased saturation temperature, it is quite evident that the divergence between advance of pressure and of temperature could have but one result, the maximum superheat possible must decrease as rapidly as the saturation temperature increases The purpose of the foregoing statements is to explain why reheating is of so much importance to the high-pressure plant The inevitable effect of higher pressures is that the saturation line is reached more quickly in an adiabatic expansion and more of the turbine stages operate in the relatively undesirable saturated steam region In order to relegate the point of saturation to a lower thermal level where high stage efficiency will not be so vital, the steam is resuperheated before it becomes wet In the resuperheating, or, as it is commonly termed, the reheating vapor cycle, the reheating is accomplished by constructing the turbine so that all of the steam may be extracted at a suitable point, resuperheated, then readmitted to the remaining stages for further expansion This is possible on both single cylinder and compound turbines but is much simpler on the compound type where the break between high-pressure and low-pressure sections offers a logical point for resuperheating An additional advantage of reheating is that the reduction in exhaust steam volume per unit of power capacity developed permits some reduction in condenser size



Elements of the reheating cycle.

There are objections to reheating, the principal ones being the added complication of the plant layout and the increased investment cost Reheat lines are of such size and are so located that concealment is virtually impossible and, furthermore, the whole of the reheat piping is difficult to construct and install Another objection arises from the energy storage in the steam contained in the reheater and the reheat piping Close governing will require governor devices on the low- as well as the high-pressure units to overcome the lag in response to normal governor movement

Considerable variations are to be found in the reheat cycles as employed at present The cycle is by no means standardized and may be expected to undergo considerable development as the very high pressures become more widely used Present methods of reheating the steam are

1 Separately fired reheat boiler
2. A reheater section in the main boiler
3 Reheater placed near turbine, using live steam from the boiler for reheating

The reheat cycle varies greatly, for instance, some plants reheat to throttle temperature, others to slightly more than throttle temperature, while the reheat temperature of still others is 150° or more below throttle temperature The reheating may take place just before saturation is reached on the expansion line, yet it will be found to occur in some plants at a temperature many degrees above that of saturation Two, three, and even four stages of reheating have been studied but it is doubtful whether the number actually employed will ever exceed two Present-day plants content themselves with one reheating All reheating vapor cycles at the present time employ regenerative feed-water heating The gains are found to be nearly additive, that is, if a reheating cycle enjoyed a 5% advantage of efficiency over the Rankine cycle, and the corresponding regenerative cycle a 7% gain, the reheating-regenerative cycle might be expected to be 12% better (F T M)

REINDEER. Mammalia, Artiodactyla A deer of arctic Eurasia It has antlers in both sexes, set well back on the head and palmately branched at the tips They are important domestic animals in Lapland and in other parts of the Old World, and have been introduced successfully into Alaska The two North American species of caribou and several other species of deer are closely related to the true reindeer. (A.W L.)

REINDEER MOSS. Lichens.

REINFORCED CONCRETE. Briefly described, reinforced concrete is plain concrete in which steel rods or bars are incorporated in such a manner as to reinforce or strengthen the more or less naturally brittle

plain concrete The use of reinforced concrete is of quite recent date, usually being considered as covering about the last seventy-five years Its discovery is commonly ascribed to a Parisian gardener named Monier in about the year 1860 Unquestionably the major development of reinforced concrete has taken place since the year 1900 and the United States leads the world in the use of this structural material

Plain concrete will carry relatively heavy compressive stresses, but any attempt to impose tensile stresses of appreciable magnitude will result in rupture and consequent failure For this reason plain concrete cannot be used for structural members subjected to a bending action or to a direct tensile action However, if steel bars are incorporated in such a manner as to carry such tensile action as may develop in the member, then a safe and satisfactory "reinforced concrete" member may be used where otherwise a plain concrete member of the same size, or even larger size, would be wholly inadequate and unsafe

There are two physical phenomena which are primarily responsible for the successful use of steel and concrete jointly to form structural units or members (a) the **coefficients of expansion** and contraction for concrete and steel are very nearly the same, thus preventing undesirable, or even disastrous, internal stresses due to differential expansion or contraction, (b) when the concrete hardens it grips the steel bars very tightly and securely and thus permits stress action between the two materials, the result of this joint action being exhibited as the strength of the structural member to resist the imposed load Usually the steel bars are roughened to give the so-called "corrugated bar" which further assists in strengthening the adhesion between the concrete and steel by affording a sort of mechanical or interlocked bond

In some structural members, where minimum cross-sectional size is desirable or necessary, steel may be used to carry some of the compressive stress as well as the tensile stress This condition may occur often in the case of columns and occasionally in the case of beams In the great majority of cases, however, the steel is used to resist tensile action Where, as in the case of a continuous girder, the tensile stress alternates between top and bottom of the member, it is customary to bend the steel accordingly, into a zig-zag shape

The amount of steel required for adequate reinforcement is commonly quite small, varying from 1% more or less for beams and slabs to as much as 6% in some cases for columns The percentage is usually based on the areas in a right cross-section of the member The bars vary by eighths of an inch from ¼ inch to 2 inches, and may be either round or square The steel may be either mild, medium, or hard, the medium grade being more commonly used with, however, an increasing preference in recent years for the use of the harder grades

A few of the more important characteristics of reinforced concrete which have made it increasingly popular with architects and engineers as a structural material are as follows durability in resisting the disintegrating action of the elements, the ease and economy with which it may be cast to any desired form or shape, the fireproof character of the construction, its massiveness and consequent freedom from vibration, and the monolithic character of construction permitted (Prepared especially for this volume by E W Saunders) (F T M)

REITBOK. Reedbuck.

REJUVENATION. The restoration of youth, a process which is in the strict sense impossible Some animals, however, gain increased vigor through special processes This change is most evident in the one-celled animals as a result of **conjugation**, but the renewal of vigor characterizes the line to which they give rise after conjugation rather than the individuals themselves, and is comparable to the maintenance of diversity by sexual **reproduction** in higher forms

Rejuvenation in complex animals, particularly man, is a partial restoration of waning functions through various means of stimulating the organs concerned Since the **endocrine glands** are important in the maintenance of normal functions, the grafting of gland tissue from other animals into the human body has been undertaken to a limited extent The gonads especially are concerned in such measures The endocrine functions of these organs have also been found to respond to other operative procedures (A W L)

RELAPSING FEVER (Tick Fever). An acute infectious disease caused by **spirochetes** which are transmitted to man by several species of the tick and the louse The disease was first recognized by Rutty in Dublin in 1741 The disease has been known all over the world but the chief centers of spread are Russia, Poland, and the Balkan states An African form is also known and is called African Tick Fever Epidemics of relapsing fever and typhus are often associated, and occur in periods of depression following war when overcrowding, famine, and lack of hygienic conditions are prevalent

The incubation period is usually seven to ten days The disease is characterized by paroxysms of acute fever lasting several days with intervals between the attacks when the patient enjoys a state of normal well-being.

In the treatment of the disease **arsphenamine** preparations are curative, ending the infection very quickly This is one of the drugs used in syphilis The mortality of the disease is about 4%

The diagnosis is easily established by finding the organism in specimens of the patient's blood during a paroxysm of fever It may be confused with malaria, typhus or dengue fever The prevention of the disease depends upon personal hygiene and destruction of vermin (R S M)

RELATION BETWEEN ROOTS AND COEFFICIENTS OF A POLYNOMIAL EQUATION. Polynomial Equations.

RELATIVE HUMIDITY. Humidity; Atmosphere; Hygrometers

RELATIVITY. It is impossible, in a brief article, to indicate more than the general trend of the far-reaching domain of scientific thought known as the theory of relativity This revolutionary philosophy, due largely to the work of Albert Einstein, had its origin in the ambiguities connected with attempts to detect absolute motion, or rather, motion with respect to a supposedly universal and omnipresent medium, the **ether** The **Michelson-Morley experiment** on the one hand and the **aberration of light** on the other, together with the results of numerous less familiar experiments to similar purpose, had given conflicting evidence The outstanding conclusion which emerged from them was that, while the motion of bodies relative to one another can be readily observed and has significant results in the physical world, the absolute motion of bodies, or motion with reference to a stationary ether, is not capable of detection and therefore may as well be omitted from physical reasoning

Proceeding on this basis, Einstein set for himself the problem of formulating the mathematical laws of physics in such a way that they should not depend either upon the positions of the points and lines chosen as a reference system (such as origin and coordinate axes), or upon whether that reference system is supposed to be moving or not To do this it was necessary, as the reasoning became more general, to give up the cherished Newtonian concepts of absolute length

absolute mass, and absolute time For the Michelson-Morley experiment, explainable only on some such basis as the **Lorentz-Fitzgerald contraction** hypothesis, had shown that length varies, in a manner not directly observable, with motion in space, so that the absolute or "static" length of a body cannot be determined. Lorentz had concluded, incidentally, that the masses of electric particles, and hence presumably of whole bodies of matter, vary with motion In the case of high-speed electrons in a vacuum tube, this variation can be detected by their failure to follow the paths prescribed by the Newtonian laws, but the actual, absolute or "rest" mass of a body must be forever unknown because we do not know its absolute motion Time, also, loses its independence If we watch things happening on two stars (such as variations in brightness), events which appear to us to be simultaneous may have actually occurred centuries apart, because of the difference in distance, and the same monochromatic light from the two stars may reach us with measurably different frequency because of the **Doppler effect.** Since all the magnitudes of physics, such as density, speed, momentum, etc, are analyzable in terms of length, mass, and time, it is clear that all magnitudes are dependent in more or less complex ways upon the forever unknowable absolute motion of the bodies concerned The outcome of all this was that, in order to avoid incorporating this unknown absolute motion in physical equations as a result of its inseparable connection with the physical magnitudes involved, the equations themselves had to be recast in such a way as to leave out that factor and permit us to forget about absolute motion altogether

Among the important by-products of this general relativity analysis were the endowment of **energy** with the characteristics of **mass,** the interrelation between **gravitation** and **inertia** (See **Einstein Equivalence Principle**), and the recognition of various fields of force (electric, magnetic, gravitational) as being different aspects of a common phenomenon—the "unified field theory"

In order to facilitate the difficult thinking required for these generalizations, Minkowski devised the plan of describing physical processes in terms of a symbolic space having four coordinates, three being the usual linear coordinates (x, y, z) and the fourth being time A graph in this four-dimensional "space-time" or "Minkowski world," called a "world line," represents the continuous history of the particle to which it pertains, any point on the graph corresponding to its position at some particular time By equations of transformation analogous to those arising upon change of axes in ordinary geometry, Lorentz showed how the description of the performance of a particle can be adapted to the viewpoints of different observers having a uniform motion relative to each other (L D W)

RELAY. The electrical relay is a device which utilizes the variation of **current** in an **electric circuit** as a controlling factor in another For example, a certain change of current in one circuit may cause current to begin to flow in another, by the operation of a relay connected between them There are numerous types of electrical relays, as they have been widely used in industry, particularly in apparatus of an automatic or semi-automatic nature, or for the protection of electric power equipment, or for communication systems Protective relays are highly specialized and developed to where they will detect any electrical abnormality, and open the circuit containing that abnormality in any required time interval Suitable relays will detect overcurrent, undercurrent, overvoltage, undervoltage, overload, reverse current, reverse power, abnormal frequency, high temperature, grounds, and phase unbalance

Usually the relay involves two circuits, the energizing circuit and the relay circuit (the latter variously the trip circuit, the sounder circuit, etc) Protective relays may close the trip circuit immediately, or after a definite time interval, or after an inverse time interval If the trip circuit contacts are normally open, the relay is called circuit closing, if they are normally closed, the relay is called circuit opening.

The automatic protection of electric power circuits is necessary for safety and economy **Fuses** and automatic **circuit breakers** are the devices most used for opening the circuit A relay must be used to operate the tripping circuit of the circuit breaker. Figure 1

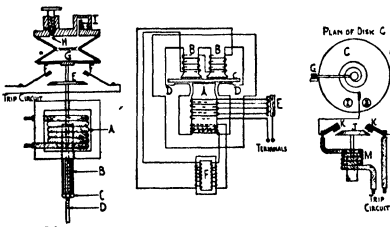


Figure 1 Relay

illustrates the principle of two types of protective relays They are, respectively, the solenoid and induction relays Simple inverse-time limit overload relays of the circuit-closing type are shown in each case Explaining the plunger type, A is the operating coil which may be connected in series with the line or through the medium of tripping transformers B is the iron plunger which will be pulled upward against gravity by the "sucking" action of the coil when a predetermined current is reached The setting for current at which the contacts are closed may be adjusted by moving the plunger up and down on its stem D by the adjusting nut C When the plunger starts upwards the pulling force on it increases due to the increased portion within the coil A Thus no floating in an intermediate position is possible However, the air compressed by bellows G delays the closing until enough can leak out through port H to permit the disk E to move up to where it will close contacts FF of the trip circuit By adjustment of the leak port needle, the amount of time delay may be changed I is a quick reset valve

The induction relay receives its current through the connection block E by means of which the number of effective turns in the primary winding may be varied The secondary winding on A is connected to the upper pole pieces BB through a torque compensator F The magnetic circuit of F becomes saturated at high overloads, the strength of the poles BB does not increase further and the relay then has a definite-time limit feature At less severe overloads the relay is inverse-time limit The interaction of magnetic fields produces a turning torque in the disk C which is resisted by a spiral spring A plan view of the disk is shown in connection with the secondary contacts The holes H are beneath the poles As they move out under the influence of an overload the torque increases and the contact G is swung around to H The holes prevent floating of G at some position G', an effect which would destroy the inverse-time feature The contacts are delicate and often the heavy trip current is passed through secondary contacts, the primary contacts carrying only enough current to energize coil M, draw up plunger J, and close secondary contacts KK

The telegraph relay has probably served man longer than any other type, and there are few persons indeed who have not listened to the busy clicking in the local telegraph office The audible signal is made by a sounder which is actuated by a polarized telegraph relay (See Figure 2) This relay consists of soft iron

cores on which windings connected to the main line are placed These cores become magnets under the action of the windings The relay is polarized by a magnet of the horseshoe type, mounted as shown in the diagram. An armature operates in an air gap between the cores With no current flowing in the windings, the armature is attracted equally by the electromagnet and the armature tends to remain in a mid position When the current flows through the windings in a certain direction it will strengthen one electromagnet and weaken the other, so that the armature will be attracted in one direction, carrying with it the contact point, which will close the sounder circuit Relays have an important place in the specialized services of the teletypewriter and in telephotography In the latter field the transmission of pictures by wire requires the use of a light relay at the receiving end This device receives the variable current from the transmitter, and converts the impulses so received into a variation of light passing an aperture This light is thrown on a revolving film which is synchronized with the film being scanned at the transmitting end (F T M)

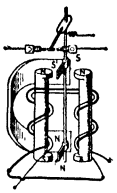


Figure 2

RELUCTANCE. Magnetic Circuit.

REMAINDER THEOREM OF ALGEBRA. If a polynomial $P(x)$ is divided by a binomial divisor of the form $x-r$, the remainder is $P(r)$, that is, the remainder may be found by substituting $x=r$ in the polynomial $P(x)$. (L L S)

REMORA. Pisces, Teleostei Marine fishes (**Pisces**) whose anterior dorsal fin is modified to form an oval sucker on the top of the head This sucker is used to attach the animal to boats, turtles, or other large objects by which the fish may be carried about without effort From their frequent attachment to sharks they are also called shark suckers, and the name sucking fish is sometimes used (A W L)

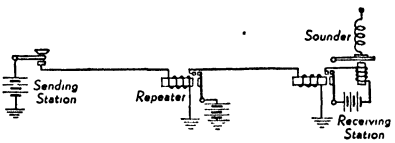
RENAL CORPUSCLE. A structural unit of the vertebrate **kidney** A renal corpuscle consists of a knot of blood vessels enveloped by a thin-walled expansion of the excretory tubule known as Bowman's capsule The knot of blood vessels, called a glomerulus, does not lie in the cavity of the tubule but merely bulges into the cavity of the capsule, covered by its thin wall The portion of the tubule which leads out of the capsule is the secretory tubule It is also involved in the removal of wastes from the blood (A W L)

RENAL PAPILLA. 1 A projection extending from the body of **cephalopod** mollusks into the **mantle** cavity It bears the opening of the excretory duct 2 The summit of a renal pyramid in the mammalian **kidney** (A W L)

RENOPERICARDIAL CANAL. A passage connecting the **pericardial cavity** of **mollusks** with the **kidney** (A W L)

REPEATED INTEGRALS. Double Integrals and Triple Integrals.

REPEATER. In telegraphing over long distances, the electrical impulse traveling on the wire becomes so attenuated that there is not enough energy received to operate a sounder In such cases repeaters or repeater stations are installed at intervals along the line to permit the introduction of additional energy In this way the distance between sending and receiving stations may be enormously increased A simple repeater installation is shown herewith by diagram In this simple form communication is possible in one direction only, for the receiving station cannot break the



Simple Telegraph Station

circuit, as it would have to do in order to insert a key A repeater station, more complicated than that diagrammed, can be installed to provide two-way telegraphy Two repeaters having holding coils, and extra batteries are required in this system

The coil and armature type of repeater is unsatisfactory for use as a telephone repeater, due to the complex nature of the current in telephone circuits The **vacuum tube** repeater is generally used as a telephone repeater element, but the electrical connections of such repeaters are rather complex (F T M)

REPRODUCTION. The production of units of living matter by other usually similar units already in existence In the ordinary use of the word these units are individual organisms but the power of reproduction is a fundamental property of living matter through which units subordinate to the individual also arise

Reproduction is at its simplest in unicellular animals (**Protozoa**) such as Amoeba These animals are single **cells**, composed of a naked mass of **protoplasm** without constant form In the process of binary fission they divide into two parts, each an independent cell like the parent Protozoans with constant body form also reproduce by binary fission but in them each half must undergo a reorganization for the development of the complete normal form of its kind Some protozoans subdivide into more than two parts by multiple fission

Fission in multicellular animals is limited to simpler forms, such as a few **coelenterates** and flatworms (**Platyhelminthes**) Here it involves a change in the relations of the cells of the body, accompanied by subdivision either longitudinally or transversely and by reorganization within the resulting halves

In true fission the individuality of the parent merges with that of the resulting offspring

Multicellular animals also reproduce by budding In this process the individuality of the parent is retained and its offspring develop gradually from a limited portion of its body The growth of a coral polyp from the extended margin of the parent is a good example The process also takes place in sponges, other coelenterates, and some of the worms

All of these processes are asexual, in contrast with the widespread process of sexual reproduction In sexual reproduction two reproductive cells (**gametes**, germ cells) normally unite to form a single cell, the zygote, which develops into a new individual In isogamous reproduction the two cells are similar More frequently they are distinctly different, a condition known as heterogamy In the latter case the differences of the cells are the foundation of **sex** in the individuals producing them. One form, the ovum or egg cell, contains a large amount of cytoplasm and often some stored food or yolk It is produced by the female. The germ cells of the male, known as sperms or spermatozoa, are microscopic in size and are motile, usually through the action of a slender tail resembling a flagellum.

The role of the parents in reproduction may be no more than the production and discharge of the germ

cells, involving some special behavior in **mating** and sometimes a close association in **conjugation** or **copulation** In other cases, notably in the mammals, the young develop in the body of the mother If the species produces eggs it is said to be oviparous If the eggs hatch within the body of the parent, it is ovoviviparous And if the young undergo a long development, nourished by close connection with the body of the mother, it is viviparous

Specialization of the body of the mother for the nourishment of the young in viviparous species is essential to reproduction, and in the mammals the secretion of milk for their nourishment after birth is equally necessary for their development to an independent stage

Incubation of the eggs by birds and extensive postnatal care by birds, social insects, and a few other forms are also essential corollaries of reproduction, although not strictly a part of the reproductive process.

Sexual reproduction has the advantage of combining hereditary qualities of different individuals Through this means it maintains maximum diversity within the species, an end of great value in meeting varied environmental conditions

A fundamental modification of the sexual process is **parthenogenesis.** (A W L)

REPRODUCTIVE SYSTEM. The assemblage of organs which give rise to the reproductive cells and carry out all accessory functions directly involved in the production of young

The essential organs of reproduction are the **gonads,** in which the reproductive cells arise, together with the ducts, if any are present, through which these cells are discharged from the body In the female the gonads are known as ovaries and their ducts as oviducts The gonads of the male are testes and their ducts are sperm ducts or vasa deferentia

Regions of the ducts are specialized for various functions in relation to the **germ cells.** In the female they give rise to yolk glands which produce the food to be stored in the egg, and glands which secrete enclosing membranes or shells, as well as glands which secrete fluids to cover the outside of the egg for various purposes Other regions become reservoirs (**receptacula seminis**) for the storage of the seminal fluid of the male after **copulation,** and the terminal part of the female genital passages becomes a **vagina** for the reception of the male intromittent organ during that act The ducts of the male produce glands whose secretions constitute a liquid medium in which the spermatozoa swim

In many invertebrates the reproductive system is independent of other organic systems, aside from the usual nervous and circulatory connections In others it is connected with the digestive tract Vertebrates, on the contrary, have the organs of reproduction usually associated with the **excretory system,** and the common ducts primitively discharge into the **cloaca,** which is also part of the digestive tract The gonads in this class arise from mesoderm in close association with the mesonephroi, although the germ cells themselves may have another origin Some of the mesonephric tubules become the slender vasa efferentia of the testes, leading to the principal ducts, the vasa deferentia, which are derived from the mesonephric ducts Thus in some fishes(**Pisces**) and in **amphibians** the male reproductive and excretory systems have common ducts, and above these classes the loss of the mesonephroi leaves their ducts to the reproductive system alone In the female a separate pair of oviducts arise, beginning near the ovaries in the funnel-shaped ostia abdominales, which open to the coelom, and extending to the cloaca.

In mammals the union of the posterior parts of the oviducts forms a single terminal passage, the vagina Anterior to the vagina portions of the ducts are specialized as the uterus, which may remain a forked or paired structure or may, as in man, become a single chamber In the last type the more slender parts of the ducts leading toward the ovaries persist as the Fallopian tubes The vagina opens independently to the exterior, but is close to the urethra in an external furrow called the vestibule

In the male the ventral part of the cloaca separates as a urogenital sinus which forms, in part, a urethra common to the excretory and reproductive systems Flanking the external opening of this structure in the embryo folds of tissue arise which join to extend the duct and to form a projecting erectile organ, the penis In more primitive vertebrates such an **intromittent organ** may arise from the wall of the cloaca As a result of this close association of the two systems, the term urogenital system is often used in vertebrate anatomy

Various accessory organs of reproduction, not an integral part of the reproductive system, appear in the animal kingdom. Among them the **mammary glands** of mammals are noteworthy They are developed in two rows along the ventral surface of the trunk or at certain points along these rows These glands secrete milk for the nourishment of the young and are subject to the intricate regulation of **hormones.** (A W L)

REPTILIA. The reptiles, including the **lizards** and **snakes, crocodiles, alligators** and related forms, and **turtles** and **tortoises.** A class of the phylum **Chordata.**

The class is characterized as follows 1 The **skull** articulates with the spinal column by a single process 2 The **mandibles** are made up of several bones, joined with the skull by the quadrate bone 3 The skin is covered with scales 4 The **heart** is four chambered but the separation of the ventricles is incomplete 5 They are **poikilothermal.** 6 They have extraembryonic membranes during development, a fundamental requirement of terrestrial life in the vertebrates

Although the group is the lowest class of vertebrates to attain the capacity for entirely terrestrial life, many reptiles are now amphibious or aquatic Even the aquatic species, however, come to the land to deposit their eggs

Reptiles are economically important to a rather limited extent The flesh of some turtles, lizards, and even snakes is used as food, and the skin of the alligator makes an excellent, if conspicuous, leather. In some regions crocodiles have been known to kill human beings Usually it seems that the danger from them is very limited Poisonous snakes also may destroy human life, but here again the danger is usually encountered only under special conditions and snake bites may be regarded as accidental

The classification of the reptiles is briefly as follows.

Order Prosauria A single living species, the tuatara of New Zealand, makes up this order It is a lizardlike animal with a few primitive structural characteristics, including a well-developed **pineal eye.** The order also bears the name Rhynchocephalia

Order Chelonia (Testudinata) The **turtles, tortoises,** and related species Characterized by the shell, consisting of an upper **carapace** and a lower plastron, formed of bony plates with a horny sheath

Order Crocodilia Large reptiles resembling lizards in form The jaws are elongated The thick skin is provided with bony plates The **crocodiles, alligators, garial,** and related species

Order Sauria The lizards and snakes In some classifications these forms are included in separate orders, and in some the lizards constitute the suborder Sauria and the snakes the suborder Serpentes of the order Squamata. The order including the lizards is also named Lacertilia All of these animals have elongate bodies. The skin bears horny scales and in some cases bony plates. (A.W.L.)

RESIDUAL RADIATION. When light or other radiation falls on the surface of a transparent body, part of it is reflected, part is transmitted, and part is absorbed The **spectrum** of the transmitted portion, when compared with that of the original radiation, may reveal that certain sharply defined wave-length ranges have failed to get through, but does not indicate whether they have been absorbed or reflected

Transparent media sometimes reflect very copiously those wave lengths whose absence from the transmitted radiation causes conspicuous absorption bands Quartz, for example, reflects (or absorbs and re-radiates) infrared radiation of 8 5 microns and also that of 20 microns wave length almost as well as a polished metal Rock salt does the same at 50 microns Rubens and Nichols devised an ingenious method of isolating beams of these infrared rays by reflection at polished surfaces of quartz or rock salt, the residue after several reflections, called by them *Reststrahlen* (residual rays), being almost monochromatic Analogous properties are exhibited in the visible spectrum by many aniline dyes, the selectively reflected light appearing as a "surface color" complementary to the transmitted portion (L D W)

RESILIENCE The resilience of a body measures the extent to which energy may be stored in it by elastic deformation The implication of the word "stored" in the above definition is that this energy may be released in the form of mechanical work when the force causing the elastic deformation is removed, and that resilience is a property of a material within its proportional limit The "modulus of resilience" is the maximum energy storage in a unit volume of the material In practical units it is the inch pounds of energy stored in a cubic inch of the material stressed to the proportional limit (**elastic limit.**) The modulus of resilience is directly proportional to the square of the stress, and inversely proportional to the modulus of elasticty (F T M)

RESINS. Natural resins (for synthetic resins, see **Plastics**) are complex compounds composed of **carbon, hydrogen** and relatively small amounts of **oxygen,** which are secreted in various tissues of many plants In the **pine family,** where resins are very common, they are secreted in resin canals, which occur in all parts of the plant, but particularly in the bark of the stem A common name given to resin in this group is pitch, which is the sticky juice which exudes from the plant wherever it is wounded On exposure to the air the **volatile oils** in this pitch gradually evaporate, leaving a clear hard glassy substance, the resin, which forms a protective coating over the wound

Most resins have the same physical properties, being clear, translucent, and of a yellow or brownish color **Amber,** a fossil resin, is a more or less familiar example Resins are insoluble in water, but soluble in common organic solvents such as ether and alcohol All resins burn with a sooty flame Resins seem to be mainly of value to the plant in that they form protective coverings against the entrance of disease-producing organisms and also prevent excessive loss of water from the thin-walled tissues exposed in the wound

Resins are separated into several classes Many of the resins contain almost no volatile oil and are hard, without taste or odor These are the varnish or hard resins Other resins, when removed from the plant in which they are formed, and dissolved in volatile oils, form a thick semi-solid mass these are the oleo-resins In still other cases the resin occurs in combination with a **gum,** forming a gum resin

Hard Resins

Several of the hard resins, used mainly for making varnishes, are called copals Most of them come from Africa and are either found in fossil form or obtained from living plants. Other copals come from Australia, New Zealand and East Indian islands The plants which form them are members of the legume and pine families The African copals are products of several species of *Trachylobium,* fairly large trees growing in east Africa and Madagascar The best resin from these trees occurs in a fossil form, often deeply buried in the ground—sometimes in regions where the trees no longer grow These resins dissolve slowly and are used in making varnishes which are very durable A South American tree of large size, *Hymenaea courbaril,* also of the Leguminoseae, yields a very similar resin, which is also fund in lumps in the ground around the trees, and used in varnishes

Another copal is obtained from *Agathis australis,* a very large coniferous tree native in Australia and New Zealand, where it is known as the Kauri pine Like the other copals, that from the Kauri pine is found in lumps buried in the ground Most of these lumps are one or two inches in diameter, but some are much larger, weighing up to 100 pounds Nearly all of this resin comes from the northern part of North Island of New Zealand It is frequently called Kauri gum, though it is not a gum, but a true copal resin Another group of hard resins, known as dammar resins, is obtained from many different trees growing in southern Asia and the East Indian Islands These resins dissolve readily in alcohol, forming spirit-varnishes

One of the commonest and most important of the hard resins is rosin, obtained by distilling the pitch, or turpentine, which is a product of several of the native pines of the southeastern United States This rosin, also known as colophony, is a very important product of that region Originally the turpentine was obtained by chopping a deep hollow in the base of the trunk of the tree and allowing it to fill up with the turpentine, which was then scooped out This method was very destructive and wasteful, since much of the turpentine was lost during the process The weakened trees were easily blown down.

Now turpentine is obtained by cutting V-shaped gouges in the bark and inserting metal gutters beneath the gouges These gutters carry the turpentine to a cup placed underneath As soon as the cut is made, turpentine begins to flow and continues to do so for two or three days, gradually slowing as the drying turpentine plugs the wounds A new flow is obtained by cutting off a narrow strip of bark from the upper edge of the cut The process is continued as long as the pitch will flow, which is usually all summer and well along into late fall Each tree may be turpentined for six or seven successive years or even longer before it ceases to be profitable

The crude turpentine collected in the cups and the product which has dried on the wound of the tree are removed and carried to the still Here the turpentine, to which a little water is added, is carefully heated to drive off the volatile oil present, together with the water added The distillate is condensed by passing it through a coil around which cold water is flowing, and collected in a barrel or any suitable container The two substances, water and turpentine, which make up the distillate, are immiscible and soon separate, the lighter turpentine rising to the top and floating on the water, which is drawn off from the bottom

The residue remaining in the tank at the end of the distillation is skimmed to remove any impurities such as twigs, bits of bark and dirt, and run into vats to cool. Then it is put into barrels and allowed to harden, forming rosin

Turpentine is used principally as a solvent for paints and varnishes, because it mixes readily with the various substances used and also because it evaporates quickly, causing the paint or varnish to dry It is also used in making such things as sealing wax and shoe polish Very pure grades of turpentine are used medicinally

Large quantities of rosin are used in sizing paper, which makes it take ink without spreading or blotting,

gives it a smoother surface and makes it heavier Rosin is also used in cheaper varnishes, in paints, and in soap making It is furthermore used as an adulterant of the more expensive resins Linoleum manufacturers use large amounts of rosin

In early times large quantities of crude turpentine were used to waterproof the rigging of the sailing vessels and to calk the seams of the hull

Since turpentine is a mixture of a volatile substance, spirits of tupentine and a hard resin, it is one of the oleo-resins

Mastic is a hard resin exuding from the branches of one of the Pistachio trees, *Pistacia Lentiscus*, native of Mediterranean Europe and Southern Asia Formerly it was extensively used medicinally, for stomach troubles and dysentery, as well as other ailments Now it is used in making varnishes and in lithographic work Natives of the region in which it is found chew mastic, which has a pleasant taste.

Oleo-Resins.

Canada balsam is one of the oleo-resins It is obtained from the bark of *Abies Balsamea*, the common balsam fir of northern North America Canada balsam, because its refractive index is so near that of glass, is much used in optical work and in preparing materials for examination with a microscope

Little used today is Dragon's blood, an oleo-resin obtained from the fruits of *Calamus Draco*, a native palm of southeastern Asia and the Molucca Islands The resin exudes from the surface of the ripening fruits It is removed from them by boiling in water The resin is then moulded into balls or long sticks It is sometimes used in making varnishes, and lacquers

True lacquer, obtained from the juice of *Rhus vernicifera*, a sumac tree of southeastern Asia, is another oleo-resin To obtain the juice lateral cuts are made in the bark The exuded sap is collected not only from these cuts but from small branches which are cut off and soaked in water The juice is cleaned of any foreign substances by straining it through hemp cloth By slow heating, either artificial or by the sun, the juice is evaporated and stored until used Lacquer is a poisonous substance, causing intense irritation of the skin in many people Others seem to be immune Lacquer is usually applied over some soft wood, commonly soft pine, the pores of which have first been filled by rubbing in a paste of rice and resin, followed by a paste of soft clay and resin The surface is then covered with cloth and layer after layer of lacquer put over that Each layer is allowed to dry and rubbed down very smooth before the next layer is added Any color which is to be added is mixed with the lacquer, with each colored layer covered by a clear layer before another is put on The final product is a thick covering composed of many thin layers of lacquers If this is carved the edges of the carving, on careful examination, will show the fine lines separating the different layers Lacquering is a very old industry, having been carried on in China since the sixth century Lacquer work is made in many other oriental countries, and the juice of many other trees used as a source for the lacquer used

Certain resins occur in combination with fragrant volatile oils One of these is benzoin, obtained from *Styrax benzoin* by cutting notches in the bark and allowing the resin to collect in them It is used in making perfumes, in incense, and as a source of benzoic acid, used medicinally

Another fragrant oleo-resin is storax, obtained from *Liquid amber orientalis*, a medium-sized tree growing in southwestern Asia The resin is obtained by boiling the bark and wood of young branches It is used medicinally and also in incense

Gum Resins

Gum resins include myrrh, which exudes from the trunk and branches of *Commiphora Myrrha*, a tree growing in the region around the Red Sea The lumps of resin are used medicinally, and also in making incense Another gum resin is frankincense, obtained by cutting notches in the stem of *Boswellia carteri*, which grows in northeastern Africa and in Arabia This resin is used in incense **Asafoetida** is also a gum resin. (R M W)

RESISTANCE. This word describes the opposition offered by a material body to forces which would tend to produce motion or to the displacement of electrons in a current The mechanical resistance of a body may arise from friction, from stresses set up in rigid anchors, from inertia forces Resistance is offered by fluids, such as air or water, to the passage of bodies through them Aerodynamic resistance is treated elsewhere in this volume See **Drag, Aeronautics, Airfoil.** Fluid friction is also treated under **Fluid Flow, Fluid Friction** See also **Friction, Mechanics**

Electrical resistance is the reciprocal of electrical conductance Electric conductors are believed to contain free electrons, the movement of which through the substance constitutes **electric conduction.** In this migration the electrons evidently meet with some restraint, since their progress is very much slower than in a vacuum tube under the same potential difference It is natural to visualize this resistance as due to collisions with the atoms, occurring so frequently that the electricity must filter along slowly If driven by considerable **electromotive force**, they produce sensible heat, but by what mechanism this comes about is not so evident, and the whole question is complicated by uncertainties as to the nature of the electron and of the atom

The measure of the resistance of a given conductor is the electromotive force required per unit current, and is usually expressed in **ohms** (See **Ohm's Law**) The resistance of a wire or other conductor of uniform cross-section is proportional to the length l and inversely proportional to the cross-section a $R = \tau l/a$ The constant τ is the "resistivity" of the substance, usually expressed in ohm-centimeters, and its reciprocal is the "electric conductivity" The dependence of resistivity upon temperature is one of the major problems of electron physics See **Resistance Thermometers** and **Superconductivity.**

Pieces of wire may be cut off at such lengths as to have definite resistances, and mounted with convenient connections to form a "resistance box," used in many electrical measurements A "rheostat" is usually a rugged conductor, often with adjustable resistance, used to introduce a resistance load into a circuit Resistances are commonly measured by means of some form of **bridge,** of which the **Wheatstone bridge** is most familiar

Some typical resistivities are given in the table below

RESISTIVITIES OF SOME COMMON MATERIALS

(In ohm-centimeters at 20° C)

Aluminum	$2\ 83\times10^{-6}$	Mercury	$95\ 78\times10^{-6}$
Brass	7	Nickel	7 8
Copper	1 72	Platinum	10
German silver	33	Silver	1 63
Iron (pure)	10	Tin	11 5
Lead	22 0	Tungsten	5 51

For some purposes it is convenient to express the resistivity as the resistance of one foot of wire of the given metal having a cross-section of one circular mil (a circular mil is the area of a circle 0 001 inch in diameter) This value may be obtained by multiplying the resistivity in ohm-centimeters by the factors $6\ 015\times10^{6}$.

The change of resistance with temperature is expressed by

$$\frac{R_2}{R_1} = \frac{234.5 + t_2}{234.5 + t_1}$$

Degrees C are to be used in the above equation

Ohm's law for d-c circuits

$$E = IR \text{ volts}$$

E is the voltage drop across a resistance of R ohms when I amperes flow.

There remains yet another type of resistance for consideration—heat resistance This might be said to be the property of offering opposition to the flow of heat This property is desirable in a heat insulator such as pipe covering, but undesirable in heat transfer equipment The term resistivity is rarely used in connection with heat flow, as its reciprocal, thermal **conductivity,** is quite satisfactory, and enjoys the advantage of common usage See **Heat Transfer, Heat Insulation.** (F T M, L D W)

RESISTANCE THERMOMETER. The fact that the electrical resistance of a metal wire increases with rising temperature is the basis of a very useful class of thermometers One has only to calibrate a given length of wire, as to its resistance in relation to its temperature, enclose it in a suitable protecting tube, and keep it connected with the resistance-measuring **bridge,** to have a resistance thermometer adapted to a variety of uses over a very wide temperature range The metal nearly always employed is platinum The variation of resistivity with temperature of platinum is very nearly linear, being closely approximated by the formula $r = 0.0000003t + 0.000011$, in ohm-centimeters and centigrade degrees Callendar found that for any given platinum resistance thermometer there is a slight systematic departure from this formula, characteristic of the particular sample of wire It is best, therefore, to calibrate each instrument throughout the range for which it is intended

Care must be taken, in mounting the platinum wire, that it does not come in contact with materials which will contaminate it at high temperatures Compensation is also necessary for the change of resistance in the wires leading to the platinum spiral This is commonly effected by balancing against these wires a pair of "dummy" wires similar to and laid alongside them The instrument is usually provided with a suitably designed resistance bridge, such as the Callendar and Griffiths or the Mueller bridge, which for practical purposes should be portable and self-contained, with battery, galvanometer, balancing rheostat, etc, all in one case, and with a cable leading to the thermometer proper The **bolometer** is a highly sensitive special type of resistance thermometer (T D W)

RESISTIVITY. Resistance.

RESOLVING POWER. Diffraction; Diffraction Grating; Microscope.

RESONANCE Every physical system, in general, has one or more natural **vibration** frequencies characteristic of the system itself and determined by constants pertaining to the system Thus a flexible string of length l and mass δ per unit length, and subjected to a tension f, will, if struck or plucked and left to itself vibrate with frequencies equal to $\frac{1}{2l}\sqrt{\frac{f}{\delta}}$ and to various integral multiples thereof (overtones) If such a system is given impulses with some arbitrary frequency, it will necessarily vibrate with that frequency even though it is not one of those natural to it These "forced vibrations" may be very feeble; but if the impressed frequency is varied, the response becomes rapidly more vigorous whenever any one of the natural frequencies is approached, its amplitude often increasing many fold as exact synchronism is reached This effect is known as resonance Thus, if one sings a clear note in front of a piano (holding down the "loud" pedal), the string nearest in tune with that note gives an audible resonant response Applications of the principle are very numerous, among them are the tuning of a radio receiving set to the carrier wave frequency of the broadcasting station, the amplification of musical sounds by resonators, as in a reed organ pipe, and the phenomenon of **resonance radiation** The resonance is said to be highly selective if impressed impulses in exact synchronism bring much more energetic response than those slightly "off key", sharp tuning of a radio set depends upon this condition. (L D W)

RESONANCE RADIATION. Radiation may be excited in a gas or a vapor by various means, somewhat as a string may give out sound by being plucked, struck, or bowed But a string may also be set into vibration by any sound which the string can itself naturally emit, this phenomenon is called **resonance.** Likewise a gas is capable of emitting radiation of certain natural frequencies (often a very complicated **spectrum**), and the excitation necessary for such emission can be imparted by passing radiation of the same kind through the gas R W Wood demonstrated this action by passing sodium light through dense sodium vapor in a dark enclosure, whereupon the track of the yellow beam became visible, not by ordinary **scattering** but by a sort of fluorescence, in which, however, there was no change of frequency as in ordinary fluorescence It seems as if the sodium atoms are able to "pick up" the frequencies natural to them and reradiate the energy as resonance radiation The same frequencies can be stimulated also by white light, and if the white light is examined after passing through the gas, it is found to exhibit an **absorption spectrum** corresponding to the bright-line resonance spectrum excited by white light (L D W)

RESORCINOL. Phenols.

RESPIRATION. The process of securing **oxygen** from the surrounding air or water and combining it with materials in the body for the release of energy

Some animals secure oxygen by diffusion through the walls of the body while others are provided with special organs for its absorption, constituting a respiratory system In either case the oxygen is dissolved in the fluids of the body in reaching the **tissues.** Transportation of oxygen to the various parts of the body may also be accomplished by diffusion in small and simple forms In the insects and some other **arthropods** it is brought about to a considerable degree by the branching air tubes (tracheae) through which air is taken into the body **Annelid** worms, **phoronids, molluska,** vertebrates, and possibly a few other invertebrate forms have respiratory pigments in the blood which combine with oxygen for transportation The more common pigments are a copper compound, haemocyanin, and an iron compound, haemoglobin They unite with oxygen readily and give up oxygen as readily to the tissues

In animals with special respiratory systems some muscular movement is necessary to bring fresh supplies of air or water to the surfaces which absorb oxygen In the terrestrial forms these are the movements of breathing Insects extend and retract the walls of the abdomen to take in and discharge air, respectively Mammals elevate the ribs and contract the diaphragm during inspiration, and when the muscles are relaxed expiration takes place Fishes swallow water and divert it through the **pharyngeal clefts,** where it bathes the **gills** in passing. Other animals carry on respiratory movements appropriate to their own structure

The intake and transportation of **oxygen** constitute external respiration Once the gas reaches the tissues it

is available for the **oxidation** of energy-bearing compounds in the process of internal respiration This union is accomplished through the action of **enzymes**

The products of oxidation are partly eliminated from the body by the respiratory system, although this phase of respiration is an excretory function (A W L)

RESPIRATORY SYSTEM. The assemblage of organs by which air or water is brought into contact with **tissues** which can absorb part of its contents of **oxygen.**

Many animals absorb oxygen through the surface of the body This is particularly true of small and simple forms, but the skin of the **earthworms** and that of some **amphibians** absorb all of the oxygen required by the animals, and any moist skin may absorb small quantities The simplest modification to be introduced as a respiratory system is some extension of the surface to provide for the needs of a more bulky body Tufted or thin platelike structures called **gills** project into the water from the surface of many aquatic animals Such structures are not adapted for air-breathing because their epithelium must be moist for the ready passage of oxygen and their extensive surface favors drying when exposed to air

In aquatic insects gills contain gas-filled tubes (**tracheae**) and are known as tracheal gills, but in most animals the blood or body fluids circulate through them Gills of this kind are found in many **annelid** worms and in the **crustaceans** In the latter group they are sometimes protected by a fold of the body wall This fold encloses them in a chamber through which water is propelled by special appendages

In many terrestrial **arthropods** the respiratory system consists of air tubes or tracheae, metamerically arranged In the primitive state each segment contains a pair of tracheae opening to the surface of the body separately through small pores called spiracles or stigmata The openings are usually guarded by some closing device or by a grating formed from the **cuticula** The tracheae have coiled **chitinous** filaments (taenidia) in their walls which keep them distended, and at their inner ends they communicate with finer tracheoles which lack these filaments These fine tubules lead to the various tissues of the body, although oxygen probably passes from them into the body fluids, rather than directly to the cells The gas-filled tubes form a closed system in aquatic insects In these forms the oxygen content is renewed by diffusion from the surrounding water in tracheal gills, as mentioned above

Spiders have a pair of lung books formed of many thin leaves in depressions in the abdomen Blood circulates in these leaves and air between them

The respiratory system of **vertebrates** is associated with the **pharynx** In primitive **chordates, cyclostomes,** fishes (**Pisces**), and larval **amphibians** the gill slits persist along this passage, so that water taken into the mouth may be expelled from the pharynx without being swallowed Finely divided blood vessels in the walls of the pharynx or in special outgrowths known as gills along the walls of the pharyngeal clefts receive oxygen from the water as it flows over these surfaces

In some fishes and in terrestrial vertebrates generally, a saccular outgrowth of the ventral wall of the pharynx forms lungs for the reception of air In the simplest forms the outgrowth branches to form two sac-like lungs In more complex lungs the surface is increased by ridges projecting into the cavities from their walls, and in the most highly developed organs of this type there are many minute chambers (alveoli) in a spongy mass of tissue containing muscle and elastic fibers The original connection with the pharynx persists, leading into a single tube, the trachea, supported by cartilage rings The principal branches of the trachea are the **bronchi** or bronchial tubes They lead into finer bronchioles whose branches communicate with the alveoli (A W L)

RESPIRATORY TREE. A branching diverticulum of the **cloaca** of sea cucumbers (**Holothuroidea**) The structure extends into the body cavity Contractions of the cloaca pump water through the pair of respiratory trees to the thin-walled ampullae with which they end, thus supplying **oxygen** to the fluid in the body cavity (A W L)

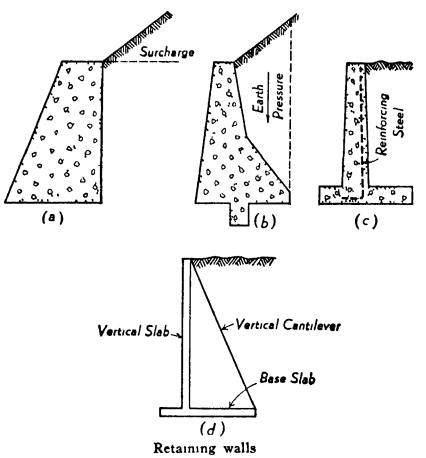
REST MASS. Relativity.

RESTSTRAHLEN. Residual Radiation.

RESULTANT. In **stress** analysis the resultant is a single vector quantity which will produce the same effect as two or more vector quantities which it replaces If these latter vectors are parallel the resultant is the scalar sum of these vectors, but if they are not parallel the addition must be made vectorially See **Vector and Mechanics.** (C W C)

RESURGENT. A term proposed by R A Daly, in 1908, for **juvenile** gases and vapors which are derived from the assimilated fragments of the intruded rock These gases may play an important role in the formation of deep-seated **igneous rocks,** or may escape as **magmatic** emanations (R M F)

RETAINING WALL A retaining wall is a structure for supporting loose material at an angle greater than its natural **angle of repose** Usually a retaining wall is of concrete construction, and used to retain a bank of earth The three principal types of retaining walls are illustrated They are the simple trapezoidal



Retaining walls

section with vertical loaded face, the section with earth pressure aiding masonry weight, and the cantilever retaining wall The successful retaining wall must be built so that it will neither slide on its base under horizontal pressure, nor tip over The pressure of the earth is, of course, variable, depending on its composition and moisture content If the earth back of the wall is well drained, so that its moisture content is a minimum, it will possess more cohesion, and exert less overturning pressure against the wall The retaining wall may, in some cases, have to be designed to withstand pressures of a surcharged embankment having a slope of at least the natural angle of repose The stability of a solid masonry section, such as that in (a) may be determined in much the same way as that for gravity masonry **dams,** except that earth pressure is not so directly and definitely computable as water pressure The section

shown in (b) will need less masonry because its shape causes it to make use of some of the vertical weight of earth as a stabilizing earth pressure Also, it is keyed into the ground so that the resistance to sliding is greatly increased A cantilever retaining wall, shown in (c), is the one with a minimum of masonry, but, because its resistance to overturning is obtained by bending action, internal moments are developed which require that this type of wall be reinforced with steel A counterfort retaining wall (d) is made up of a continuous vertical slab which is connected to a continuous horizontal base slab or footing and supported at intervals by vertical cantilevers (counterforts), which rest on the base slab The earth pressure is carried by the vertical slab, which transfers this load by beam action to the vertical cantilevers · Since concrete is weak in **tension**, the sections of this type of wall must be properly reinforced with steel rods (F T M)

RETICLE. A reticle is a set of two or more fine wires placed at the principal focus of a **telescope** lens The reticle wires are usually sections of spider web or some equally fine fiber In accordance with the fundamental principle of telescope construction this reticle must also be in the principal focus of the **eyepiece**, and when the telescope is directed on an object both the object and the reticle will be in clear view in the eyepiece

The simplest form of reticle is two perpendicular wires so placed that their point of intersection is on the collimation axis of the telescope In this case, when an object appears to be on the intersection of the wires the telescope is pointing directly at the object This is the type of reticle found in telescopic gun sights. Other types of reticles are described under such instruments as the **meridian circle** and the **zenith telescope.**

For convenience in measuring small angles with a telescope the reticle wires are frequently so spaced that two points in a distant object apparently separated by the distance between the reticle wires will subtend some particular angle (e g , ten seconds of arc, or one minute of arc) Reticle wires so spaced are commonly known as "stadia lines" and are frequently found in the telescopes of sextants, field glasses, or surveyor's instruments (W K G)

RETINA. The sensory layer of the camera **eyes** of mollusks and vertebrates The retina of the human eye includes a layer of nerve fibers on the inner surface which converge to the optic nerve, and various cellular and fibrous layers Numbering from the inner layer of nerve fibers these are an inner reticular layer, an inner nuclear layer, an outer reticular layer, Henle's fiber layer, the outer nuclear layer, a limiting membrane, the layer of rods and cones, and the pigmented layer The rods and cones are characteristically shaped sensory cells which are sensitive to light (See **Vision**)

The retina is involved in disease by various inflammations, especially in **diabetes**, **kidney** disease, and **syphilis**, and by circulatory changes in **anemia**, **arteriosclerosis**, and **thrombosis**. Detachment of the retina from the underlying layer is very serious, and complete blindness is a usual termination **Tumor** formation may also occur (A W L, R S M)

RETINULA. A visual element of the **eyes** of **arthropods** The retinula consists of a group of cells containing pigment and a central rod, the rhabdom, formed by the cells It is sensitive to light In the compound eye each ommatidium contains a single retinula, but in simple eyes a group of retinulae lie beneath the single lens. (A W L)

RETRACTOR. A muscle which pulls an eversible or extensible part back to its normal resting position in the body In the starfishes (**Asteroidea**) a pair of muscles in each ray, attached to the pouches of the stomach, serve as retractors for that organ, and in the mussels retractors draw the foot back into the mantle cavity when the animal closes its shell (A W L)

RETROGRADE MOTION. Planetary motions.

RETRO-VERSION. Uterus.

REVERBERATION. Acoustics.

REVERSE FAULT. Fault.

REVERSIBLE PROCESSES. Some physical processes are of such a nature that if they are made to take place backward, that is, to go through the same stages in reverse order, the corresponding transfers of energy at each stage are reversed in direction but not in amount Such processes are briefly characterized as "reversible" Thus a gas may have its density ρ and pressure p increased without any change in temperature (an isothermal compression) This is shown by the curve AB in Figure 1, and necessitates the removal of heat exactly as fast as it is generated by the work of compression. The

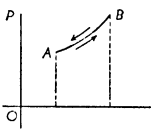


Figure 1 Reversible pressure density change in a gas

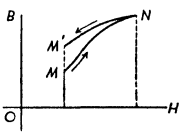


Figure 2 Irreversible induction intensity change in iron

process may, in theory at least, be duplicated in reverse, so that BA coincides with AB, by allowing the gas to expand and restoring the withdrawn heat energy just as fast as needed to keep the temperature constant Each change of a **Carnot cycle** is likewise reversible

On the other hand, consider the magnetization of iron, represented by the B-H (induction-intensity) curve MN in Figure 2 If, after increasing the magnetization of iron until its condition reaches the stage N, the intensity of the magnetizing field is reduced, no amount of care will avail to make the curve retrace itself The iron persists in retaining some of the energy that was imparted to it, and returns along NM' to a condition, represented by M', of higher magnetic induction than at first Magnetizing iron is therefore an irreversible process (L D W)

REVERSIBLE REACTIONS. Equilibrium.

REVERSING LAYER. The lower part of the sun's atmosphere is frequently referred to as the reversing layer It is a gaseous layer which is cooler than the **photosphere**, only a few hundred miles in thickness, and gradually merges into the **chromosphere** The reversing layer receives its name because it is in this region of the sun that the thousands of dark lines in the solar **spectrum**, commonly known as the **Fraunhofer lines**, are produced As a result of a tremendous amount of research on the identification of the Fraunhofer lines, it is confidently believed that they are all due to elements which are to be found on the earth These elements are reduced to the gaseous state in the reversing layer because of the tremendous heat from the photosphere. (W K G)

REVERSION. The appearance in an organism of hereditary characters which were not present in its parents but were found in previous generations The term has been interpreted as the skipping of one generation, a condition more accurately known as atavism, but these two terms are essentially synonymous The reappearance of characters after one or several generations is made entirely clear by the facts of **heredity** (A W L)

REYNOLDS' CRITERION. Important information as to the behavior of fluid flow was secured experimentally by Reynolds, and the results of his work have a definite bearing upon the field of hydraulics and aerodynamics The critical velocity range above which a liquid flow will be turbulent, below which it will be viscous, and in which it may be either viscous or turbulent, depends upon the velocity of flow, the size or shape of the conduit, and the viscosity of the liquid This latter property varies, of course, with the liquid and with its temperature Reynolds established the fact that the ratio of

$$\frac{\text{fluid velocity} \times \text{hydraulic radius}}{\text{kinematic viscosity}}$$

was the same for all liquids at the critical velocity The ratio just given is known as the Reynolds' criterion In the field of aerodynamics, a similar ratio is known as the Reynolds' number It is the ratio of

$$\frac{\text{air velocity} \times \text{chord of the airfoil}}{\text{kinematic viscosity of the air}}$$

These two ratios are valuable in their respective fields because tests of models are directly comparable to full scale results of geometrically similar shapes if the Reynolds' ratio for the model equals that of the actual or full scale project This has its practical applications in the field of **hydrodynamics** in the study of water resistance of hulls or floats, and in the study of water velocities, levee problems, etc , of large rivers It is used also to establish the best proportions of hydraulic turbines through the use of models Much of the science of **aeronautics** rests upon experimental data obtained in **wind tunnels** Dangerous inaccuracies might exist in drawing conclusions for actual construction from model tests, unless either the model were tested at a Reynolds' number equal to that of the completed project, or due corrections and allowances were made for the Reynolds' number (F T M)

RHABDITE. A crystalline rod-shaped body found in the cells covering the body of **turbellarian** flatworms They are formed in cells lying between or just below the ectodermal cells, from which they migrate to the outer cells They have been interpreted as defensive structures but the exact nature of their functions has not yet been established (A W L)

RHABDOCOELIDA. Turbellaria.

RHABDOM Eye. Retinula.

RHABDOMERE. A segment of a **rhabdom** when it is made up of clearly distinguishable parts (A.W L)

RHAGON. Porifera.

RHEA. Aves, Rheiformes *Rhea* Large flightless birds (**Aves**) of South America They are called the American ostriches but differ from the true ostriches in the fully feathered head and neck, the longer wings, and the lack of a tail There are three toes on each foot (A W L)

RHEBOK. Mammalia, Artiodactyla *Pelea* A small **antelope** found in hilly sections of eastern and southern Africa It has been compared with the chamois in habits (A.W L)

RHEIFORMES. The rheas An order of birds containing only the few South American species of this name They resemble the ostriches but differ in details of structure mentioned under **rhea.** (A W L)

RHENIUM. Symbol Re Atomic number: 75 Atomic weight 186 31 Density of metal powder 10 (approximate) Melting point 3000° C Isotopes: 185 (38 2%), 187 (61 8%)

Rhenium is a platinum-white, very hard metal, stable in air below 1000° C ; practically insoluble in **hydrochloric acid** or **hydrofluoric acid,** but soluble in **nitric acid** with the formation of perrhenic acid, forms sodium rhenate when fused with **sodium** hydroxide and nitrate Discovered by Noddack and Tacke in 1925 in **tantalite, wolframite,** and **columbite** by the Moseley **x-ray** spectographic method of analysis, and later found present in **molybdenite,** from which rhenium is obtained Predicted by Mendeléeff in 1871 as an element to be discovered with properties resembling **manganese,** and named by him dvi-manganese

Rhenium is obtained from molybdenite by dissolving in nitric acid, precipitating molybdenum as phosphomolybdate, and from the filtrate recovering rhenium as sulfide by **hydrogen sulfide** (1% Re in the product). This product is oxidized and the sublimate of rhenium heptoxide is later reduced to rhenium metal by heating in hydrogen

Chloride Rhenium tetrachloride ($ReCl_4$), black liquid, boiling point 500° C

Oxides Rhenium dioxide (ReO_2), black solid, trirhenium octaoxide (Re_3O_8), blue solid, rhenium trioxide (ReO_3), red solid, rhenium heptoxide (Re_2O_7), yellow solid, rhenium tetroxide (ReO_4), white solid, all by burning rhenium in a current of **oxygen** gas

Perrhenate Potassium perrhenate ($KReO_4$), stable in acid solution, reduced in acid medium by iodide but not by sulfide

Rhenate Sodium rhenate (Na_2ReO_4), yellow solid, soluble, stable in alkaline solution

Sulfides Rhenium disulfide (ReS_2), rhenium heptasulfide (Re_2S_7), black solid, by reaction of perrhenate solution and hydrogen sulfide

Rhenium compounds color the bunsen flame pale green (R K S.)

RHEOSTAT. A rheostat is a **resistance** used for operation or control of electrical equipment Fixed resistances are frequently termed resistors, and the word rheostat is reserved for a resistance which can be adjusted or varied Rheostats might be classified as metallic, carbon, and electrolytic types The most common form is the metallic type, in which the resistance is in the form of a metal wire or ribbon, or cast grid, these being made of a metal having poor conductivity, and little deterioration from heating The variable resistance of metallic rheostats is obtained by bringing out taps from different points of the resistance wire to the points of a multi-pointed switch which can be used to short-circuit different sections of the resistance Laboratory rheostats are frequently coils of resistance wire wound closely on an insulating cylinder and provided with a sliding contact finger which will bear on the wires themselves, and which can be employed to short-circuit any desired number of turns of the resistance wire

A carbon rheostat is made of granules of carbon plates held in a frame The resistance of carbon to flow of **electric current** varies with the pressure on it, and so by providing the rheostat with a screw clamp or other means of changing the pressure, the resistance is made variable This type of resistor is seldom used with other than small currents On the other hand, **electrolytic** rheostats are well adapted for large currents They consist of a tank or barrel containing a solution of salt or acid into which are dipped **electrode** plates The electrode plates should not be of a metal which is attacked by the solution The energy is dissipated in heat in the solution, which boils it, so that the heat is ultimately liberated by vaporization of the solution Since water is capable of absorbing nearly 1000 B T U per pound if vaporized, it is readily seen why this type of rheostat can be used for large currents There are many and varied uses for rheostats, and in many cases where resistances are used some degree of variability of the resistance is desirable A few of the applications of rheostats are for starting or controlling the speed of motors, for adjusting the field strength of generators,

for varying the circuit characteristics of radio receivers, for testing electrical equipment by interposing variable artificial loads for dimming lights, and for adjusting current flow of any description (P T M)

RHEUMATIC FEVER. (Acute rheumatic fever, acute articular rheumatism, acute rheumatism) A disease of unknown origin, probably caused by a strain of the **Streptococcus** family It is characterized by fever, toxicity, pain and inflammation of various joints. The seat of the disease is in the heart and blood vessels, where many small nodules of infection are scattered throughout their walls Where the central **nervous system** is involved in the rheumatic infection, **chorea** (St Vitus Dance) develops

Rheumatic fever is of commonest occurrence during the first three decades of life, the peak being at from nine to twelve years of age Predisposing causes are malnutrition and unhygienic living conditions There is also in some families what seems to be an hereditary lack of resistance to this type of infection Focal infection, especially of the teeth and tonsils plays an important role as a portal of entry to this particular strain of streptococcus

During the acute attack, the mortality rate is low—usually from 3% to 5%, but if permanent cardiac damage has occurred, many of the patients succumb around puberty due to the excessive growth changes taking place at this time Rheumatic fever is one of the chief causes of heart trouble in adolescent and adult life and the mortality, preceded by a long period of disability and suffering, is high In children and adolescents it is the largest single cause of death (R S M)

RHEUMATISM. Rheumatic Fever.

RHEUMATOID ARTHRITIS Arthritis.

RHINENCEPHALON The portion of the vertebrate **brain** with which the **olfactory** nerves are connected. It is the lower part of the telencephalon (A W L)

RHINITIS. Infection of the mucous membrane of the nose The common head cold (See **Coryza**) (R S M)

RHINOCEROS Mammalia, Perissodactyla *Rhinoceros* A large animal of the Oriental region or Africa, with rather short legs and a long muzzle bearing one or two conical horns behind the nostrils There are four species in the Oriental region and two in Africa The common African species stands almost six feet high at the shoulder and has an anterior horn over three feet long Because of its thick skin it can be killed only by carefully placed shots All of the rhinoceroses are described as dull and timid animals but when brought to bay they are aggressive, and because of their great size they are dangerous opponents under some conditions (A W L)

RHINOLOGY. That branch of medicine which has to do with the diagnosis and treatment of diseases of the nose (R S M)

RHINOPHORE. A posterior tentacle of **olfactory** function in some of the marine mollusks (**Gasteropoda,** Opisthobranchiata) These forms have two pairs of tentacles Those of the posterior pair have a simple eye at the base and bear organs of the sense of smell. (A W L)

RHIZOIDS Rhizoids are filamentous outgrowths from the surface, or from epidermal cells, formed of one or many cells, which serve to hold the plants of **mosses** and hepatics or the prothalli of **ferns** to the substratum Similar structures occur in the **thallophytes.** (R M W)

RHIZOME. A rhizome or rootstock is a horizontal stem growing beneath the surface of the ground or at times, at the surface It has all the characteristics of a **stem,** such as nodes and internodes, leaves and branches Often the rhizome is very much enlarged and contains much reserve food material. (R M W)

RHIZOSTOMAE. Scyphozoa.

RHODESIAN MAN. Paleontology of Man.

RHODIUM. Symbol Rh Atomic number· 45 Atomic weight 102 91 Density 12 44 Melting point: 1985° C

Compact rhodium is a white metal, almost insoluble in acids, including **aqua regia,** and is attacked by **chlorine,** by hot concentrated sulfuric acid, and by fused **potassium** bisulfate Discovered by Wollaston in 1804 Rhodium metal is used chiefly as an alloy with **platinum,** resulting in a hard, durable alloy Such an alloy (10% Rh) is used in conjunction with pure platinum in a **thermocouple** for the measurement of high temperatures

Rhodium occurs native in platinum ores, sometimes to the extent of 2% When **osmium** and **ruthenium** are present, they are removed as volatile oxides, when platinum and **iridium,** by precipitation of the ammonium chloro-compound, insoluble in alcohol, upon addition of ammonium chloride, and when **palladium,** by the precipitation of the ammonium chloro-compound with **ammonium** chloride and **chlorine.** Rhodium remains in the solution in each case, and is precipitated by the addition of a reducing agent, such as **titanium** trichloride, as rhodium metal

Hydroxide Rhodium hydroxide ($Rh(OH)_3$), yellow precipitate, by solutions of hydroxides, *e g*, **sodium** hydroxide, soluble in excess of the reagent.

Alum See Sulfate, below

Chloride Sodium rhodium chloride ($Na_3RhCl_6 \cdot 12H_2O$), dark red crystals, by ignition with **sodium** chloride and **chlorine** and crystallizing from water

Oxides Rhodium sesquioxide (Rh_2O_3), black, rhodium dioxide (RhO_2), brown

Sulfates Potassium rhodium alum ($K_2SO_4 \cdot Rh_2(SO_4)_3 \cdot 24H_2O$), potassium rhodium sulfate ($K_3Rh(SO_4)_3$, rose-colored crystals, by ignition with bisulfate and crystallizing from water (R K S)

RHODOCHROSITE. Rhodochrosite, **manganese** carbonate, $MnCO_3$, is a rose pink to red **hexagonal** mineral, occurring as small crystals, in cleavable masses, granular or compact It is a brittle mineral, hardness, 3 5-4 5, specific gravity, 3 3-3 6, luster, vitreous to pearly, color, various shades of pink, red and reddish brown, transparent to opaque, streak, white Rhodochrosite has a perfect **rhombohedral** cleavage Rhodochrosite is formed by replacement and is found as well in sedimentary deposits precipited like **siderite** by organic matter acting, in the absence of oxygen, upon bicarbonates It may occur also as a **gangue** mineral Localities for this mineral are in Rumania, Saxony, Westphalia, and Cornwall, England. In the United States rhodochrosite is found at Franklin, New Jersey, Butte, Montana, and in various localities in Colorado and Nevada The name rhodochrosite is derived from the Greek meaning rose, and color (E S C S)

RHODODENDRON. Heath Family.

RHODONITE. The mineral rhodonite, **manganese metasilicate,** $MnSiO_3$, is a **triclinic** pyroxene forming large, irregular, tabular crystals but usually occurring massive Prismatic and basal **cleavages** excellent, fracture, conchoidal to uneven, hardness, 5 5-6 5, specific gravity, 3 4-3 7, luster, vitreous to pearly on cleavage faces; color, red to pink and occasionally greenish or yellowish shades, **streak,** white, transparent to translucent A variety containing much **calcium** is called bustamite **Zinc** may replace the manganese in rhodonite, it is then known as fowlerite Rhodonite is

found in the Harz Mountains, Germany, in the Urals of Russia, in Hungary, Italy and Sweden Bustamite from Mexico, Franklin and Sterling Hill, New Jersey, occurs with **fowlerite.**

Rhodonite has been occasionally used for an ornamental stone Its name is derived from the Greek meaning a rose, because of the color. (E S C S)

RHOPALIUM. A tentaculocyst.

RHUBARB, PIE PLANT. *Rheum Rhaponticum* Polygonaceae The rhubarb plant is perennial from thick short **rhizomes.** The large somewhat triangular leaf blades are elevated on long fleshy **petioles.** The flowers are small, greenish-white and borne in large compound leafy **inflorescences.** The plant is principally grown for its fleshy petioles These are stewed to yield a tart sauce used as filling for pies and tarts The plant is indigenous to Asia

From the rootstocks of another species, *Rheum officinale,* or Medicinal Rhubarb, also native to Asia, is prepared the drug Rheum, used as a strong cathartic, and for its tonic effect on the mucous lining of the nasal cavity (R M W)

RHUMB LINE. Unless a ship is tacking or executing some other maneuver its **course** is generally constant for several hours at least In such a case the ship is said to be following a rhumb line ' The rhumb line, or loxodromic curve, may be defined as any curve on the surface of the earth such that the tangent of the curve at any point cuts the **meridian** through that point at a constant angle In case this angle has any value other than 0° or 90° it may be proved that the rhumb line is a spiral approaching one of the poles of the earth as a limit

Obviously the rhumb line course between any two points is the simplest course to follow for once having set the course it will not have to be changed until the destination is reached However, except in the particular cases where the two points are either on the same meridian or are both on the equator, the rhumb line will not be the shortest distance between the two points The **mercator** chart was designed for the purpose of facilitating the laying down of rhumb line courses On a mercator chart, and only on this chart, the rhumb line appears as a straight line (W K G)

RHYNCHOBDELLIDA. Hirudinea.

RHYNCHOCEPHALIA. Reptilia.

RHYNCHODAEUM. The part of the **proboscis** of **nemertine** worms which lies in front of the brain The proboscis is an eversible structure When retracted it lies almost entirely behind the brain, but when extended the brain is near its base, thus the greater part of the proboscis constitutes the rhynchodaeum (A W L)

RHYOLITE. The general term for a group of **acidic igneous rocks,** the **effusive** equivalent of the **granites.** It occurs as lava flows, **breccias,** and in volcanic necks and dikes In the porphyritic varieties the **phenocrysts** are frequently quartz or **orthoclase feldspar** imbedded in a highly **felsitic** or glassy ground mass Rhyolites, including **obsidian,** frequently show **flow, spherulitic, nodular,** and **lithophysal structures.** (R M F)

RIBBON-FISH. Pisces, Teleostei Peculiar marine fishes (**Pisces**) with very long compressed bodies. They may reach a length of many feet with a dorsoventral thickness of less than a foot and a width of only an inch (A W L.)

RIBS. In man, the ribs number twenty-four, twelve on a side They are attached to the vertebral column behind The first seven pairs are connected with the **sternum** in front and are called true ribs The remaining five are called false ribs. The eighth, ninth and tenth are attached in front to the cartilaginous portion of the next rib above The lower two, that is the eleventh and twelfth, are not attached in front at all and are called floating ribs The spaces between the ribs are called intercostal spaces and contain the intercostal muscles, nerves and arteries The ribs form the greater part of the bony cage of the **thorax,** and preserve its outline and allow for easy motion in breathing due to their elasticity (R S M)

RICE. *Oryza sativa* Gramineae Rice is an annual grass which grows wild in tropical Asia and Africa Cultivated rice is probably derived from an Asiatic species, and is especially adapted to grow in swampy or very wet lowlands It is a shallow rooted plant, the stems of which tiller abundantly and grow from two to six feet or more in height The leaves are long and smooth The **inflorescence** is a **panicle** the branches of which may occur singly or in pairs The laterally compressed **spikelets** are one-flowered, and have a pair of small bristle-like **glumes;** the **lemma** is tough, parchment-like and sometimes **awned;** the **palea** resembles the lemma, but is somewhat smaller A distinctive character of the flower is the presence of six functional **stamens.** Commonly rice is self-pollinated The grain or karyopsis is enwrapped in the palea, and frequently also in the lemma In this condition rice grain is known as paddy, or rough rice The grain itself is smooth and shining, has a pair of longitudinal grooves on its surface, and a glassy endosperm In structure it is very similar to wheat grain

The milling of rice involves several processes First the outer coverings are removed by revolving stones and fans After this the outer seed-coats and **embryo** are largely removed by rubbing, the remaining grain is scoured and polished by rubbing on leather surfaces Finally the polished grain is given a coat of glucose and talc, and is ready for market

The principal use of rice is as a food stuff for human consumption, with China, India and Malaysia consuming the greatest quantity In the United States rice is used to a slight extent as a breakfast food and in the preparation of other foods Some rice is used in the manufacture of **starch** The hulls and residues from polishing are sometimes fed to stock Rice straw is used as stock food, for making strawboard and in the orient for making hats, and many other articles From the grain the fermented drink, sake, is prepared

In North America two native grasses are frequently called wild rice These are *Zizania aquatica* and *Z miliacea,* tall swamp grasses closely related to *Oryza* The grain is an important food for wild fowl, and finds a very limited use as a food for man, largely as a novelty. (R M W)

RICE BIRD. Aves, Passeriformes 1 The American **bobolink.** 2 The Java **sparrow,** also known as the paddy bird (A W L)

RICHARDSON'S EQUATION. Thermionic Phenomena.

RIEBECKITE The mineral riebeckite, essentially **sodium iron silicate,** $NaFe(SiO_3)_2$, is a monoclinic member of the **amphibole** group, usually in prismatic crystals It has a prismatic **cleavage;** hardness 4 ; specific gravity 3 4, vitreous luster, color dark bluish to black It occurs in **granites** and **syenites** chiefly. It is found in Greenland, Portugal, Madagascar and in the United States at Quincy, Massachusetts, near Pikes Peak, Colorado, and the San Francisco Mts, Arizona (E S C S)

RIECKE'S PRINCIPLE. The term for **thermodynamic** processes by which recrystallization may take place in **metamorphic rocks.** An explanation of one form of **foliation** and **schistosity,** whereby tabular minerals such as **hornblende** and **biotite** recrystallize with their longest dimension parallel to the developing planes

of foliation The result of differential pressures and the consequent solution where pressure is greatest, and redeposition and recrystallization where pressure is least (R M.F.)

RIFFLEFISH. Pisces, Teleostei A small fish (**Pisces**) of the genus *Cottus*, related to the miller's thumb of the eastern half of the country A **sculpin.** It is found from Alaska to the Sacramento river (A.W L)

RIFLE BIRD. Aves, Passeriformes A bird of **paradise** found in Australia and New Guinea The several species make up the genus *Ptilorhis* (A W L)

RIGHI-LEDUC EFFECT. If heat is flowing through a strip of metal and the strip is placed in a magnetic field perpendicular to its plane, a temperature difference develops across the strip This effect, discovered in 1887 independently by Righi and by Leduc, bears the same relation to the **Nernst effect** that the **Ettingshausen effect** bears to the **Hall effect.** It may indeed be regarded as analogous to the Hall effect, but with a longitudinal flow of heat replacing the electric current and a transverse temperature difference replacing the potential difference If, to one looking along the strip in the direction of the heat flow, and with the magnetic field downward, the decrease of temperature is toward the right, the effect is said to be positive It is positive in iron and negative in bismuth (L D W)

RIGHT ASCENSION Equatorial coordinates.

RIGHT TRIANGLES. Triangles.

RIGIDITY. Elasticity.

RING CANAL. 1 In the phylum **Bryozoa,** a part of the body cavity which is incompletely separated from the principal chamber and prolonged into the tentacles 2 A canal of the water vascular system of starfishes (**Asteroidea**) which forms a complete circle in the disk It is connected by the stone canal with the madreporite and gives off a radial canal into each arm The ring canal also bears the Polian vesicles and Tiedemann's bodies (A W L)

RING-DYKE A more or less circular dyke controlled by a ring-shaped **fault.** (R M F)

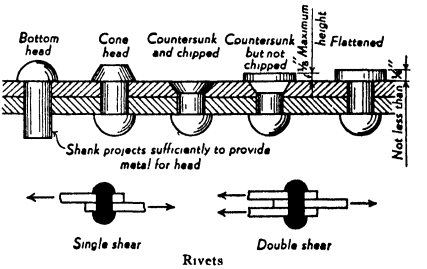
RING-TAILED CAT. Cacomistle.

RINGWORM (TINEA) A contagious disease of the scalp usually seen in children In this country it is caused by various **fungi**—usually the microsporon Circular reddened patches with crusting and pustules with loss of hair occur (R S M)

RIPPLE MARK Corrugations developed in sands and muds by currents in the water which covers them Ripple marks may be classified as due either to oscillation or translation The former are the result of oscillation currents set up in the water by the wind, the result of ordinary water waves The latter are the result of progressive, directional water currents, and the resulting ripple mark is essentially a sub-aqueous **dune.** Ripple mark is helpful in determining the conditions under which aqueous, clastic sediments are deposited Ripple mark has also been used to help determine the depth of water in which the rippled sediments have been deposited Ripple mark is also helpful in determining the original position of formations which have been subsequently deformed or overturned (R M F.)

RITZ PRINCIPLE. Atomic Spectra; Combination Principle.

RIVET. The rivet is a round bar upset on one end to form a head The length of round bar left attached to the head is called the shank of the rivet The shank must be long enough to pass through the parts being riveted and extend sufficiently for the formation of a head on the other end A rivet is driven by heating it, inserting it in the hole, and deforming the shank end into a head under the influence of a riveting machine or a pneumatic hammer As the rivet cools it shrinks lengthwise and grips the plates tightly Rivets of soft metal, such as copper or aluminum, can be set up cold Rivets for pressure tanks, structural work, hulls, or machine parts are made of a tough ductile steel or iron. Various styles of heads are employed, and the more com-



Rivets

monly used are shown in the figure A riveted joint is a permanent joint in that it cannot be disassembled without cutting off the rivet heads The hole which is made to receive the rivet should be 1/16 inch larger than the rivet for clearance and for allowance for expansion of the heated rivet The holes are generally punched but they must be drilled when the thickness of the material exceeds the diameter of the rivet or when the specifications require drilling It is impossible to punch certain kinds of steel consequently the holes have to be drilled Rivets should be driven at right angles to the forces which load them, so that they are stressed in shear or *bearing* They should not be placed so that the heads will be stressed, as the heads is the weakest part of the rivet The strength of a rivet in single shear is

$$\frac{f_s \pi d^2}{4}$$

In double shear it has twice this value Its resistance to crushing (bearing resistance) is $f_b dt$ f_s is the unit allowable shearing stress, f_b the unit allowable bearing stress, d the diameter of the rivet and t the thickness of the material (F T M)

ROAD-RUNNER. Aves, Cuculiformes A long-tailed desert bird (**Aves**) of the southwestern United States The species, *Geococcyx californianus*, is closely related to the cuckoos It is useful as a destroyer of harmful insects and reptiles The name comes from its ability to run rapidly, a power which very nearly supplants flight. Also called the snake bird, chapparral çock, and ground cuckoo (A W L)

ROASTING. Calcination.

ROBBER FLY. Insecta, Diptera A predacious **fly** of the family Asilidae Many of these flies are large and all capture living insects as prey, including bees of all kinds Most of the included species have smooth slender bodies but some are quite hairy and one group is characterized by stout form and dense vestiture. These last mimic bumblebees closely and furnish an apparent case of aggressive mimicry, since the bumblebees are said to be among their victims (A W L)

ROBIN. Aves, Passeriformes 1 The European redbreast, *Erithacus rubecula*, a **warbler,** and a related species of the Canary Islands 2 The American robin, *Turdus migratorius*, a **thrush.** 3 In Australia a species related to the **wheatear** and in New Zealand other birds of the same group (A W L)

ROC, RUC. A semifabulous bird (**Aves**) of enormous size, said to be capable of carrying an elephant in its talons The tales have been traced to a gigantic bird of Madagascar, somewhat like the ostrich in form, which is now extinct From the scattered remains and egg shells of these birds, the genus *Aepyornis* has been established, containing several species. (A W L)

ROCHELLE SALT. Tartaric acid.

ROCHES MOUTONNÉES. The term given by de Saussure, in 1796, to glaciated rock hills resembling the wigs which were fashionable during the late eighteenth century Typical roches moutonnées have rounded surfaces sloping gently in the direction of the ice movement with steeper slopes on the lee side, due to the plucking action of the ice (R M F)

ROCK DRUMLINS. Drumlins.

ROCK-FLOUR. A peculiar and distinctive white mud the product of the grinding action of **glaciers.** When deposited in lakes rock-flour forms an important constituent of **varves,** or the type of annual cyclic stratification used by glacialogists in determining glacial time When desiccated and transported by wind this material may form extensive deposits of **loess.** (R M F)

ROCK SALT. Halite.

ROCKY MOUNTAIN SPOTTED FEVER. (Black Fever, Blue Disease, Tick Fever) An acute infectious fever limited to the Rocky Mountain region of the United States It is caused by a bite of one of a species of wood-tick found in this region The disease has been known since Indian times in Idaho, Wyoming, Montana, and other Western states The organism carried by the wood-ticks has been isolated from the blood of infected patients

The disease begins four to eight days after the bite of the tick The symptoms come on suddenly and are characterized by chills, high continued fever, severe pains in bones and muscles, acute headache, and a deep red or purplish widely spread rash Mortality rate varies markedly in different regions It has been reported from around 4% up to as high as 90% The danger of death increases with the age of the patient A preventive vaccine having some remedial effect is distributed by the United States Public Health Service (R S M)

RODENTIA An order of gnawing **mammals** characterized particularly by the two chisel-like incisor teeth in each jaw These teeth oppose each other and are worn down by use to maintain a keen enamel edge on the front, while the softer dentine slopes away inward Most species are small but the **beavers** and **capybara** are moderately large animals The rats and mice are the most familiar species, with the rabbits, squirrels, chipmunks and woodchucks scarcely less known Because of their vegetarian habits and their destructive gnawing many rodents are serious crop pests, and as household nuisances they are all too common

The **rabbits** and their allies are usually included under the Rodentia as a separate sub-order, the Duplicidentata, but are sometimes assigned to an order of their own, the Lagomorpha (A W L)

RODINAL. Photography.

ROEBUCK. Mammalia, Artiodactyla *Caprealus* The male of the roe **deer** of the Old World The species is small and the antlers of the male reach a length of little more than a foot They are rough, and in normal specimens have only three tines The roe deer is a woodland species (A W L)

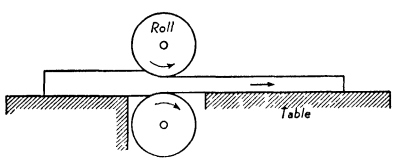
ROENTGEN RAYS. X-Rays.

ROLLER. Aves, Coraciiformes Birds (**Aves**) of several species found in Africa, the Oriental region, and Europe and Asia They are brightly colored birds, named from their habit of turning over in flight (A W L)

ROLLE'S THEOREM. Rolle's theorem is a mathematical result concerning the vanishing of the derivative of a function

Let $f(x)$ be a **function** which vanishes at $x = a$ and at $x = b$, and which has a finite **derivative** $f'(x)$ at all points in the interval (a, b) Then $f'(x)$ vanishes at some point ξ between a and b (L L S)

ROLLING MILL Steel produced from either the **open hearth** or **Bessemer** furnaces is cast into ingots of large size These ingots are then used to produce steel by different methods of working, such as cutting, forging, grinding, etc Finishing of the steel by mechanical working, such as pressing, forging, or rolling, constitutes the most important group The extensive use of steel in modern times is due to the perfection of methods and technique of shaping steel from ingots by rolling A rolling mill in the broadest sense consists of the equipment necessary to convert ingots into the finished steel shapes by the rolling process The principle of shaping steel by rolling is one wherein a rough steel shape is passed between revolving rollers whose clearance is less than the thickness of the steel piece The steel is heated to about 2000° Fahrenheit, and fed into these revolving rolls The rolls bite into the hot steel and pull it forward, deforming it and causing it to flow forward in the

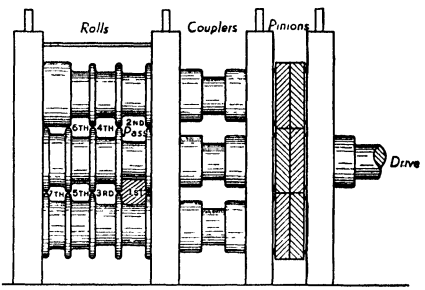


Principle of the rolling mill

direction of motion of the periphery of the rolls The piece is reduced in thickness to the clearance between rolls, and is elongated The difference between the size in the piece before and after passing the rolls is known as the draft By passing the piece through several sets (stands) of rolls, or by returning it through the same rolls after reducing their clearance and reversing them, the work can be passed through the rolling operation a sufficient number of times so that it is ultimately reduced to the desired size

While the above is briefly descriptive of the nature of rolling of steel, the rolling mill is a complicated affair Steel is rolled to so many different finished products that one rolling mill is not set up to produce all shapes, but rather a certain group of them Furthermore, the rolls which are suitable for roughing the ingot are unfit for finishing operations, and these two operations are often carried out in separate mills For example, from steel ingots come flat plates, armor plate, bars and rods, bands, structural shapes, rails, pipe and tube skelp, car wheels, and many special shapes The ingots are first rolled into blooms or slabs for use in the finishing mills The blooms are square lengths of steel 6 inches on a side, or larger, while slabs are similar to blooms, except that the width exceeds the thickness Mills for producing these shapes are called, respectively, blooming mills and slabbing mills, and are characterized by rough, heavy rolls Blooms are further reduced to smaller billets which form the stock from which most shapes are rolled in the finishing mills A rolling mill for the production of billets is a billet mill These billets, blooms or slabs, are then taken into the specialty mills, such as plate mills, structural shape mills, etc, and rolled to final form A set of rolls, together with bearings and housings, is known as a stand, and there are many of these in the ordinary rolling mill The principal parts of a rolling mill are, in

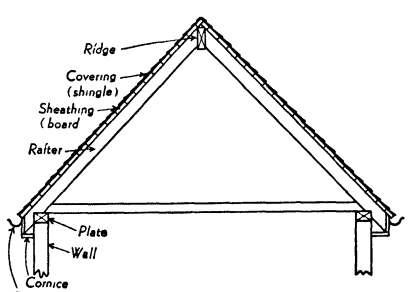
addition to storage space and handling equipment, the soaking pits in which the stock is brought to rolling temperature, the rolling mills, the straightening and cool-



Three high blooming mill

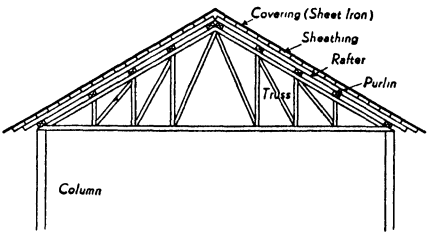
ing tables, and the cut-off shears Formerly, the rolls were driven by steam engines and a great many are still performing in that capacity, but installation of new mills at present is usually with electrical drive A stand in a rolling mill may be either two high or three high, depending upon the number of rolls In a two high stand there are two rolls, and if the work is to be passed a second time through the rolls, their direction of rotation is reversed This requires a steam engine or reversing motor for the drive In a three high mill there are three rolls, the lower and the upper turning in the same direction, and the center roll in the opposite direction A return pass can be made between the middle and upper rolls without reversing the drive Several passes of the piece may be made on one stand The rolls are made of chilled cast iron or cast steel, and are solid Large heavy journals are turned on their ends, and these fit into babbitted bearings which are carried in housings mounted in the frame of the stand The rolls are connected by couplings to pinions which insure synchronization of the rolls One of the pinions is connected to the source of power It may be directly connected or belted to a steam engine, or directly connected to an electric motor Rope drive is frequently used for rolling mills Sometimes a shape can be completely rolled on one three high stand, but usually a minimum of three stands is used First the billet is put through the roughing stand, then it is worked to approximately the final shape in the strand rolls The final stand alters the shape as received from the strand only slightly, but gives the exact final dimensions to the shape (F T M)

ROOF. When a region is covered above to shed rain or snow, the covering is known as a roof It is an essential feature of all buildings, sheds, etc A roof consists of a



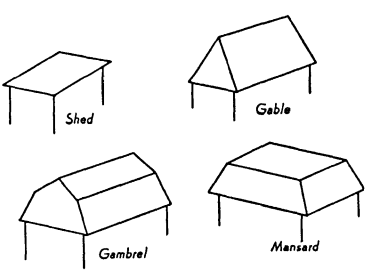
Dwelling roof

weatherproof covering supported on a smooth surface which, in turn, is supported by certain structural members In ordinary building construction, the roof covering is supported by a wood sheathing which is laid on rafters The latter are structural members of wood which, in the case of ordinary dwellings, form the basic structural members of the roof, but which in the case of large roofs, are themselves, laid on purlins (See **Bent**)



Mill roof

which are supported by wood or steel trusses The most common roof covers are slate, composition or wooden shingles, composition roofing paper, galvanized iron sheets (either smooth or corrugated), tinned sheets (smooth), and tile The type of roof depends upon the expense which the owner is willing to incur in order to secure permanence and also on the kind of building which the roof is to cover Typical roofs are shown in the



Roof types.

accompanying diagram The loads to which these roofs are subjected consist of dead load and live load The dead load is the weight of the roof itself plus snow, and any structures that may be erected on the roof or suspended from it The live load is wind or any movable loads which may be suspended from the roof, or which may roll over it The dead weight varies with the composition of the roof, and the allowance for snow varies with the climate Wind load varies both with the area and the slope of the roof The steeper the slope, the greater the live load from wind Pressure of wind against a vertical surface is approximately $.004v^2$, in which the velocity is given in miles per hour. This is resolved in pressure normal to a roof surfaced by one of the following formulae

$$\text{Normal pressure} = P \times \frac{2 \sin i}{1 + \sin^2 i} \quad \text{(Duchemin's Formula)}$$

$$\text{Normal pressure} = \frac{P \times i}{45} \quad \text{(Hutton's Formula)}$$

P = vertical plate pressure in pounds per square foot
i = roof angle in degrees

The roof load is delivered to a plate which caps the bearing wall, or is carried to suitable foundation by means of vertical steel columns The latter is favored in

industrial buildings having large roofs supported by steel roof trusses. (F.T.M.)

ROOK. Aves, Passeriformes. A European bird (**Aves**), *Corvus frugilegus*, related to the crows. Its black plumage is glossed with purple and the face of the adult is usually naked and grayish. (A.W.L.)

ROOM RATE. This refers to a method of charging for electrical service. It is believed to be a somewhat more accurate allocation of costs than could be obtained by a simpler, uniform charge based on energy consumption. In a room rate, the electric service company is using number of rooms (active) as an indication of maximum demand. This has the advantage of eliminating the installation of some meter equipment which would otherwise be needed. An example of a room rate charge would be:

10¢ per kilowatt-hour per month for the first 3 kilowatt hours per counted room.
7¢ per kilowatt-hour per month for the next 3 kilowatt-hours per counted room.
4¢ per kilowatt-hour per month for the excess over 6 kilowatt-hours per counted room.

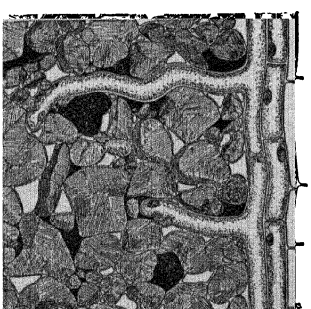
This room rate form is also having increasing acceptance because of its follow-on feature. It is superseding in many locations the older forms of rates. It is particularly advantageous in large cities, where people live in apartments, because the real estate ratings established by the local real estate boards are used as a criterion of the number of rooms, upon which the primary charge is based. (F.T.M.)

ROOT OF AN EQUATION. A root of an **equation** with one unknown is a value of the unknown which satisfies the equation, that is, which makes the two sides of the equation identical in value. (L.L.S.)

ROOTS. In seed plants, the root is generally the first part of the plant to emerge from the germinating seed.

Commonly one thinks of the root as the part of a plant which is found in the ground. While this is true in the majority of cases, in some plants the roots are found in the air. So the common definition of the root is only partly correct.

On breaking through the seed coats of the germinating seed, the seed root, or hypocotyl, turns downward and soon puts out an abundance of minute hairs.

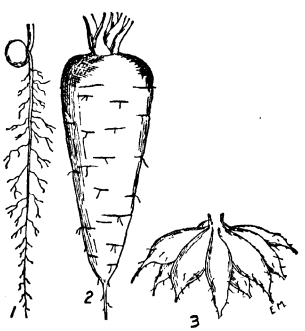


Root hairs penetrating the soil. Note the tiny rock particles, the bits of humus, the films of water, and the air spaces.

These serve the twofold purpose of attaching the hypocotyl firmly in the soil and of absorbing moisture and mineral solutions from the soil. The hypocotyl continues to grow into the soil, elongating and branching and becomes the root.

Externally there are certain characteristics which distinguish a root from a stem, even when the latter grows underground. The root bears no leaves on its surface and is not separable into nodes and internodes, as is the case in the stem. The apex of the root is covered by a protective structure called the root-cap, a distinctive feature never found in stems. Just back of the tip, the surface of the root is provided with root-hairs. Branching in roots is quite distinct from that in stems, the branch-roots appearing at irregular intervals; frequently these branch-roots are borne in longitudinal rows, a fact which is correlated with their origin. Branch-roots develop from the pericycle, a tissue deep in the root, and not from the epidermis as do stem branches. In many lower plants the root forks into two equal branches, a method of branching called dichotomous. In higher plants this does not occur.

Several types of roots are recognized. In many plants, the first formed, or primary, root continues to grow downward to form a long root which penetrates deep into the ground. Branch roots arising from this are commonly much shorter, and of smaller diameter. Such a root is called a tap root, and the entire root system in such cases is known as a tap root system. Familiar examples are found in the **dandelion,** burdock, and in **oak** trees. **Monocotyledonous** plants rarely show this form of branching. In them and in many other plants, the primary root soon loses its individuality, the secondary roots becoming larger, and forming an extensive root system, in which no single root is distinguished from the others by its larger size and more obvious downward growth. Such a system is called a fibrous root system, and the individual roots are known as fibrous roots. The common **plantain** has such a root system. In many plants the roots become important



Different kinds of roots. 1, fibrous tap root of pea; 2, fleshy tap root of carrot; 3, fleshy fascicled roots of Dahlia.

places of storage of food materials, the roots often being conspicuously enlarged because of this storage. Such roots are called fleshy roots. Their existence is of great value to man, since many of them become important crop plants, as for example, carrots, parsnips, turnips and beets. In many plants, several roots are swollen with food so that a group or fascicle of storage roots is formed, as in the *Dahlia*.

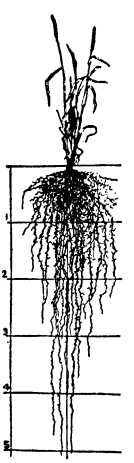
In many plants, especially in the tropics, the roots are formed in the air. Such aerial roots are often quite different from ordinary roots, being much coarser, less branched and lacking root-hairs. In aerial roots the outer portion is frequently modified to a spongy tissue capable of absorbing moisture rapidly and retaining it tenaciously. This tissue, the velamen, is particularly well developed in epiphytic orchids. Other plants have aerial roots which extend either downward from the branches, or from the lower part of the stem. Such roots are called, respectively, prop roots or brace roots.

The terms are often used interchangeably. These roots soon penetrate the surface of the ground and become like ordinary roots. The **Banyan** tree shows the downward-growing prop-roots particularly well, while in the Screw-Pine and in **Corn** plants, brace roots are well-developed. They are especially conspicuous in the **Mangrove** plants, where they form an extensively branching system supporting the plant in the soft mud in which it grows. In many tropical plants, especially in those of large trees, the roots radiate out over the surface of the ground. Often these roots are conspicuously developed vertically, forming thin plates of considerable depth, but only a few inches thick; they are called buttress roots.

A type of modified roots—Aerial roots of poison ivy, *Rhus Toxicodendron.*

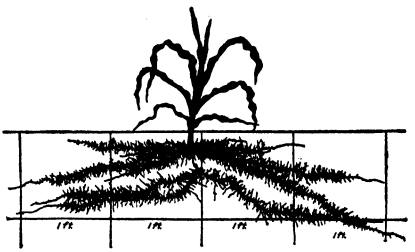
In **parasitic plants** the roots may be curiously modified or replaced by absorptive organs which penetrate the tissues of the host plant until they reach the conducting system, from which they obtain their nutrient supply. In some plants, roots are entirely lacking, their functions being taken over entirely by other parts of the plant. In the **saprophytic** Orchid, *Corallorhiza,* for example, the much-branched coarse underground stem, or rhizome, functions as a root; in the **Bladderworts,** *Utricularia,* floating in water, roots are entirely unnecessary, and non-existent. In the **Spanish Moss,** *Tillandsia,* growing epiphytically in tropical and subtropical America, roots are entirely lacking, absorption occurring over the surface of the plant.

Commonly the extent of a root system is very much underestimated. Only when the entire plant is removed from the soil by careful and extensive digging is the great spread of the entire root system seen. Then it is found that the roots may penetrate the soil to a depth much greater than was supposed. In common Red Clover, for example, the roots may go downward to a depth of eight or nine feet, while in **alfalfa** depths of 15 to 20 feet or more are found. The lateral spread of roots is also often very great. In the common Squash the lateral roots may extend outward 10 to 15 feet, while other roots of the same plant penetrate the soil to depths of 4 to 6 feet, forming a very extensive system. The nature of the soil, and especially the amount of oxygen present in it, are important factors in determining the amount of branching and the extent of the root system. In general, porous well-aerated soil favors extensive branching.



Root system of wheat plant at blossoming time. Figures indicate depths in feet. (From Weaver's *Root Development of Field Crops,* McGraw-Hill Book Company, Inc.)

Roots do not seek water, as popularly supposed from the fact that they seem to grow toward water. This tendency is explained by the fact that roots respond very definitely to certain external factors, such as gravity. Most roots react positively to gravity, that is, are positively geotropic, growing directly downward into the soil. If a young plant is placed so that its root is horizontal, in a short time it will be found that this root has changed its direction of growth, and is growing downward again. Many roots are also affected by light, from which they turn away, being negatively phototropic. Temperature also affects roots, so that a root encountering a region having a temperature more favorable for its growth will increase more rapidly than other roots. Entirely like this is the response of roots to favorable moisture conditions, which lead to greater growth of the roots extending in that direction. It is such phenomena which lead to the statement that roots seek water. Often they do seem to, especially when they penetrate joints in sewer pipes, sometimes at distances of 30 to 60 feet or more from the stem of the plant, and form great masses of much branched roots which may completely clog the sewer pipe, and become a source of great inconvenience and expense. Other factors such as the nature of the soil and its contained minerals, also influence the growth of roots.



The root system of Iowa Silver Mine corn 36 days old. (From Weaver's *Root Development of Field Crops,* McGraw-Hill Book Co., Inc.)

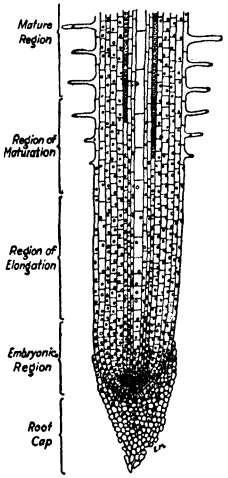
The internal structure of the root is quite constant and distinct from that of the stem. In the tip of the root the apical meristem or zone of dividing cells is found. The cells of this region are more or less cubical in shape, thin-walled, and contain a dense protoplasm and a relatively very large nucleus. Because of this last characteristic, the root tip is a particularly suitable place to study nuclei during their divisions.

Over the apical end of the root, and covering the activity dividing cells is the root cap. This is a mass of loosely aggregated cells arising in various ways. In some plants the cells of the root cap are formed from the meristem cells in general. In **dicotyledonous** plants there is frequently a special layer of cells called the protoderm, covering the apical surface of the root. These cells divide and form cells which become the root cap. As the root elongates, the protoderm cells give rise to the epidermis of the root. In many **monocotyledons** there is a special layer of cells external to the root itself. These cells are meristematic and by their divisions form the root-cap.

However formed, the root-cap persists throughout the life of the root, forming a protective cover over the tip. The outer and consequently older cells of this cap are loosely arranged. Their walls become considerably modified to form a mucilaginous mass, which greatly reduces the friction of the elongating root against the soil particles. This mucilaginous mass is often very conspicuous in the brace roots of corn.

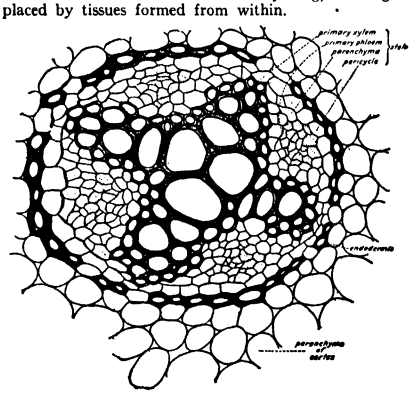
Just back from the apical meistem of the root is the zone of elongation. In this region the cells show very characteristic changes. The most obvious of these is the increase in length which occurs in most of the cells. At the same time there appears in the cell a conspicuous central vacuole which enlarges greatly, the cytoplasm being pushed out to a thin peripheral layer in which is found the nucleus. In roots this elongating region is much shorter than is the corresponding region in the stem, a fact presumably correlated with the denser medium through which it grows. Usually it is less than a centimeter long.

As the root continues elongating the cells gradually change to form a third zone not sharply set off from the second. In this, the zone of maturation, the cells gradually assume their final form. Externally the most conspicuous feature of this zone is the presence of the root hairs. A root hair is a slender outgrowth of an epidermal cell. In size they vary from 0.1 to 10 millimeters long, with a diameter averaging about 0.01 millimeter; the number of them formed on the root surface varies from 200 to 400 or more, so that they cause a tremendous increase in the surface of the root. The life of a root hair is not long, being commonly only a few days, after which it disappears. In a few cases root hairs may persist for two or three years, as in the Honey Locust or in certain **Composites.** In such cases they do not have the structure typical of root hairs, but are tough rather thick-walled objects. Usually the wall of a root hair is very thin and modified externally to a pectic substance which sticks closely to the soil particles and absorbs water readily therefrom. Within the wall is a thin peripheral layer of actively streaming **cytoplasm.** The central part of the hair is occupied by an evident **vacuole** which is continuous with that in the basal portion of the cell from which the hair protrudes.



Longitudinal section of onion root showing the regions of development.

As the root grows older and the cells composing it mature, a very definite structure appears. The outer portion is composed almost entirely of **parenchyma** cells, which are of irregular shape, loosely aggregated, and serve mainly for storage of materials. In general the cortex of the root does not last very long, it being replaced by tissues formed from within.



A cross section of the stele of a young root of the buttercup, *Ranunculus acris.*

The innermost layer of **cortical** cells is very distinct, forming the endodermis. In this layer, the walls, especially the radial ones, become thickened and suberized; so that it forms a barrier against the passage of air into the central tissues of the root or of water outward.

Within the endodermis is the stele, or central cylinder. The first cells to differentiate in this region are the water-conducting **xylem** elements, which arise in discrete groups. The number of these groups is usually constant for any given species of plant, cross-sections through the root at this stage showing a number of isolated groups of cells surrounded by unmodified cells. Between these groups of cells and somewhat farther from the center of the root other groups of cells become evident as the root grows older. These are the **phloem** cells. While the walls of xylem cells soon become thickened by the formation of **cellulose** against the primary wall, those of the phloem cells remain constantly thin. With continued growth of the root, the cells of the central portion gradually become changed into additional xylem cells, so that finally, in most roots, no unmodified cells remain in the center; that is, characteristically the root does not contain pith cells, though many **monocot** do. Remaining outside the phloem and xylem cells are many only slightly changed cells which form the pericycle. This is the region from which branch roots originate, and also the region which by the division of its cells forms the **periderm** and other tissues which replace the cortex as the root grows older. The root therefore contains the following tissues derived entirely from the modification of the cells originally resulting from the divisions of the apical meristem; a central cylinder of alternate masses of xylem and phloem cells, surrounded by a sheath of slightly modified cells called the pericycle, these composing the central cylinder. Outside this is the endodermis, with its cells showing characteristic thickenings of the walls. Around the endodermis is the cortex. All these tissues are collectively known as primary tissues.

With further growth of the root, secondary tissues appear. These are formed from a special group of cells known as **cambium** cells. Cambium cells first appear in the region inside the phloem patches, appearing in cross-sections of the root as crescent-like patches which gradually extend radially until they unite to form a continuous sheath around the xylem. By their divisions new cells are formed both inside and outside the cambium band. Those inside gradually develop into xylem cells, while those outside become phloem cells. Continued development of the **cambium** band causes the phloem cells and all other cells formed externally to be pushed outward and gradually crushed. Meanwhile the xylem cells within increase greatly in number. Since growth often occurs periodically in the root, especially in regions having alternations of favorable and unfavorable climates, **annual rings** are found in roots as in stems. As root enlargement occurs, the pericycle cells become meristematic and by their divisions form a mass of cells around the central cylinder. These are the periderm cells, which form a protective layer surrounding the conducting cells. In large roots additional periderm is formed by divisions of the phloem cells.

The functions of the root are primarily anchorage of the plant, absorption of water and mineral salts in solution, and conduction of these to the stem, and also storage of elaborated food materials. Anchorage is obtained by the much-branched far-reaching root system, which penetrates deeply into the ground and resists such forces as wind acting on the top of the plant.

The water of the soil, together with substances in solution, is taken into the plant largely through the portion of the root which is covered by root hairs. The outer wall of the latter soaks up water readily. The wall of the cell is permeable, permitting water to pass through easily. The outer surface of the cytoplasm of the cell is also a membrane, which is semipermeable, that is, readily permits certain substances such as mineral salts in solution to pass through, but does not allow organic substances to pass. A similar condition exists

in the membrane of the cytoplasm which separates it from the cell sap in the vacuole This cell sap has a high concentration of solutes dissolved in it, so that it has an osmotic pressure of 4 to 10 atmospheres, which is much greater than that of the liquids in the soil. Since these two liquids are separated by a semipermeable membrane, it is but natural that water molecules should pass more freely into the cell than out, causing water to move through the soil to the plant Once in the root hair, the water increases the turgor of the latter This water then passes into the cortical cells and through them to the central cylinder There it enters the xylem cell and is forced up through the root into the stem

In many plants, the root, once formed, shortens, apparently by a change in the shape of its cells, and as a result pulls the top down against the ground or even under the surface. Such a phenomenon occurs in the Dandelion

Food storage, one of the main functions of roots, results from the movement of food materials downward from the green leaves into the roots Often food is stored in such quantities as to cause considerable enlargement of the root In addition to food materials, water is also stored, especially in many desert plants

Of secondary importance is the habit which many plants have of propagating themselves by means of roots In this process, **adventitious buds** appear on the root, especially when the latter is exposed to the air These gradually develop into new plants This is very important to man, since it is a way of propagating many plants Sweet potatoes are propagated in this way (R M W)

ROOTS OF NUMBERS. An n^{th} root (where n is a positive integer) of a given number a is a number whose n^{th} **power** is equal to a The number n is called the index of the root

Thus, x is a square root of a if $x^2 = a$; that is, the square root of a number when multiplied by itself produces the given number Every positive number a has two real square roots, one of which is positive and the other negative, both having the same **absolute value.** The positive square root of a is called the principal square root of a, and is generally denoted by the radical symbol $\sqrt{a}$

Every negative number has two **imaginary** square roots, either of them may be chosen as the principal square root

Every real number has n distinct n^{th} roots One of these is selected as the principal n^{th} root as follows

If n is even and a is positive, the one positive n^{th} root of a is called the principal n^{th} root of a,

If n is even and a is negative, any one of the **complex** n^{th} roots of a may be called the principal n^{th} root of a,

If n is odd and a is positive, the one positive n^{th} root of a is called the principal n^{th} root of a,

If n is odd and a is negative, the one negative n^{th} root of a is called the principal n^{th} root of a

The principal n^{th} root of a is denoted by the **radical** symbol $\sqrt[n]{a}$, or by the **fractional exponent** symbol $a^{1/n}$

The n n^{th} roots of any number (real or complex) are given by one form of **DeMoivre's theorem.**

Tables of principal roots of numbers, usually square roots and cube roots, are often contained in collections of mathematical tables (L L S)

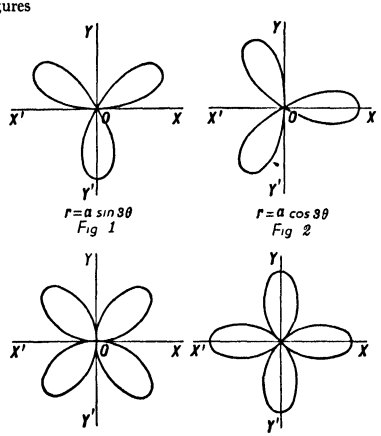
ROPE DRIVE. Ropes passing, in the manner of belts, over **sheaves** are used for the transmission of mechanical power between rotating shafts Rope drives have been used where conditions were unsuitable for leather belts Center distances of fifty to three or four hundred feet are possible with rope transmission, but not with belts Ropes are suitable for outdoor location, and for transmission of large amounts of power between shafts which are not parallel. Belting is not suitable for these drives Extremely long rope drives using wire ropes have been built, but they are rarely constructed today, because the electrification of industry offers more economical transmission of power over long distances The ropes of rope drives are made of manilla, cotton, or steel 4 and 6 strand manilla ropes are commonly found in this country, varying in size from 1 inch to 1½ inches diameter These ropes run like belts over grooved sheaves, and any amount of power can be transmitted merely by providing enough rope and sufficient number of grooves on the sheaves One system of rope drive is known as the multiple system, another as the continuous system In one the drive is made of a number of separate endless rope elements, in the other, the rope is continuous, passing from one groove on the driving sheave over a groove on the driven sheave, back to the next groove on the driving sheave, thence again to the driven sheave, etc, finally passing over a tautening carriage which maintains tension In the continuous system a single break in the rope closes down the drive, which is not true of the multiple system However, the efficiency is better than in the multiple system, and quarter turn drives can be made more easily It is readily possible to obtain driving efficiencies of better than 90% in rope drives (F T M)

RORQUAL. Whale.

ROSE CHAFER. Insecta, Coleoptera. A medium sized gray-brown **beetle** which eats the flowers and fruit of roses and various fruit trees Spraying has not been found an effective method of control although damage to grapes is said to be prevented by the use of **lead** arsenate The spray recommended is made up of three pounds of lead arsenate and two gallons of molasses to one hundred gallons of water It should be applied when the beetles first appear and again after the lapse of a week (A W L)

ROSE COLD. See **Hay Fever.**

ROSE CURVES. The three-leafed roses with equations in **polar coordinates** $r = a \sin 3\theta$ (Figure 1), and $r = a \cos 3\theta$ (Figure 2) are shown in the accompanying figures



$r = a \sin 3\theta$ Fig 1 $r = a \cos 3\theta$ Fig 2

$r = a \sin 2\theta$ Fig. 3 $r = a \cos 2\theta$ Fig 4

Rose curves

The four-leafed rose with equations in polar coordinates $r = a \sin 2\theta$ (Figure 3), and $r = a \cos 2\theta$ (Figure 4), are shown in the figures

The equation $r = a \sin 4\theta$ represents in polar coordinates an eight-leafed rose. (L L S)

ROSE FAMILY. Rosaceae Comprising this family are some 2000 species of plants, a few of which are of tremendous value to man Most of them are perennial plants, either trees or shrubs or herbs Nearly all have alternate leaves, either simple or compound, with stipules present The flowers are of many forms, and grow in **racemes** or **cymes.** Frequently the receptacle is more or less hollowed and often forms a part of the mature fruit The flowers are commonly perfect and have their parts in multiples of five The fruit may be either dry or fleshy, and in many species is an aggregate of many individual fruits The flowers are usually conspicuous, and insect pollinated The most important economic members are found in three of the five or more suborders One of these, the Pomoideae, has the **carpels** often united together and fused with the inner wall of the receptacle, which becomes fleshy, such a fruit is called a pome In this subfamily are found the apple, pear, and quince

The apple, *Pyrus Malus,* is a medium-sized tree, usually less than forty feet in height The wood of the tree is red in color, hard and dense, and frequently used for making tool handles The flowers are borne on short lateral branches known as spurs, and are pink and pleasantly fragrant They are insect-pollinated, particularly by the honey bee The fruit is a pome, the fleshy part of which is regarded as either a swollen **calyx** tube or modified stem tissues When upripe the fruit contains much malic acid and starch On ripening the amount of malic acid decreases, while the sugar content increases considerably At the same time characteristic aromas and flavors develop When ripe a change occurs in the middle **lamella** of the cell wall, the substance dissolving away in part so that the cells become more or less separate On further ripening the flesh becomes mealy and loses most of its tastiness Each of the five carpels which form the parchment-like core of the apple contains two seeds

Propagation of the apple tree may be accomplished by seed planting, but with doubtful success since the new plant will usually bear small undesirable fruits To perpetuate desirable strains, therefore, **grafting** or budding is usually practiced Many people top-graft old apple trees over to new varieties, frequently a single tree may have a dozen or more varieties grafted thereon

Apple trees do best only in regions having a fairly cool climate, they are not entirely hardy, temperatures below — 20° F seriously damaging old and well-established trees Many varieties of apple trees are grown These fall into three main classes, according to the time when the fruit is mature, summer apples appear first, being ready for use in late July and August, fall apples follow, with Gravenstein one of the most popular varieties of this class, the principal class is the winter apple, the fruits of which keep well so that they are available throughout the winter months Apples of this class stand storage and shipment through long distances

Apples are used in several ways Many are eaten raw, others used as sauce or made into pies and tarts The high **pectin** content causes them to be much used in the making of jelly Large quantities of apples, particularly cull fruit, are ground up and the juice pressed out to produce cider. Fermentation causes cider to acquire a considerable percentage of alcohol, it then being known as hard cider By the action of acetic acid **bacteria,** cider may be changed to vinegar From the crushed pulp, called pomace, remaining after the juice is expressed, commercial pectin is obtained

The pear tree, *Pyrus communis,* of Eurasian source, differs in several ways from the apple Usually it is a taller tree, with a tendency to more upright growth In contrast to the rough leaves of the apple, those of the pear are smooth and glossy The wood is very dense and used much as apple wood is used The flowers are white The fruit is more juicy and sweeter than is the apple, and the flesh especially when green contains an abundance of stone cells. Pears are used almost entirely as edible fruit, eaten either fresh or canned

The quince, *Cydonia oblonga,* is a far less important member of this group than are the pear and apple It is a small, rather shrubby tree The fruit is large, more or less hairy during growth and hard and yellow at maturity Each carpel contains several seeds which are invested with a mucilaginous pulp The main use of quinces is for jams and marmalade

Another genus included in this group is *Crataegus,* the Hawthorn, many of whose species are planted for ornament The wood of the larger species is sometimes used in inlay work and for engraving The genus contains many species, which hybridize freely, offering great difficulty to the taxonomist

A second subfamily is the Rosoideae, a large one containing many genera and species Here the fruit is one-seeded and indehiscent, with usually many carpels borne on an enlarged central stalk or carpophore In some genera the floral axis encloses the **carpels** in the mature fruit Shrubs or herbs with simple or compound leaves and various inflorescences comprise the group Several are important plants extensively cultivated

One of these is the genus *Rubus,* which includes Raspberries, Blackberries, and Dewberries In these the **fruit** is an aggregate of many small drupelets, which cling closely to the axis in the Blackberries and Dewberries, but slip free therefrom in the Raspberries An erect habit distinguishes Blackberries from the prostrate Dewberries All have a perennial root system from which arise annual or biennial stems Propagation is mainly by suckers and root cuttings The fruits are largely consumed fresh near the place of growing, or canned Another large genus in this subfamily is *Rosa,* grown widely for its beautiful fragrant flowers In this genus the fruit or hip is a hollow urn-shaped torus surrounding the many carpels From the flowers of certain species, notably *Rosa damascena,* **Rose** oil is obtained

Another very important genus is *Fragaria,* the Strawberry Strawberries are low herbs with short thick stems, tough fibrous roots, and trifoliate leaves The fruit is composed of many small achenes irregularly scattered on the surface of a very much enlarged fleshy receptacle The hull of the fruit is the persistent calyx and the remains of the stamens Propagation is mainly by means of the numerous long slender runners, modified branches, which root at their tip and are then severed from the parent plant Strawberries are used as dessert, or for making preserves, jams, and in ice cream The many varieties are derived from *Fragaria virginiana* of Eastern North America and *Fragaria chiloensis* of the Andean region of South America

The third subfamily containing genera of importance to man is the Drupoideae, members of which are trees or shrubs with simple leaves and the fruit, a **drupe,** usually one-seeded, in which the **ovary** wall or **pericarp** is differentiated into a fleshy outer portion, the exocarp and mesocarp, and an inner endocarp which is very hard or stony In these plants the bark contains a gum which frequently exudes in masses The leaves, bark and seeds are bitter, due to the presence of a glucoside amygdalin which in the presence of an **enzyme** emulsin, produces prussic acid, a deadly poison Due to this reaction animals eating these parts are frequently killed The important economic members are *Prunus persica,* the peach, *Prunus armeniaca,* the apricot, *Prunus domestica* and related species, the plums and prunes, and *Prunus avium* and *P. Cerasus,* the cherries.

Peaches are derived from a native Chinese tree. The trees are small and usually not very long-lived They are only semi-hardy, and due to their habit of producing flowers very early in the growing season, before the leaves appear, are frequently badly damaged by late heavy frosts The flowers are borne singly, are brilliant pink and fragrant The calyx tube of the flower surrounds the pistil, but is not adnate thereto. The

ovary is one-celled, but frequently contains two ovules when young, only one of them developing Peach fruits, the largest of any member of this subfamily, are of two types In one, the fleshy mesocarp slips readily from the stony endocarp, these are freestone peaches In the other the two layers are closely adherent, giving clingstone fruits Peach fruits are very perishable when mature, and are mostly consumed fresh, canned, or dried Almond oil may be made from the kernels During the World War charcoal made from the hard endocarp was used in filters for gas masks

The apricot likewise is a Chinese plant The trees are usually rather larger than peach trees, and not so hardy The flowers are pink, and the fruit smooth-skinned, smaller than peaches, and of the freestone type. Apricots are consumed fresh or dried or canned Commercial growing is largely restricted to California

Plums are small to medium trees of several different species, some of which have been cultivated since before the Christian era Many kinds of plums are consumed fresh Others are unpalatable when fresh, being used mainly for making preserves and marmalades Others are very sweet and capable of being dried without souring. When dried these are known as prunes To prepare prunes, the ripe fruits are picked from the trees and cleaned The skins are broken to expedite drying If the climate is suitable the fruits are then spread in the sun to dry Otherwise drying is done by artificial means The dried fruit is finally dipped in hot water or scalded in steam, thus destroying any insect eggs which might later develop and cause spoilage of the product The prunes are now ready to market California leads the states in prune production

Cherries are relatively small-fruited trees of medium size, indigenous to Europe In cultivated kinds, the flowers are borne in small umbels, usually opening just as the leaves develop Sweet cherries are largely consumed fresh Sour cherries are canned, and used for making pies Maraschino cherries are artificially colored cherries, the flesh of which has been hardened by soaking in brine and sodium sulfite Wild cherries, especially black cherries, are frequently used in making jellies and wine

To this subfamily also belong the **Almonds** (R M W)

ROSEMARY. Mint Family.

ROSEMARY, OIL OF. Volatile oils.

ROSE OF SHARON. Mallow family.

ROSIN. Rosin is a yellow non-crystalline substance of unknown structure produced as a residue on distillation of turpentine. See **Resins.** (R K S)

ROSTELLUM. A projection at the end of the scolex of a tapeworm which bears the hooks. It serves as an organ of attachment. (A.W L.)

ROSTRUM. A snout The term is applied particularly to the elongated snouts of certain fishes and to the labium of the bugs (Hemiptera) The latter is grooved or folded to form a troughlike support for the slender mandibles and maxillae (A.W L)

ROTARY ENGINE. At one stage during the course of development of aircraft engines, the rotary engine made its appearance. This engine, although eventually superseded by engines with static cylinders, was sufficiently interesting mechanically to justify some brief description, and had, furthermore, the interest attached of being a type employed on aircraft engaged in military service during the Great War Often today uninformed persons confuse the radial engine with the rotary, which it resembles in appearance The rotary engine is so called because the cylinders and crankcase rotate. One reason for its early adoption was that this rotation aided in effectively cooling the cylinders Since that time much has been learned about the scientific dissipation of heat from static finned cylinders The crankshaft was made stationary on the rotary engine, and in this respect the rotary engine is a kinematic inversion of the modern radial engine See **Aeronautical Engine.** The introduction of a gasoline-air mixture was through a hollow crankshaft into the crankcase A valve in the piston head allowed this gas to flow from the crankcase into the cylinder during the suction stroke Castor oil had to be used for lubrication, since ordinary mineral oil would be cut by the gasoline in the crankcase The crankshaft bearing on the crankcase was more complicated than in static engines, and lubrication was difficult due to the rotation of the crankcase Also, gyroscopic effects were noticeable when maneuvering an aircraft having the flywheel effect provided by these rotating cylinders (F T M)

ROTARY FIELD. Polyphase Currents.

ROTARY PUMP. A rotary pump is one in which the driving element is a rotating shaft, but which, unlike the centrifugal pump, is a positive displacement device In this class of pumps may be found the gear wheel pumps, in which two spur gears meshing together fit tightly in a casing, one driving the other The spaces between the casing and the teeth are filled with a liquid being pumped, but on the return, the teeth meshing together leave no such space, so that the liquid must be passed out through a discharge opening The efficiency of this pump depends upon the elimination of clearances between teeth and casing, and upon close fit of the meshing teeth This is the type of pump most often used to circulate oil in the lubrication systems of automotive engines Of similar nature is the Roots rotary pump with its two-lobed impellers Another type of rotary pump has the rotating element located eccentrically with respect to a circular casing A number of blades are provided to slide radially in the rotor, and close the gap between rotor and casing Still other types use screws These rotary pumps possess one important advantage—they may be direct connected to electric motors (F T M)

ROTATION. Kinematics; Dynamics of Rotation.

ROTATION SPECTRUM. Molecular Spectra.

ROTATORIA, ROTIFERA. The wheel animalcules, minute animals with a circlet of cilia at one end of the body, whose movements in some species give the appearance of rotation to the entire disk They live in water, even in the small quantities found in matted vegetation and temporary pools, and are adapted to withstand long dry periods in such situations The group is a phylum of minor importance

Although rotifers are minute their bodies are complex in structure The body wall consists of an external cuticle and a syncytial ectodermal layer which bounds the internal cavity There are no muscle layers but bands of muscle are present The alimentary tract (digestive system) is tubular and includes a pharynx with an elaborate grinding apparatus, known as the mastax, an expanded stomach, with a ciliated (cilia) lining, and a short intestine Near the anus is an expanded cloaca which receives the ducts of the excretory and reproductive systems. The essential unit of the excretory system is the flame cell, like that of flatworms. The pair of ducts bearing these cells empty into a contractile vesicle or bladder Reproduction in this phylum is complex, owing to the frequent occurrence of parthenogenesis and to the adjustment of the life cycle to fluctuating environmental conditions

Some authorities regard the rotifers as a phylum and others associate with them two other forms of animals,

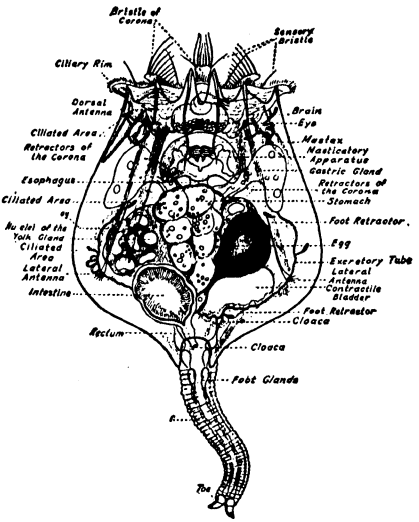


Diagram of a rotifer, *Branchionus rubens* Gosse. (After Wesenberg-Lund.)

making each of the three groups a class in the phylum Rotifera, also named Trochelminthes. This classification is as follows:

Class Rotatoria. The true rotifers, as described above.
Order Seisonidea. Ovary paired. The foot, a tapered posterior part of the body, is without subordinate lobes. Both males and females are well developed.
Order Bdelloidea. Ovary paired. Males unknown. Foot sometimes with subordinate lobes.
Order Monogononta. Ovary single. Males usually present but very small.
Class **Gastrotricha**. Minute wormlike creatures.
Class **Kinorhyncha**. Minute wormlike animals found at the bottom of the sea. (A.W.L.)

ROTATORY POWER. Polarized Light.

ROUND-MOUTHED EEL. Cyclostomata.

ROUNDTAIL. Pisces, Teleostei. A common fish (**Pisces**), *Gila robusta*, of the Colorado and Gila rivers, related to the chubs and dace. (A.W.L.)

ROVE BEETLE. Insecta, Coleoptera. A **beetle** of the family Staphylinidae, characterized by the long flexible abdomen which is exposed behind the short wing covers (elytra). (A.W.L.)

ROWLAND GRATING. Diffraction Grating.

ROYAL JELLY. The food given by worker **honeybees** to the young **larvae** during the first three days of their existence and to the larvae of queens until they are fully developed. It is a thick white liquid formed in the stomach of the worker by partial digestion of honey and pollen, and is apparently a highly concentrated food. Queen cells are supplied with the material in excess of the needs of the larva. If conditions within the colony deprive queen larvae of this abundance they fail to become as large, and in some cases they may even develop as intermediate forms between queen and worker. Such individuals may, however, have the instincts of queens and so may mate and lay fertile eggs. The change from royal jelly to a less concentrated food in the case of worker larvae apparently is responsible for the development of worker bees, since both queens and workers may develop from identical eggs. (A.W.L.)

RUBBER. Rubber is a product obtained from **latex**, a milky secretion which is found in the tissues of a large number of different plants. When the plant is injured, latex flows from the wound. On exposure to air latex coagulates and darkens. Rubber particles occur in the latex in the form of minute spherical globules. While it is true that the latex of many plants will yield rubber, yet few do so in quantities sufficient to give them commercial value.

Rubber was known to early American peoples before the arrival of Columbus. Several tribes used hard balls of rubber in playing a game, other tribes made use of it to render their shoes waterproof, while still others chewed the product. For a long time no use was made of the substance by civilized races. French explorers discovered the source plant and used the native name for the product, changing it, however, to the form caoutchouc, a name by which rubber was long known. The word rubber was a result of its use to rub out pencil marks, discovered by Priestley.

Of the many plants yielding rubber in quantity, the Pará Rubber Tree, *Hevea brasiliensis*, stands in first place. This plant, a member of the **Spurge Family**, is a tree of the Amazonian jungle. It grows as high as 125 feet, has three-parted leaves of large size, the smooth leaflets being about two feet long. The flowers are **monoecious** and without petals, and the fruit three-parted, **dehiscent** and containing three large seeds with mottled seed coat very similar to castor beans. These seeds are ejected rather forcibly from the ripened fruit. While attempts have been made to establish plantations of cultivated *Hevea* in South America, little success has attended the attempt, most of the crude rubber being obtained from wild trees. These wild trees grow scattered widely and irregularly in the jungle. They are tapped by ignorant half-breeds who locate the trees. Tapping consists of hacking through the bark, a destructive method which leads the way to infection of the tree by various diseases which finally bring about its destruction. The latex is collected in small cups which are stuck by their edges into the bark below the cut. The flow continues through the morning, but gradually stops when the heat becomes great at noon. The latex is gathered from the cups into pails and rubber-covered bags. If allowed to stand the rubber globules contained in the latex gradually rise. Commercial preparation of rubber is a faster process; a rubber film is fastened around a stick. This is held in the smoke of a fire and additional latex gradually poured over the film, accumulating slowly to form an ever-increasing ball. Kneading and working cause the elimination of any uncoagulated material. Finished balls of crude rubber weigh about 150 pounds. Sometimes the latex is coagulated over the end of a flat wooden paddle, producing a flat pocket-like cake; this is known as knapsack rubber. Besides *Hevea brasiliensis* and other species of *Hevea*, several species of *Castilloa*, of the **Mulberry Family**, are used as a source of rubber. The product obtained from them is known as Gaucho rubber. It is relatively unimportant. In addition to these, many Euphorbiaceous plants are sources from which rubber may be obtained in South and Central America. In Africa, species of *Funtumia* and *Landolphia*, members of the Apocynaceae, are sources of rubber. The first genus contains large tropical trees; the second, vines of immense size growing in the Congo Free State. Methods of obtaining rubber were extremely destructive—mostly the plants were chopped down and cut up, a procedure which soon all but wiped out the African rubber supply. In recent years plantations of *Hevea* have been established in Liberia, mainly by American tire interests.

In Asia, native rubber is obtained from *Ficus elastica*, a member of the Mulberry Family. The plant is familiar to many as the ordinary "Rubber Plant" grown as an ornament in conservatories In its native home the plant becomes an enormous tree with large spreading branches supported in part by the development of prop-roots similar to those of its relative, the **Banyan tree** It is not an important source of rubber at the present time, the product being inferior to that obtained from *Hevea*

In North America, rubber has been obtained in quantities from various plants Unlike the tropical rubber sources, those of North America are herbaceous or shrubby plants Of these the one most used to date is *Parthenum*, a desert shrub occurring in Mexico The plant has been extensively cultivated in various arid regions of the southwestern United States, and improved strains developed Chewing of the plant will produce rubber, but in rather small quantities In commercial preparation the entire plant is crushed and broken up in water The particles of rubber thus liberated float to the surface of the water and are removed They are cleaned, rolled into sheets, washed, and dried, yielding a dark gray product known as guayule rubber

In the United States several plants have been examined as sources of rubber, among them milkweeds, Indian kelp, and goldenrod At present none of them produce rubber in any quantity, and the expense of extracting any quantity of latex makes it unlikely that they will compete with the rubber trees

Most of the immense amount of rubber demanded by present-day civilization is obtained from plantations of *Hevea brasiliensis* grown in the Dutch East Indies, in the Malay Peninsula, and in Ceylon There the plants are grown from seed, the seedlings being planted out when large enough, or budded with desirable stocks from high-producing trees Growth is rapid, trees being large enough to tap in five or six years In tapping plantation trees, a spiral cut is made in the bark, care being taken not to injure the cambium A spout is placed at the lower end of the cut and the exuding latex collected in porcelain cups When exudation from the cut ceases, a thin shaving is removed from the lower edge, a new flow of latex at once resulting Shaving continues over a period of three to eight weeks, after which the tree is left undisturbed to recover Complete renewal of bark over the cut area requires about four years of growth

The latex is gathered from the cups and coagulated by different methods In one of these **acetic acid** is added to the fresh latex, which has been set in shallow pans The rubber then forms as a sheet on the surface of the liquid The sheets are removed and squeezed between rollers to remove excess moisture The resulting product is crepe rubber Another method of obtaining the rubber is to spray the crude latex into a stream of hot dry air, which quickly evaporates the moisture of the latex, leaving fine particles of rubber, which settle down Recently much latex has been treated with **ammonia** and shipped in liquid form to the rubber factories of the United States

Rubber is a terpene **hydrocarbon**, forms a pseudo-solution with **carbon tetrachloride, chloroform, benzene, turpentine, carbon disulfide**, petroleum naphtha, reacts with ozone to form an ozonide—Harries (1905) deduced the formula of rubber from this reaction as 1,5-dimethylcyclo-octadiene-1,5—reacts with sulfur to form the substances commonly known as hard and soft rubber The hot vulcanization process was discovered by Goodyear in 1839 In this process rubber, alone or dissolved in naphtha, and **sulfur** are intimately mixed, after which the mixture is subjected to a temperature of 114° C (melting point of sulfur) to 130° C, preferably under pressure, as in an autoclave The cold vulcanization process was discovered by Parkes in 1846 and is used for thin rubber goods In this process thin rubber sheets, formed from naphtha solution of rubber and then evaporating the solvent, are treated in a vat with **sulfur** monochloride, dissolved, in order to diminish the violence of the reaction, in carbon disulfide Rubber may be electro-deposited on metals.

The rate of vulcanization depends upon the percentage of sulfur present, the temperature, and the presence of a **catalyzer** In the hot cure, **magnesium** oxide was early found to act as a catalyzer or accelerator, and since then organic bases have been found to be excellent accelerators—**aniline** and piperidine were among the first to be used Para-nitrosodimethyl aniline (0 4 part, by weight) shortens the time of vulcanizing a 90% rubber-10% sulfur mixture at 140° C from 60 minutes to 20 minutes The activity of many accelerators may be improved by the addition of such substances as **zinc** oxide, **lead** monoxide, **magnesium** oxide, **stearic acid, oleic acid**, pine tar The hardness of the product depends upon the percentage of sulfur present and the time of heating Soft rubber contains 5% to 10% sulfur, hard rubber 25% to 40% sulfur, and the latter takes about three times as long as the former for heating Hard rubber is softened by heating, may then be molded and pressed (an important **plastic**), when cold may be machined and polished, is capable of being bent without breaking, is hard and inelastic, in contrast to the high elasticity of soft rubber Vulcanized rubber is not reactive with ordinary acid solutions of moderate strength, including **hydrofluoric acid**, but excluding concentrated **nitric and sulfuric acids**, nor with alkaline or salt solutions

Rubber may be compounded or have blended with it in the process of manufacture, various materials, such as pigments, fillers, waxes, oils, fibers, to obtain a wide range of properties, and may be combined with various structural materials, e g , with textile fibers to produce rainproof clothing, machinery **belting**, and automobile tires, with metals, concrete, and wood, to produce acid-proof vessels

The permanence of rubber is increased by the use of antioxidants (0 5% to 2%) in the mix before vulcanizing Paraminophenol, phenylalphanaphthylamine, phenylbetanaphthylamine, and other substances are used The use of antioxidants has greatly increased the useful life of soft vulcanized rubber, as in automobile tires

Unvulcanized rubber in pseudo solution is used as adhesive Vulcanized rubber is remarkable for its resistance to **abrasion**, its flexibility, **elasticity**, extensibility (10 times the original length for soft rubber bands), resilience, absorption of shock, inertness to water, solutions, gases, high frictional resistance when dry, low frictional resistance when wet, high electrical resistance, low heat conductivity, resistance to moderately high temperature (about 200° C), plasticity under proper conditions These properties enable rubber to be utilized in a variety of ways, possibly not exceeded in this respect by any other material

The uses of rubber hardly need enumeration They include automobile tires and tubes, rubber boots, rubber tubing, belting, and rubber hose Ebonite or hard rubber, used in making battery boxes, combs, and many other products Recently considerable progress has been made in developing a synthetic rubber The product obtained is not exactly like natural rubber, it can be used in several ways in which natural rubber cannot, and it cannot always be substituted for natural rubber (R M W, R K S)

RUBELLA (GERMAN MEASLES). An acute, very contagious disease resembling measles and **scarlet fever** but distinct from them The disease is caused by a filterable **virus** which as yet has not been isolated Infection occurs directly from mouth or nasal secretion It is most prevalent during the first half of the year

The incubation period is longer than that of measles or scarlet fever, being usually from seventeen to eighteen days Children who have had measles are more likely to develop rubella One attack usually protects

against another, but does not protect against measles or scarlet fever.

Symptoms resemble those of a light attack of measles with the following exceptions: the mouth is not involved, the rash lighter, less persistent, and complications are rare.

Treatment is the same as for measles. Quarantine usually lasts for about ten days. (R.S.M.)

RUBELLITE. Tourmaline.

RUBICELLE. Spinel.

RUBIDIUM. Symbol: Rb. Atomic number: 37. Atomic weight: 85.44. Density: 1.53. Melting point: 38.5° C. Boiling point: 700° C. Isotopes 85 (72.7%) and 87 (27.3%).

Rubidium is a silver-white, very soft metal; tarnishes instantly on exposure to air, soon ignites spontaneously with flame to form oxide; best preserved in an atmosphere of **hydrogen** rather than in naphtha; reacts vigorously with water forming rubidium hydroxide solution and hydrogen gas. Discovered by Bunsen and Kirchoff in 1860 by means of the spectroscope.

Rubidium occurs in **lepidolite** (lithium aluminosilicate, in amount up to 1% Rb), in certain mineral waters and rare minerals. Rubidium salts may be recovered from the mother liquor upon crystallization of (1) **lithium** salts; (2) **potassium** salts, Stassfurt, Germany. Rubidium metal is obtained by **electrolysis** of the fused chloride out of contact with air.

Chloride: Rubidium chloride (RbCl), white deliquescent solid, melting point 715° C., soluble.

Hydroxide: Rubidium hydroxide (RbOH), white, deliquescent solid, melting point 300° C., soluble.

Oxide: Rubidium oxide (Rb_2O), pale yellow solid, by heating rubidium metal in oxygen or dry air, reactive with water to form soluble rubidium hydroxide.

Other soluble salts: Rubidium sulfate (Rb_2SO_4); rubidium nitrate ($RbNO_3$); rubidium carbonate (Rb_2CO_3).

Slightly soluble salts: Rubidium perchlorate ($RbClO_4$), insoluble in alcohol; rubidium chloroplatinate (Rb_2PtCl_6); rubidium periodate ($RbIO_4$); rubidium permanganate ($RbMnO_4$); rubidium fluosilicate (Rb_2SiF_6).

Volatile rubidium salts, such as the chloride, color the bunsen flame violet. (R.K.S.)

RUBY. CORUNDUM.

RUDACEOUS. A term proposed by A. W. Grabau in 1904 for coarsely graded **clastic** sediments. (R.M.F.)

RUDD. Pisces, Teleostei. A common European freshwater fish (**Pisces**), *Scardinius erythropthalmus*, related to the roach and ide and belonging to the carp family. Also called the red-eye. (A.W.L.)

RUFF. Aves, Charadriiformes. A European bird (**Aves**), *Machetes pugnax*, related to the sandpipers. The name comes from the seasonal development of a large ruff about the neck of the male. The females are called reeves. (A.W.L.)

RUFFE. Pisces, Teleostei. A small species of **perch**, *Acerina cernua*, found in slow gravelly streams of England. It is also called the pope. (A.W.L.)

RULED SURFACES. A **surface** generated by a moving straight line is called a ruled surface. Cylinders and cones are the simplest examples.

The **hyperboloid of one sheet** and the **hyperbolic paraboloid** have two systems of rectilinear generators and are ruled surfaces. (L.L.S.)

RUMINANT. An animal that chews its cud. The term applies to the **oxen, sheep, goats, antelopes** and **deer, camels,** and **chevrotains.** It does not indicate a taxonomic group, although the term Ruminantia has been applied to this part of the order **Artiodactyla** in some classifications. The stomach of the ruminant consists of four chambers. When food is swallowed it passes into the rumen or paunch, where it is stored temporarily while the animal eats. Chewing and digestion are carried out at leisure. The food passes from the rumen to the reticulum or honeycomb, where it is formed into small masses and elevated to the mouth to be chewed. When swallowed the second time it follows a different course through the esophagus to another chamber, the omasum or psalterium, whence it continues to the abomasum. In these two parts gastric digestion is completed and the food is passed on to the intestine. (A.W.L.)

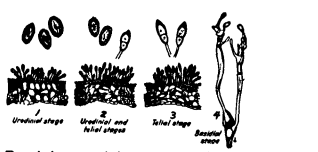
RUNNER. The principal revolving part of a hydraulic reaction turbine is called the runner. It consists of suitably curved blades, the hub, rim, crowns, etc. The runner of a hydraulic turbine is usually quite massive. The corresponding part of an impulse turbine is called the wheel. See **Hydraulic Turbine.**

In foundry practice, the channel, made in the sand of the mold, which connects the pouring basin and gate is called a runner. (F.T.M.)

RUPTURE. Hernia.

RUST FUNGI. Uredinales. The rust fungi are parasitic **basidiomycetes** which owe their popular name to the reddish color of the **spore** masses in some of the commonest species. Because many of the thousand species found in North America attack important cultivated and wild plants, they are of great economic importance. The group possesses a remarkable variety of spore types. Many species have five kinds of spores. It is notable that any given species has a very limited range of host plants.

One of the best-known species of Rusts is the common Wheat Rust, *Puccinia graminis*, which has long been known. Five spore forms are included in its complex life-history.



Puccinia graminis in wheat leaves. 1, uredinial stage; 2, uredinial stage changing to telial stage; 3, telial stage; 4, basidiospore germinating and forming basisia and basidiospores. (After Tulasne).

On wheat plants, and on various grasses, there appear during the summer on the stem and leaves reddish spots which on examination are found to contain large numbers of one-celled spores which are called uredinio-spores. These are scattered by the wind and reinfect wheat plants continuously during the growing season. Near the end of the growing season, when the host plant is maturing, a new form of spore appears either with the urediniospores or in separate **pustules.** These spores are two-celled, of dark color, and have a very thick wall. They are called teliospores, or winter spores, and are able to survive the winter season independent of any host plant, for they can neither attack one nor parasitize it. In the spring each cell of the teliospore puts out a short tube which becomes four-celled. From each of the four cells a small spore is formed: this is the basidiospore and the four-celled tube is therefore a basidium. The one-celled basidiospores are carried by air-currents to suitable host plants, which in this case are not wheat plants, but barberry plants. In contact with the young leaves of the latter plant the basidiospore develops a short tube which penetrates the leaf epidermis and forms a myce-

1, Section of barberry leaf infected with *Puccinia graminis* and producing pycnia and aecia; 2, section through pycnium; 3, three pycniospores.

lium within the leaf. After a time this mycelium gives rise to a new type of spore which appears on the upper surface of the barberry leaf in small pustules called pycnia or spermagonia These contain masses of small **hyphae**, from the tips of which are cut off minute one-celled bodies called pycniospores or spermatia, which seem incapable of reinfecting the host plant. Soon after the formation of the pycnia there appear on the under side of the leaf clusters of orange-colored cups These are the aecia or cluster cups, in which are formed chains of tightly packed aeciospores These spores, when released, cannot reinfect barberry plants but must be carried to wheat plants before they can grow On the wheat plant each aeciospore puts out a short germ tube which penetrates the tissue of the leaf or stem within which it forms an extensive mycelium, from which the urediniospores and later teliospores are formed So it is apparent that for the completion of its life-history *Puccinia graminis* must have two very different host plants Many rusts show this character of requiring alternate hosts, and are called heteroecious Other rusts complete their life-cycle on a single host they are said to be autoecious

Another rust of great economic importance, especially in the northern United States and Canada, is the white pine blister rust, *Cronartium ribicola*, which, like wheat rust, has two alternate hosts, white pine having the pycnia and aecia, and currants and gooseberries the uredinia and telia stages

In many rusts one or more of the spore forms may be entirely lacking For example, in *Gymnosporangium Juniperi-virginianae* there is no uredinial stage, while in the common hollyhock rust, *Puccinia malvacearum*, pycnia, aecia, and uredinia are all lacking, only the teliospores and basidiospores being formed

A study of the nuclear condition of the various types of rust spores reveals several interesting facts The basidiospores are uninucleate, as are the minute pycniospores which follow them in the life-cycle of wheat rust For a long time these pycniospores were considered to be without function, they being held to be either degenerate male cells or an asexual type of spore Recent evidence, however, has been offered that they may actually function as male cells, in some rusts at least. It is considered that these minute spores, after discharge from the pycnidia, in some way come in contact with the mycelium within the leaf and unite with it so that a binucleate condition results This binucleate condition then appears in the aeciospores, the urediniospores, and the teliospores Before the basidiospores are formed, nuclear fusion occurs, the basidium having but a single fusion **nucleus** This leads to the conclusion that in the complex life-cycle of the rusts there is a definite **alternation of generations**, the uninucleate basidium, the basidiospores, and the pycniospores being **gametophytic**, while the rest of the cycle is **sporophytic**

In the control of rusts, three methods of attack are available In those rusts which require alternate hosts, the removal of one of the hosts naturally suggests itself This has been done with considerable success in combating white pine blister rust by destroying all currant and gooseberry plants in regions where white pine is an important timber tree Similarly, removal of barberry serves to minimize wheat rust infection in regions where the winters are cold enough to prevent continuous infection by urediniospores When constant reinfection of the same host occurs a second method of control may be found in the breeding of rust-resistant strains Such strains now exist, for a great many susceptible plants are of great commercial importance Control of rusts has also been attempted with various sprays with varying results (R M W)

RUTABAGA. **Brassica.**

RUTHENIUM. Symbol· Ru Atomic number· 44. Atomic weight: 101 7 Density· 12 06 Hardness 6 5. Melting point. 2450° C. Isotopes 96 (5%), 99 (12%), 100 (14%), 101 (22%), 102 (30%), 104 (17%)

Compact ruthenium is a grayish-white metal, somewhat harder and more brittle than **platinum**, difficultly soluble in **aqua regia**, and attacked by **chlorine**. Discovered by Claus in 1845

Ruthenium occurs native in platinum ores, sometimes to the extent of 2% When **osmium** is present it is removed as volatile osmium tetroxide, and the residue is heated with a mixture of **nitric** and **perchloric acids** to fuming of the latter, whereupon ruthenium tetroxide distils over, and is absorbed in **sodium** hydroxide solution The resultant orange-red solution is reduced to ruthenium sesquioxide by alcohol **Ignition** of the sesquioxide in hydrogen forms ruthenium metal

Ruthenium at 600° C, and ruthenium tetroxide at 106° C yield a sublimate of rutherium dioxide

Hydroxides Ruthenium trihydroxide ($Ru(OH)_3$); ruthenium tetrahydroxide ($Ru(OH)_4$)

Oxides Ruthenium dioxide (RuO_2), green crystals; ruthenium sesquioxide (Ru_2O_3), black, ruthenium tetroxide (RuO_4), golden-yellow crystals The last compound is volatile upon heating in a mixture of nitric and perchloric acids to fuming of the latter (R K S)

RUTILE. A mineral composed of **titanium** dioxide which occurs in three distinct forms as rutile, a **tetragonal** mineral usually of prismatic habit, often twinned, as octahedrite, a tetragonal mineral of **octahedral** habit, and as **brookite**, an **orthorhombic** mineral Both octahedrite and brookite are relatively rare minerals

Rutile has a sub-conchoidal fracture, is brittle, luster, metallic-adamantine, color, commonly reddish brown but sometimes yellowish, bluish or violet, streak, brown, transparent to opaque Rutile may contain up to 10% of iron

Experiments in the artificial preparation of titanium dioxide appear to show that rutile is the most stable form and produced at the highest temperature, brookite at a lower temperature, and octahedrite at a still lower temperature

Rutile is found as an accessory mineral in many kinds of **igneous rocks**, and to some extent in **gneisses** and **schists** In groups of **acicular** crystals it is frequently seen penetrating quartz as the "fleches d'amour" from Grisons, Switzerland Rutile is found also in Austria, Italy, Norway, South Australia, and Brazil In the United States it occurs in Vermont, Massachusetts, Connecticut, New York, Pennsylvania, Virginia, Georgia, North Carolina, and Arkansas

Rutile derives its name from the Latin *rutilus*, red, in reference to the deep red color observed in some specimens when viewed by transmitted light (E S C S)

RYDBERG CONSTANT. A quantity which enters into the frequency or wave number formulae for all **atomic spectra** It has nearly the same value for all elements, and has only to be multiplied by a factor dependent in a regular way upon the ordinal number of the line to give the wave number of each line in a given spectral series Rydberg derives the following expression for the constant in the case of any atom, the mass of whose nucleus is M:

$$R = \frac{2\pi^2 me^4}{ch^3(1 + m/M)},$$

in which m is the mass and e the charge of the electron, c is the **electromagnetic constant** (speed of light), and h is Planck's constant Since m/M is in any case very small, it is clear that R cannot vary much from element to element Its smallest value (for hydrogen) is about 109,678 reciprocal centimeters, and it can never exceed 109,737 reciprocal centimeters If R is multiplied by c, the result is the "Rydberg fundamental frequency" (called by some writers the Rydberg constant); and if this be used in place of R, the spectral series formulae give frequencies instead of wave numbers (L D W)

RYE. *Secale cereale.* Gramineae. Rye is an annual plant which has a tendency to become perennial. It is a sturdy cereal grass having a much-branched root system which penetrates from four to six feet into the ground and tough slender stems which may grow as tall as six feet. The leaves are like those of other **cereal** grasses, but have a definite bluish color, as does the stem. The **inflorescence** is a **spike**, with the individual spikelet three-flowered and occurring singly at each of the twenty or more joints of the **rachis**. Of the three flowers in a spikelet, only the two lower ones mature, the third aborting. The two **glumes** are narrow, the **lemma** is broad, distinctly keeled, and has a long stiff terminal **awn**, while the **palea** is thin and blunt. Unlike most of the cereal grasses, rye must be cross-pollinated in order to set fruit abundantly. The fruit, a grain, is very similar to that of wheat in structure, and readily separated from the lemma and palea when mature. The grain is long and slender and of much darker color than wheat grains.

Rye apparently originated either in central or southwestern Asia, and is a grain of much more recent cultivation by man than are the other cereal grasses. Rye is now extensively cultivated, especially in cold or dry climates, since the plants are capable of growing in much colder regions than wheat, and also on poor soils deficient in moisture content. Russia produces a large part of the world's rye crop, with Germany a second large producer.

Rye is much used in making flour. From this flour is made the dark-colored, somewhat bitter-flavored bread which forms the principal bread of the poorer classes of Europe. Rye grain is also used as a stock food, while the grass is used as forage or dried for hay. The ripened stem, or straw, is much used for bedding, as packing material, and in the manufacture of straw board. Much of the mash used in distilling whiskey and **alcohol** is made from rye.

Rye is subject to attack by a parasitic fungus known as ergot, *Claviceps purpurea*, which causes the grains to hypertrophy. Ergot is a violent poison, and if ground up with rye into flour, may cause serious epidemics of poisoning. (R.M.W.)

S

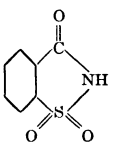
SABINE'S LAW. Acoustics.

SABLE. Marten.

SACCHARIDES. Carbohydrates.

SACCHARIMETER. This is a special type of polarimeter designed for use in the analysis of sugar solutions. It comprises a polarizing device, commonly a Nicol prism, to effect the polarization of the light, and an equalizer which permits the determination of the amount of rotation of the plane of polarization of this light that has been brought about by passage through a standard thickness of the solution undergoing analysis. Incidently, such instruments are designed to use or produce monochromatic light since the angle of rotation varies inversely with the wave length of the light. The specific rotation or specific rotatory power of optically active substances are known and, therefore, if there is only a single optically active substance present in the solution undergoing analysis its concentration may readily be calculated

SACCHARINE. This is an artificial sweetening agent which is not a **carbohydrate** but a cyclic imide of ortho sulphobenzoic acid.



It is synthesized from **toluene** and is seven hundred times as sweet as ordinary sugar. The sodium salt is used in **diabetes.** (R.K.S.)

SACCHAROIDAL. Used by petrologists as a textural term meaning granular (sugary). (R.M.F.)

SACCULINA. Crustacea, Cirripedia A parasitic **crustacean** which lives on crabs. The name is that of the genus to which the animal belongs When first hatched sacculina is an active **larva** (Nauplius) without a mouth or alimentary tract. It transforms into a Cypris larva which attaches itself to a crab and undergoes a transformation including the development of a perforating organ. By means of this organ the body wall of the crab is penetrated and the parasite, an almost shapeless mass of cells, enters the body cavity. It becomes attached to the alimentary tract of the crab and forms roothke processes which extend ultimately to all parts of the body. As the parasite reaches adult life it bulges from the under surface of the crab's abdomen. A conspicuous effect of the attack is the castration of the host, with accompanying changes in its visible sexual characteristics. (A.W.L.)

SACRUM. The portion of the spinal column of **vertebrates,** usually formed of several fused vertebrae, with which the pelvis is articulated. **Skeletal system.** (A.W.L.)

SAFETY VALVE. The common form of the safety valve is the pop valve held against its seat by a heavy spring and having a "huddling chamber" to make it open quickly and remain open until a predetermined pressure drop (2–4% of the working steam pressure) has occurred. The A.S.M.E. Boiler Construction Code requires **boilers** having more than 500 square feet of heating surface, or those generating better than 200c pounds of steam per hour, to have two or more safety valves. The safety valves should have sufficient relieving capacity to prevent more than 6% pressure rise at maximum rate of **combustion.** Required discharge capacity of a safety valve may be based either on the heat units in the **fuel** consumed or on the amount of steam generated.

In case more than one safety valve is used the smaller one can be set to pop at the desired maximum pressure and the larger at 2 or 3 pounds higher. The main safety valves of a large boiler operate to blow down several pounds pressure before closing. A smaller "**vernier**" safety valve giving less pressure drop between pop and close is installed, usually on the **superheater** outlet, though sometimes on the boiler lead, for the purpose of giving partial relief to the high pressure, warning the attendants of high pressure, preventing overheating of superheater tubes, and possibly forestalling popping of the main safety valves and the resultant waste of high-temperature potential heat. Since most safety valves discharge horizontally into a pipe that then turns upwards, an impulse force is given to the vent piping which, at least for large valves, needs special anchorage.

The relief valve is a form of safety valve, but usually intended for less severe service and of less importance from the safety viewpoint. Relief valves are applied to air, water, and steam lines, also to tanks, heaters, etc. Among them could be mentioned the back pressure valves and atmospheric relief valves. (F.T.M.)

SAFFLOWER. *Carthamus tinctorus.* **Composite Family.**

SAFFRON. *Crocus sativus.* Iridaceae. *Crocus sativus* is a perennial herb, the native home of which is the eastern Mediterranean region. The stem is an underground flattened **corm,** the surface of which is covered by a few scaly leaves. At the top of the corm is a terminal bud, which develops into linear leaves 5 to 9 inches long, and flowers. The flowers are white or lilac-tinted, with the **perianth** six-parted and with a very long tube, so that the **ovary** remains below the surface of the ground. The three **stigmas** are bright red These, when dried, are known as saffron, an orange-yellow dye with a considerable percentage of volatile oil present. Saffron is used in medicines, and in various liqueurs and dishes, to add a pleasant taste and color. (R.M.W.)

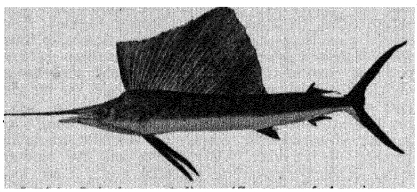
SAGE GROUSE, SAGE HEN. Aves, Galliformes. The largest species of **grouse** in North America, *Centrocercus urophasianus.* It ranges from southwestern Canada to Nebraska and central California, inhabiting chiefly the arid plains. It also wanders over grass lands and reaches high altitudes in the mountains. Sometimes called the cock of the plains. (A.W.L.)

SAGITTARIUS (The archer) (Map, page 306). This large **constellation** is the ninth sign of the **zodiac.** Lying as it does in a particularly rich portion of the milky way, it contains a large number of star **clusters** and gaseous **nebulae** of great beauty in a moderate sized telescope. From the large number of faint stars, **cepheid** variables, and globular clusters that seem to congregate in this region, it seems highly probable that the stellar **galactic** system has its greatest extension in this direction. Long-exposure photographs indicate that large numbers of dark or obscuring nebulae lie in this portion of the milky way. (W.K.G.)

SAIBLING. Pisces, Teleostei. A fish (**Pisces**) related to the trout. The name has been applied to a species of charr found in mountain lakes of central Europe (*Salvelinus salvelinus*) and in North America to the introduced European trout (*S. alpinus*), a usage also found to some extent in Europe. A related species, *S. aureolis*, found in lakes of the northeastern states, is called the American saibling. The name is also spelled saebling. (A.W.L.)

SAIGA. Mammalia, Artiodactyla. *Saiga.* A small and clumsy **antelope** found on the steppes of western Asia and eastern Europe. Its most conspicuous feature is the peculiarly swollen face. (A.W.L.)

SAILFISH. Pisces, Teleostei. *Istiophorus.* A large marine game fish (**Pisces**) whose dorsal fin is long and



Sailfish, *Istiophorus gladius.* (Courtesy of American Museum of Natural History.)

exceptionally high, resembling a sail. The upper jaw is prolonged into a sharp sword like that of the related swordfish. Also called spike-fish. (A.W.L.)

SAILINGS, THE. The position of a vessel at sea, or in the air, is defined by the **latitude** and **longitude.** The position at any particular instant is connected with any other position, either the one just left or the one toward which the vessel is proceeding, by means of the true **course** and distance.

Any given course and distance may be resolved into two components at right angles to each other; the northing or southing and the easting or westing, each expressed in **nautical miles.** The northing or southing may be immediately converted into difference of latitude, expressed in angular units, for the nautical mile is, by definition, approximately equal to a minute of arc along a great circle. However, the conversion from easting or westing, commonly known as **departure**, into difference of longitude, can be accomplished only after taking into account the shape of the **earth**, and the approximate latitude of the ship.

The navigator is continually faced by one of two problems: (1) Given the difference of latitude and longitude between two points on the surface of the earth, to find the course and distance between them. Or (2) Given the course and distance followed by a ship, to find the difference of latitude and longitude between the point of starting and the destination. The different methods of solving these problems are known as the sailings, and include **plane, parallel, middle latitude, mercator, great circle,** and **composite** sailings. (W.K.G.)

SAINT HILAIRE. The method for laying down a **line of position** from the observation of the **altitude** of a celestial object announced in 1875 by the French Admiral, Marcq Saint Hilaire, forms the basis of most of the so-called modern methods of nautical astronomy.

To lay down his line of position by this method the navigator first obtains his **dead reckoning** position at the time that he observes the altitude of the object. Then, using this position, the **azimuth** and geocentric **altitude** of the object are computed. If the computed altitude agrees with that observed, after it has been corrected and reduced to geocentric altitude, the navigator knows that his dead reckoning position is correct and the line of position must pass through his dead reckoning position perpendicular to the azimuth of the observed object. In case the computed and observed altitudes differ, the difference between them expressed in minutes of arc is known as the intercept, and may be expressed in **nautical miles.** To obtain his line of position in this case the navigator draws a line on a **mercator chart** through his dead reckoning position in the direction of the computed azimuth and lays off along this azimuth line the intercept, either toward or away from the direction of the observed object, depending upon whether his observed altitude is greater or less than the computed value. The line of position is then drawn through the point thus determined, perpendicular to the azimuth line.

This method of laying down the line of position has many advantages over the methods discussed under the **Sumner Line** article. It may be shown mathematically that the point on the azimuth line determined by laying off the intercept is the most probable of all the possible positions of the ship on the line of position. This position may be readily computed by the methods of dead reckoning, using the azimuth of the object as course and the value of the intercept as the distance from the assumed dead reckoning position. Various modifications of the Saint Hilaire method also lend themselves readily to tabulation, and many sets of tables, such as Hydrographic Office Publications—Nos. 201, 202, 203, de Acquino's Tables, Dreisonstok's Tables, and a variety of others, have been published. The use of these tables makes it possible to lay down a line of position within a very few minutes after the observation has been completed, which is of great importance to airplane navigators where speed in obtaining position is a vital factor. (W.K.G.)

SAKI. Mammalia, Primates. A New World **monkey** of the genus *Pithecia.* Most of the species bear the name of the group, as the white-headed saki and the whiskered saki, but native names have been adopted for some. The hairy saki is called the parauacu and the black saki is also known as the cuxio. No members of the genus have prehensile tails. (A.W.L.)

SAL. Latin term for various salts, much used. Sal ammoniac, **ammonium** chloride; sal soda, **sodium** carbonate; sal volatile, **ammonium** carbonate. (R.K.S.)

SALAMANDER. Amphibia, Urodela. A **vertebrate** with a slender body, short legs, and a long tail. The moist skin of the amphibians limits them to protected habitats, either near water or under some protection on moist ground, usually in the woods. Some species are aquatic throughout life, some take to the water intermittently, and some are entirely terrestrial as adults. The salamanders resemble the lizards superficially but they are easily distinguished by the moist skin, without scales. (A.W.L.)

SALIC. A term proposed by Cross, Iddings, Pirrson, and Washington, in 1906, for the group of relatively common or standard **aluminum-silicate** minerals such as **quartz, feldspars,** and **feldspathoids.** (R.M.F.)

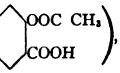
SALICYLIC ACID AND SALICYLATES. Salicylic acid or $C_6H_4(OH)(1)(COOH)(2)$ is a white solid, melting point 159° C., sublimes at 76° C., insoluble in cold water, soluble in hot water, alcohol, or ether. With **ferric** chloride solution, salicylic acid solutions are colored violet (distinction from **benzoic acid**).

Salicylic acid may be obtained (1) from oil of wintergreen, which contains methyl salicylate, (2) by heating dry sodium phenate (C_6H_5ONa) plus **carbon dioxide** under pressure at 130° C., and recovery from the resulting sodium salicylate by addition of dilute

The following are representative esters of salicylic acid

Methyl salicylate	$HOC_6H_4COOCH_3$	Boiling point 222° C
Ethyl salicylate	$HOC_6H_4COOC_2H_5$	Melting point 1° C , boiling point 231° C
Phenyl salicylate	$HOC_6H_4COOC_6H_5$	Melting point 43° C , boiling point 173° C at 12 mm. pressure

sulfuric acid. Salicylic acid is a mild disinfectant and antiseptic, and has been used as a food preservative Salicylic acid and certain salicylates are used in medicine as anti-rheumatics Aspirin is acetylsalicylic acid



, white solid, melting point 135° C , used for headaches and colds (R K S)

SALIENTIA. Amphibia.

SALIVARY GLANDS. Glands whose ducts discharge into or near the oral cavity In the **vertebrates** they are a group of digestive glands lying in various parts of the wall of the oral cavity, chiefly near the bases of the jaws, but among the invertebrates they are an extremely varied assemblage Thus in the insects some of the salivary glands lie in the **thorax**, and the silk glands of some species are modified salivary glands which may extend through almost the entire length of the body

The principal salivary glands of man are three pairs the sublinguals lie in the floor of the oral cavity, the submaxillaries below the angles of the lower jaw, and the large parotids in front of and below the ears They produce a digestive **enzyme**, ptyalin, which acts on starches, forming maltose, from which glucose is formed by the action of a second salivary enzyme, maltase (See **Carbohydrates**). The presence of digestive enzymes in the salivary secretions is by no means the rule among mammals in general Among birds it is not common (A W L)

SALIX. Paleobotany.

SALMON. Pisces, Teleostei Important game and food fishes (**Pisces**) The true salmons are found only in the northern hemisphere but some closely related forms are found in the Australian region The family includes the trout also

Salmon are remarkable for their migration into fresh waters from the sea for the breeding season Although this is so common as to be almost distinctive, there are fresh-water species which never migrate These are the so-called landlocked salmon of New England lakes and northward, which are regarded as among our finest game fishes Two varieties, the ouananiche and the sebago salmon, are classified as subspecies of the Atlantic salmon, *Salmo salar*, an important game fish in the rivers of the Atlantic coast and Europe

The rivers of the western coast of North America have several species of salmon which are taken in immense numbers to be canned and, to a less extent, to be marketed fresh The most important species is the chinook, king, or quinnat salmon (*Oncorhynchus tschawytscha*), and next in order come the blueback or redfish (*Oinerka*), and the silver salmon (*O kisutch*) Other species are of little importance as food

After the young salmon hatch in the headwaters of the rivers they work their way gradually to the sea, where they remain until mature Many of the adults perish in their breeding migration but some return to salt water. (A W L.)

SALOL. Drugs.

SALPIAN. Urochordata, Thaliacea A free-swimming tunicate (**Urochordata**) with a transparent body, marked by opaque muscle bands and internal organs **The salpians live near the surface of the ocean, some as solitary individuals and some in linear series as colonies.** They resemble the sessile ascidians in early life, but differ in remaining motile after the transformation of the larva (A W L)

SALPINGITIS. Infection of the **fallopian tubes** This common disease is most frequently due to a gonorrheal infection More rarely, it may be due to tuberculosis, *Streptococcus* infection, or even the *Pneumococcus* Gonorrheal salpingitis is not only most prevalent but is most disabling in its after-effects Salpingitis may not occur for months or even years after the original gonorrheal infection

The symptoms of acute salpingitis are severe, lower abdominal pain with marked tenderness over this region There is usually some fever and vomiting generally occurs The symptoms may closely resemble those of acute appendicitis and it is often very difficult to distinguish between the two conditions A patient may be incapacitated for more than six weeks After cessation of the acute symptoms the disease runs a chronic course that may last for years, lighting up at occasional intervals with a more or less acute attack

Chronic gonorrheal salpingitis is of great seriousness because of the tenacity of the infection and because its general constitutional symptoms are varied and far-reaching The most constant symptom is intermittent, dull, dragging pain in the lower abdomen which is usually made worse by exertion Patients appear worn and tired The dull pain often makes the subject irritable, nervous, and neurotic Digestive disturbances are common As it is the one greatest source of sterility, many women with this disease are sterile and this is often the source of mental worry Leukorrhea is usually present The formation of peritoneal **adhesions** accounts for many of the direct and associated symptoms Treatment is both medical and surgical, the surgical being resorted to when conservative treatment fails (R S M)

SALSIFY, OYSTER PLANT. *Tragopogon porrifolius* **Composite Family.**

SALTATION. This term, as proposed by McGee, in 1908, is used by geologists to designate the particular mode of the stream transportation of **clastic** sediments by intermittent leaps or bounds Probably an important factor in the ultimate transportation of the coarser fragments by streams and rivers (R M F)

SALT DOME. Halite.

SALTPETER Sodium nitrate

SALTS. See individual salts under each metal, also **Acids, Bases, and Salts**

SALVARSAN. Arsphenamine.

SALVE BUG. Crustacea, Isopoda A marine **crustacean** (*Aega psora*) parasitic on various fishes It is elongate oval in form and is a little more than one-half inch long Found on both sides of the Atlantic It is said to be used as a salve by fishermen (A W L)

SALVIA. Mint Family.

SAMARA. Fruit.

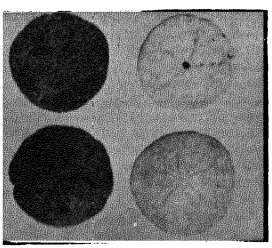
SAMARIUM. Symbol· Sm Atomic number 62 Atomic weight 150 43 Density 7 7 Melting point >1300° C Type of compound Sm_2O_3, white Color of salts· pink Discovered by Boisbaudran in 1879 A member of the **cerium** sub-group of the rare earth metals. (R K S)

SAND BOX TREE. Spurge Family.

SAND COLLAR. A thin collar-shaped plate formed of sand glued together with mucus. It is formed by marine **snails** of the family Naticidae in depositing their eggs. (A.W.L.)

SAND CRICKET. Insecta, Orthoptera. *Stenopelmatus.* Thick-bodied clumsy **insects** with large heads and long slender antennae. They live in loose soil, usually under some protective object, in the western United States. They are not true crickets but are more closely related to the long-horned grasshoppers. (A.W.L.)

SAND DOLLAR. Echinodermata, Echinoidea. A sea urchin (**Echinoidea**) with a very thin body, almost



Sand dollars.
(Courtesy of American Museum of Natural History.)

circular in outline and with a diameter of less than three inches. It is common on both coasts of North America. (A.W.L.)

SAND EEL. Pisces, Teleostei. A long slender marine fish (**Pisces**) found near sandy shores on both sides of the Atlantic. They have a single very long and low dorsal fin and a much shorter median ventral fin. Used chiefly for bait. (A.W.L.)

SAND GROUSE. Aves, Columbiformes. A small group of birds (**Aves**) related to the pigeons but in some ways resembling game birds. They are found chiefly in Africa and Asia but extend to Europe and Madagascar. As the name suggests, they frequent open ground. Their flight is powerful, hence some species migrate over considerable distances. (A.W.L.)

SANDPIPER. Aves, Charadriiformes. Long-legged shore birds (**Aves**) related to the snipes and plovers. They are named from their association with the bare margins of streams and ponds, where their clear piping calls are a familiar sound. North America has a score of species, some bearing other names such as sanderling and knot, and every other continent has representatives of the group during at least part of the year. (A.W.L.)

SANDSTONE. Sand grains cemented by such substances as **silica, carbonate** of **lime** or **iron** oxide, so as to form a solid rock is called sandstone. It occurs usually in beds of varying thickness, depending upon the conditions under which the original sediments were laid down. Because it is normally well jointed and easy to work, sandstone has been much used for building purposes. Unfortunately, however, as most sandstones are quite porous, the weathering action of the atmospheric agencies may have a very deleterious effect upon them. (E.S.C.S.)

SANDSTONE DYKES. Sandstone occurring in **fissures** which have been filled from above, or from beneath. The latter type are usually the result of earthquake fissures in great flood plain or delta deposits in which the sands have been injected from below. (R.M.F.)

SANIDINE. **Feldspar.**

SAP. **Ascent of Sap.**

SAPAJOU. Mammalia, Primates. **A capuchin monkey.** (A.W.L.)

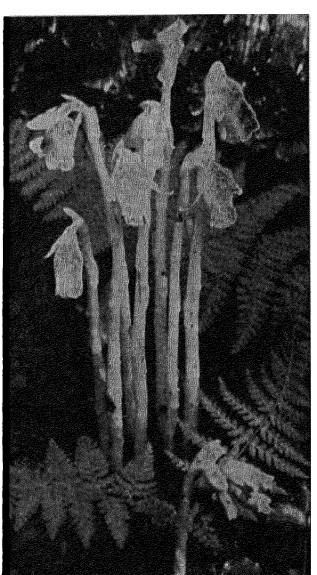
SAPONIFICATION. This is a special case of **hydrolysis** of **esters** in presence of alkali. See **Soap.** (R.K.S.)

SAPPHIRE. **Corundum.**

SAPROPEL. **Cannel Coal.**

SAPROPHYTES. These are plants which obtain their food material from non-living organic material. Most of the saprophytes are **fungi.** Among the higher plants, a small number of flowering plants and perhaps a few **mosses** are also saprophytes. It is characteristic of these saprophytic plants that they have little or no **chlorophyll,** and so are not able to carry on **photosynthesis.** Their energy is derived from the complex organic substances which they absorb. In many instances the absorption of these substances is greatly advanced by the presence of **mycorhizae.**

Especially is this the case with various species of saprophytic **orchids** which have mycorhizae within the cells of the



Left, Indian pipe, *Monotropa uniflora;* right, beach-drop, *M. Hypopitys;* two saprophytic flowering plants.

roots or **rhizomes.** The various species of Coralroots (*Corallorhiza*) are common saprophytic orchids

of American woods. These orchids have no roots, absorption occurring in the much-branched fleshy rhizome which gives the plant its name In this rhizome the mycorhizae are found These plants have erect stems, leaves reduced to scales, and no chlorophyll Other saprophytic orchids occur in the continents of the Old World

Another well-known saprophytic plant is the weird Indian Pipe or Ghost Plant, whose snow-white body is so striking an object, seen in the dark woods it inhabits In this and the related Pinesap, which has a yellowish color, the mycorhizae do not enter deeply into the tissues of the plant roots The latter form a considerable mass in the decayed vegetable substance on which they grow On these roots **adventitious buds** appear and develop to the erect flowering shoots

Other North American saprophytes are found in the Gentian family These, species of *Bartonia*, have a little chlorophyll, which gives them a greenish color The leaves are minute scales Many other saprophytes are found among the **monocotyledonous** plants of the tropical forests both in the New World and the Old (R M W)

SAPSUCKER. Aves, Piciformes A North American **woodpecker** which cuts rows of small holes around the trunks of trees and visits them for the sap which exudes and the insects that are attracted by it The rows of holes are so regular as to be conspicuous They are said to damage some trees seriously and in some cases to kill them The yellow-bellied sapsucker, *Sphyrapicus varius*, is the common eastern species It is represented in the western states by a variety, the red-naped sapsucker, and two other species, the red-breasted and the Williamson sapsuckers, occur in the far west (A W L)

SAPWOOD. Wood.

SARCODINA. One-celled animals whose organs of locomotion are temporary or semi-permanent protoplasmic processes known as **pseudopodia** These processes are thrust out and retracted at the surface of the body A class of the phylum **Protozoa.**

These animals vary from formless masses of **protoplasm** to species which secrete an enveloping test or enclosed hard parts which give them a characteristic shape Both free and parasitic forms are known Among the latter the species which causes amoebic dysentery is the most serious to man

The classification of the class is as follows

Subclass Rhizopoda With pseudopodia which are not of the straight semipermanent radial form known as axopodia

Order Proteomyxa Without hard parts Pseudopodia radiating and sometimes branched and united with each other

Order Mycetozoa Without hard parts Pseudopodia rootlike These animals form a plasmodium consisting of an extensive mass of cytoplasm with many nuclei Formerly classed as plants and called the slime molds

Order Foraminifera With an enclosing test of various colors and forms, calcareous or silicious, and often of several chambers Most species marine

Order Amoebaea Without an enclosing structure. Pseudopodia thick and temporary

Order Testacea With a test of one chamber, usually chitinous

Subclass Actinopoda With slender radiating pseudopodia

Order Heliozoa Usually spherical, with radiating pseudopodia Body not divided by a central capsule into distinct inner and outer zones Chiefly in fresh water

Order Radiolaria Usually spherical. Body divided into two regions by a central capsule Marine (A W L)

SARCOMA. Cancer.

SARCOSINE. Aminoacids, Polypeptides and Proteins

SARCOSPORIDIA. Sporozoa.

SARD. Chalcedony.

SARDINE. Pisces, Teleostei *Sardina* A small fish (**Pisces**) related to the herrings It is abundant in the English Channel and the Mediterranean, where it is also known as the pilchard Immense numbers of these fishes are taken each season, to be marketed in tins They are delicate, hence they must be prepared promptly in canneries located near the places where the fish are taken (A W L)

SARDONYX Agate.

SARGASSUM. Algae.

SARGO Pisces, Teleostei Compactly built marine fishes (**Pisces**) of Eurasian waters They have cutting teeth at the front of the jaws and strong molars Used as a food fish in Italy under the name dentice The sheepshead of the Atlantic and Gulf coasts of North America is a member of the same genus. (A W L)

SAROS. The fact that **eclipses** occur in periodic intervals was known to the ancient Chaldeans, and probably even in prehistoric times This period of 18 years, 11⅓ days (10⅓ days if there happen to be five leap years in the interval) is known as the Saros If an eclipse should occur on January 1st, 1937, at noon, another similar eclipse would occur on January 12th, 1955, at eight o'clock in the evening The eclipse would not occur at the same point on the earth but would be about eight hours farther west in **longitude**

During the course of a Saros there are about twenty-nine lunar and forty-one solar eclipses, each repeated during the next Saros, but not at the same portion of the earth (W K G)

SARRACENIA. Insectivorous plants.

SARSAPARILLA. *Smilax* sp Liliaceae The genus *Smilax* contains some 200 species, most of which are tropical, though a few such as the carrion flower, *Smilax herbacea* and the cat briar, *Smilax rotundifolia*, occur as far north as the New England states The tropical species are mostly climbing shrubs or vines, usually with prickly stems The leaves are entire and of oblong to ovate shape At the base of the leaf is a pair of **tendrils** which are perhaps to be interpreted as modified **stipules,** though such structures are not usually found in **monocotyledons.** The flowers are small, **dioecious** and borne in **umbels.** The fruit is a berry Some of the South American species are the source of Sarsaparilla, which is obtained from the dried roots. Sarsaparilla is used as a flavoring for beverages and formerly in medicine in the treatment of rheumatism (R M W)

SASSABI. Mammalia, Artiodactyla An African **antelope,** *Damaliscus lunatus*, also called the bastard hartebeest It is almost four feet high, with horns up to fifteen inches long Their color is deep reddish, blending into black on the back (A W L)

SASSAFRAS, OIL OF. Volatile oils.

SATELLITE. The term satellite is usually reserved in astronomy for small planet-like objects that are revolving about the individual **planets** in orbits The **moon** is the satellite of the earth and has been known from remotest antiquity The name and dates of discovery of the other satellites of the **solar system** will be found in the accompanying table. In this table there will also be found other data relative to the satellites The defini-

THE SATELLITES OF THE SOLAR SYSTEM

Number, Name and Date of Discovery		Mean Distance in Miles from Primary	Sidereal Period days hours	Apparent Stellar Magnitude	On Scale Moon = 1	
					Diameter	Mass
Satellite of the Earth						
Moon		238,857	27 7 720	−12 3	2160 mi	
Satellites of Mars						
1 Phobos	1877	5,826	0 7 654	11 5	0 0043	
2 Deimos	1877	14,580	1 6 299	12 0	0 0023	
Satellites of Jupiter						
5	1892	112,600	0 11 956	13 0	0 0460	
1 Io	1610	261,800	1 18 459	5 5	1 0731	1 09
2 Europa	1610	461,600	3 13 228	5 7	0 9062	0 65
3 Ganymede	1610	664,200	7 3 709	5 1	1 4816	2 10
4 Callisto	1610	1,168,700	16 16 536	6 3	1 4902	0 58
6	1904	7,114,000	250 68	13 7	0 0374	
7	1905	7,292,000	260 06	16	0 0115	
8	1908	14,600,000	738 9	16	0 0072	
9	1914	15,000,000	745 0	18	0 0072	
Satellites of Saturn						
7 Mimas	1789	115,300	0 22 618	12 1	0 1870	0 0005
6 Enceladus	1789	147,800	1 8 885	11 6	0 2445	0 002
5 Tethys	1684	183,000	1 21 307	10 5	0 3740	0 008
4 Dione	1684	234,400	2 17 686	10 7	0 3452	0 014
2 Rhea	1672	327,300	4 12 420	10 0	0 5034	0 033
1 Titan	1655	758,800	15 22 691	8 3	1 2083	1 86
8 Hyperion	1848	919,700	21 6 640	13 0	0 1438	0 002
3 Iapetus	1671	2,210,000	79 7 940	11 0	0 5178	0 08
9 Phoebe	1898	8,034,000	550 44	14 5	0 0575	
Satellites of Uranus						
1 Ariel	1851	119,100	2 12 489	15 2	0 2589	
2 Umbriel	1851	165,900	4 3 460	15 8	0 2014	
3 Titania	1787	272,200	8 16 941	14 0	0 4891	
4 Oberon	1787	364,000	13 11 118	14 2	0 4315	
Satellite of Neptune						
1	1846	219,800	5 21 044	13 6	1 4384	

tions of the various column headings will be found elsewhere in this work Further information regarding the different satellites will be found in the articles on the individual planets

Satellites serve a useful purpose to astronomers since the mass of a planet can be determined accurately only if the planet has a satellite By application of the rigorous expression for the harmonic **Keplerian law of planetary motion** the mass of any planet and satellite may be found in terms of the mass of the earth-moon system after the distance of the planet from the satellite and its period of revolution are known The problem of the determination of the masses of the satellites themselves is a more difficult problem The mass of the moon can be determined in terms of the earth's mass by means of the so-called **barycentric parallax** as described elsewhere in this work Approximate values of the masses of the satellites or Jupiter can be obtained by the mutual **perturbations** which they exert on each other In the case of Saturn the masses of the satellites may be approximately determined from their mutual perturbations and an approximate check is provided by the positions of the divisions in the rings

The two outer satellites of Jupiter, the outer satellite of Saturn, the four satellites of Uranus, and the satellite of Neptune all revolve about their primaries in the retrograde sense, i e , in the direction contrary to that in which all other planets and satellites are revolving and rotating This retrograde motion can be completely explained on the basis of modern **celestial mechanics**

The influences which satellites exert on their primaries are very slight The tidal forces which they exert have some slight effect upon the rotation periods of the primaries but such effects are so small as to be beyond observational measurement The tidal effects which the planets exert upon the satellites, on the other hand, are in many cases so large that the satellites rotate in approximately the same period as that in which they revolve

The question as to the origin of the satellite systems is still unanswered The systems bear so much resemblance to the solar system itself that there is the suggestion that their evolutionary process may be the same as that discussed under the topic of **solar system,** but there are many objections to such a theory Since the moon is the largest satellite in the solar system in comparison with its primary, and also being larger in proportion to the earth than any other planet is to the sun, it presents some very particular problems If they ever formed one single mass, that mass must have been rotating with a period of approximately four hours, and have been greatly flattened at the poles Such a mass would tend to break up under the influence of the rapid rotation, but would remain intact unless some external force was present Such a force is found in the tidal effects of the sun, and the earth-moon system may have been formed by the breaking up of a large parent mass However, the alternative hypothesis that the earth and moon were formed as two separate bodies at the time that the solar system was formed cannot be disproved (W K G)

SATURATED In **geochemistry** this term is used by mineralogists and petrologists to designate minerals, such as **feldspars** which can form in the presence of an excess of free **silica.** The term was proposed by Shand, in 1911, and is frequently used to describe **igneous rocks** which are entirely composed of minerals of this type. (R M F)

SATURATED VAPOR. A vapor which has a temperature of boiling at the pressure existing on it, is said to be saturated Expressing the same thought another way, a vapor is saturated when its temperature is a function of its pressure alone A saturated vapor may be wet or dry, and the term does not imply, necessarily, a **wet vapor. A vapor of 100% quality having no superheat,** is said to be dry and saturated In contrast to a saturated vapor, the temperature of a superheated vapor depends both on the pressure and the degree of superheat The temperature of a saturated vapor depends on its pressure and increases with increasing pressure By virtue of the importance of water in both its liquid and vapor phases, its properties have been completely investigated and recorded in tables and charts The properties of saturated steam will be found among such compilations The physical attributes of saturated steam are the pressure, temperature, volume, heat, and **entropy** These are always given for steam which is dry and saturated, leaving the reader to apply the **quality** factor when it occurs The increase of volume on vaporization, and the latent heat of evaporation, are present in wet steam to the extent of the percent dryness of the steam One of the most important entries in the saturated steam table is that for atmospheric pressure At 14 7 pounds per square inch absolute pressure, the saturation temperature of steam is 212° F The heat contained in it as a boiling liquid is 180 B T U (above 32° F), and its latent heat of evaporation is 970 2 B T U per pound (F T M)

SATURATION. Color; Magnetism; Vapors; Humidity.

SATURATION CURRENT. Ionization Chamber.

SATURATION TEMPERATURE. Saturated Vapor.

SATURN. (Cf tables of planetary data, page 865) Saturn, the "ringed planet," is the sixth major **planet** in order of distance from the sun and was the outermost planet known to the ancients In point of size Saturn is the second largest among the planets, having a diameter slightly more than nine times that of the earth and but slightly less than the diameter of **Jupiter.**

The physical characteristics of the planet itself are approximately the same as those for Jupiter The low density, high rotation speed, and variation of rotation period with planetary latitude all point to the probability that the solid core of the planet is relatively small and is surrounded by an atmosphere of very great thickness As in the case of Jupiter, **spectroscopic** analysis indicates that the **atmosphere** is composed to a large extent of ammonia and methane All evidence, both observational and theoretical, indicates the surface temperature of the planet to be in the neighborhood of 123° K (— 238° F) This low temperature coupled with the lack of oxygen in the planet's atmosphere indicates the impossibility of there being any life on Saturn such as we have on the earth

To the naked eye, Saturn appears comparable to the brighter stars In a telescope the planet itself has a belted appearance similar to that of Jupiter, but without as many distinctive surface features as are to be seen on the larger planet From these semipermanent surface features the rotation period of the planet has been determined and found to be but slightly over 10 hours There is also considerable evidence that the rotation period varies with planetary latitude, being the shorter at the equator.

Undoubtedly, the most remarkable and best known characteristic of Saturn is the ring system which surrounds the planet These rings have the appearance of circular disks of paper, pierced with a hole in the center to admit the planet The rings were first noticed by **Galileo** in 1610 when he first applied the telescope to astronomical observation, but it was not until forty years later that Huygens was able to accurately describe them Twenty years later, in 1675, Cassini found that the rings were separated into two parts, and in the middle of the 19th century Bond found a second division of rings, discovering the third or "dusky" ring, close to **the planet itself.**

Starting from the outside the rings are usually designated by the letters *A*, *B*, and *C* The outer ring, *A*, has a diameter of approximately 171,000 miles and is about 10,000 miles wide Cassini's division, between *A* and *B* is about 3,000 miles wide and ring *B* has a width of 16,000 miles Between *B* and *C* there is a narrow space of about 1,000 miles and ring *C* itself has a width of about 11,500 miles, leaving a space of about 7,000 miles between the inner edge of *C* and the planet itself In contrast to the great width of the rings their thickness is very slight Actual measurements of the thickness are very difficult but it certainly is not more than 10 miles On a model of 10,000 miles to the inch the ring system would have a width of about 17 inches while the thickness would be less than that of the thinnest paper

The rings are parallel to the planet's equator and, since the equator is inclined to the ecliptic at an angle of about 28°, the plane of the rings is inclined to the plane of the ecliptic by the same amount Saturn revolves about the sun with a period of about 29 5 years and twice during this period the plane of the rings passes through the orbit of the earth The plane of the rings takes nearly a year to pass the earth's orbit and during this period the earth may pass through the plane of the rings either once or three times At these times the rings are seen edgewise from the earth and appear as thin needles of light extending out from the planet's equator Intermediate between the passage of the earth through the plane of the rings they "open out" to their maximum angle at which time they appear as an ellipse produced by tipping a circle by about 27°, or an ellipse with an apparent width about half its maximum length

The problem as to the constitution of the rings of Saturn was a problem which vexed astronomers from the time when they were first discovered down to the middle of the last century It was recognized more than a hundred years ago that such a wide, thin system could not be in stable equilibrium if it were composed either of a solid or a liquid After the discovery of the inner ring by Bond and the discovery of a number of very fine divisions in both the *A* and *B* rings the mathematician, Clerk Maxwell, proved that the rings are in reality composed of millions of small particles each moving about the primary in orbits It was further proved that the divisions in the rings are produced by perturbations due to the outer satellites of Saturn The theoretical proofs were later verified experimentally by Keeler who, using the spectroscope and the Doppler principle, was able to show that the outer edges of the rings were revolving with longer periods than the inner edge Such a condition could never maintain for a solid and could only be accounted for on the basis of a swarm of satellites moving under the Keplerian laws of planetary motion

The question of the origin of the ring system of Saturn is still a much debated problem The two main theories postulate either that a large satellite was "spoiled in the making," or that a large satellite was formed and then exploded under the influence of some unexplained force

In addition to the millions of satellites that go to make up the ring system Saturn has a system of nine satellites These outer satellites of Saturn are, on the average, smaller than the satellites of Jupiter, Titan the largest of them having a diameter of about 2,600 miles Titan is visible in a three-inch telescope and seven of the others may be seen with telescopes of moderately large aperture Phoebe, the faint outer satellite of Saturn, has a **retrograde** motion (i e, revolves about the planet in the direction opposite to the revolution and rotation of the great majority of the other members of the solar system) (W K G)

SAUERKRAUT. Brassica.

SAUGER. Pisces, Teleostei A North American fish (**Pisces**), *Cynoperca canadensis*, related to the walleye A pike. Found in streams of the St Lawrence basin and the upper part of the Mississippi River system. (A W L)

SAURIA. Reptilia.

SAUROPSIDA. A term applied collectively to the reptiles and birds It is not a taxonomic group but indicates the relatively close similarity of birds and reptiles as contrasted with the Ichthyopsida, consisting of fishes and amphibians, and the mammals, which stand alone. (A W L)

SAW. A saw is a narrow sheet of metal having, along one edge, teeth cut from the metal or affixed to it, for the purpose of cutting material with which the saw blade is brought into contact Universally, the saw is moved during the sawing, and the material remains stationary, or is simply fed into the saw However, some saws move past the work continuously in the one direction (the band and circular saws), while others reciprocate on the work being sawed Examples of the latter are the common hand saw and the hack saw Saws may be classified on the basis of the material they cut As sawing has been the principal method of working wood, saws for wood work are more numerous and more widely used than are metal cutting saws There is a considerable amount of sawing done on metals, but by no means is the metal saw as important to the field of metal working as the wood saw in the wood working field Wood saws may be classified as hand saws, circular saws, jig saws, and band saws In these saws the teeth on the cutting edge are sharply pointed and set at a slight angle to the plane of the saw, alternate teeth being bent in opposite directions This set gives clearance to the blade of the saw, which prevents its binding in the sawed slot Saws with insufficient set tend to stick in the saw slot, or to overheat from friction The wider the set, the less trouble there will be with a saw binding, but the rougher the sawed edge, the more the lumber wasted Hand saws are further classified as crosscut or rip, straight or skew back, and by the number of teeth per inch, i e, eight point, nine point, ten point, etc There are special hand saws such as compass saws, keyhole saws, etc

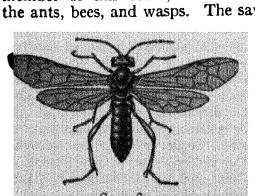
Circular saws are power driven disks of steel having the teeth set on the circumference The disk is held in an arbor which rotates in horizontal bearings The drive is usually taken from a pulley and belt The saw projects through a slot in a fixed table, which holds the work to be sawed Sawing is accomplished by moving the work into the saw blade, the direction of motion being exactly perpendicular to the axis of rotation The size of circular saws varies from 6 inches commonly used for small bench models, up to 6 feet and greater, in diameter The larger sizes are used in the saw mills, and the logs are fed into them by being mounted on a traveling carriage Large saws are of the inserted tooth type A variation of the circular saw is the swing cut-off saw, in which a motor-driven saw is mounted on a compound pendulum so that the center of the saw travels in the arc of a vertical circle When using this saw, the operator pulls it back from the saw table far enough to clear the work being placed thereon, then swings the saw into it The jig saw is particularly adapted for irregular holes, which are cut from the interior of a sheet of wood It consists of a short, thin, straight saw blade which is caused to reciprocate by a crank and connecting rod, or similar mechanism Since one end of the saw blade may be released from its clamp, and the saw passed through a hole which has been previously drilled in the wood, it is possible to saw out an opening with this type of saw which is impossible with any other power saw The band saw is an endless belt of metal bearing teeth along one edge, and running over two large pulleys which are set exactly in line The pulleys are faced with rubber or some other friction

material, and one is powered by pulley and belt. The adaptability of the band saw is great, and it has become an important type in all fields. While it was originally designed for rather light work, especially work on curves, it has since been built in much larger sizes so that the band saw is adaptable for sawing large timbers. Most resaw work, in which boards or planks are sawed into thinner lumber, is done with a band saw because the width of cut and material wasted as sawdust is much less on the band saw than on the circular saw. When the teeth are specially tempered and hardened, the band saw can be used for sawing metal.

Heavy metal sawing is done by the powered hack saw or sawing machine. A hack saw is a thin steel saw blade having small teeth very lightly set. The material of the blade must be hard; even so, the life of the teeth of the hack saw does not begin to compare with those on the hand saw. This saw blade is securely held with a considerable tension in a frame which can be used by hand with the ordinary sawing motion. When a motion similar to that used in a hand saw is given to the saw mechanically by a crank and a connecting rod, the saw becomes a power hack saw. Considerably advanced over the power hack saw is the modern metal sawing machine, which uses high quality hack saw blades. The sawing machine reciprocates the blade and moves it into the work parallel to its original position. It is equipped with a pressure feed which can be adjusted for sawing different metals. These machines are further equipped with a blade lubricating system, automatic stops, and speed adjustments. (F T.M.)

SAWFISH. Pisces, Plagiostomi. A large marine fish, *Pristis*, one of the rays. It has the upper jaw prolonged into a slender snout set with numerous sharp spines on each side. It is found in tropical America and Guinea. The name is also applied to *Pristiophorus*, a genus of sharks found in Japan and Australia. (A.W.L.)

SAWFLY. Insecta, Hymenoptera. A plant-feeding member of this order, whose more familiar species are the ants, bees, and wasps. The sawflies have four wings, somewhat like those of the wasps, but the abdomen is broadly connected with the thorax, in contrast with the thin-waisted bodies of the other forms. They are named from the saw-like ovipositor with which slits are cut in the tissues of plants to receive the eggs. Some species are of economic importance. Since the larvae eat leaves they can be destroyed by the usual arsenical sprays. (A.W.L.)


Saw fly.

SCABIES. A skin disease caused by an animal parasite (*Sarcoptes Scabiei*) characterized by an itching eruption which involves the hands between the fingers, the axilla, nipples, lower abdomen, buttocks and external genital organs. The head is not affected in adults.

The female parasite burrows beneath the skin where eggs are laid, causing slightly elevated, grayish, tortuous, or dotted lines on the skin surface.

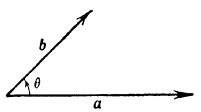
The treatment is internal and directed toward killing the parasite. (R.S.M.)

SCAD. Pisces, Teleostei. A fish (Pisces) related to the pompanos, of the family Carangidae. One species, common in the region of the West Indies, is called scad, cigar fish, or round robin. Another, also common in warmer waters although it ranges north to Cape Cod, is known as the big-eyed scad, goggler, or chicharro. The name has also been applied to the related horse mackerel, a European species occasionally taken on the Atlantic coast of North America. (A.W.L.)

SCALAR. Vectors.

SCALAR PRODUCT OF TWO VECTORS. The scalar product (or dot product) of two vectors **a** and **b** is defined as a **scalar** equal in magnitude to the product of the magnitudes of the two vectors by the cosine of the angle between them.

The symbol for the scalar product of **a** by **b** in the Gibbs notation is $\mathbf{a} \cdot \mathbf{b}$; in another form of vector notation the symbol (**a**, **b**) is used, while in the Hamiltonian notation the symbol $S\,\mathbf{a}\,\mathbf{b}$ is used.



Then

$$\mathbf{a} \cdot \mathbf{b} = ab \cos \theta,$$

where θ is the angle between **a** and **b**.

The scalar product of two vectors may also be interpreted as the length of one vector multiplied by the projection of the other on it.

The scalar product of two vectors obeys the commutative and distributive laws:

$$\mathbf{a} \cdot \mathbf{b} = \mathbf{b} \cdot \mathbf{a}, \quad \mathbf{a} \cdot (\mathbf{b} + \mathbf{c}) = \mathbf{a} \cdot \mathbf{b} + \mathbf{a} \cdot \mathbf{c}.$$

If **a** is perpendicular to **b**, then $\mathbf{a} \cdot \mathbf{b} = 0$; and conversely, if $\mathbf{a} \cdot \mathbf{b} = 0$, then **a** is perpendicular to **b**.

If **a** is parallel to **b**, then $\mathbf{a} \cdot \mathbf{b} = ab$. Hence, $\mathbf{a} \cdot \mathbf{a} = a^2$.

For the unit vectors $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, $\hat{\mathbf{k}}$, we have:

$$\hat{\mathbf{i}} \cdot \hat{\mathbf{i}} = \hat{\mathbf{j}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{k}} = 1, \quad \hat{\mathbf{i}} \cdot \hat{\mathbf{j}} = \hat{\mathbf{j}} \cdot \hat{\mathbf{k}} = \hat{\mathbf{k}} \cdot \hat{\mathbf{i}} = 0.$$

If $\mathbf{a} = a_1\hat{\mathbf{i}} + a_2\hat{\mathbf{j}} + a_3\hat{\mathbf{k}}$, $\mathbf{b} = b_1\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} + b_3\hat{\mathbf{k}}$, then

$$\mathbf{a} \cdot \mathbf{b} = a_1b_1 + a_2b_2 + a_3b_3. \qquad \text{(L.L.S.)}$$

SCALE. A flat structure developed as a covering. 1. The scales of fishes (Pisces) are in many cases arranged like shingles to form a complete armor at the surface of the body, and in other forms are small and scattered, merely adding to the resistant qualities of the skin. The elasmobranch fishes have placoid scales, whose form includes a broad base and a projecting enamel-covered point. This form of scale is much like the teeth of these fishes and is supposed to be ancestral to all vertebrate teeth. Ganoid scales, found in relatively few fishes, are regarded as a modification of the placoid type by the loss of the point and the addition of a hard outer layer known as ganoin. Some of the more primitive fishes of other groups have rounded scales with smooth margins, known as cycloid, and others have ctenoid scales, with comblike edges. The two last forms are found in the higher fishes. They bear neither enamel nor ganoin.

2. The scales found over the entire surface of the body in reptiles, on the legs of birds (Aves), and to a much more limited extent in mammals, as on the tails of rodents, are quite different from the scales of fishes. Each is a modified area of the skin, thickened and hardened by the development of the horny substance, keratin. Scales reach their highest development among the mammals in the pangolins and armadillos. In the latter they are underlaid by bony plates.

3. The butterflies and moths, a few beetles, and some other insects have the surface of the body and wings more or less covered by flattened scales. These structures are modified setae. They often contain pigments and in many species are so formed that they produce iridescent, metallic, or glossy physical colors by breaking up the light rays which they reflect.

4. Scale insects, often called scales, are highly specialized sucking insects which live on plants. They belong to the order Homoptera and are related to the

plant lice and phylloxerans. Most species are minute The young and the female adults are simplified and remain closely attached to the plant, secreting over themselves a protective covering or scale which gives them their name This covering is usually characteristic of the species

Scale insects include many species of economic importance Among them are the useful cochineal insect, a source of dye, and the lac insect whose scale is the raw material from which shellac is made China wax is also a scale insect product Among the harmful species the purple scale of citrus fruits, the San Jose scale, and the oyster-shell scale are important Because of the protective scale these species are not easily destroyed by the usual contact sprays They are controlled by spraying but the concentration of poison must be high and spraying during the dormant stage of the plant is often necessary as a result Fumigation of citrus trees with cyanide is practiced extensively This method requires special equipment since the tree must be enclosed in a tent. (A W L)

SCALE EFFECT. Wind Tunnel.

SCALE EFFICIENCY. Wind Tunnel.

SCALING. Feed Water Treatment.

SCALLOP Mollusca, Lamellibranchiata *Pecten* Marine bivalves of wide distribution in both shallow and deep water The symmetrical shells are beautifully marked with radiating grooves which give them a scalloped edge The large muscle which closes the shell of the scallop is eaten but the body is discarded (A W L.)

SCALP. The soft tissues covering the vertebrate cranium The term is usually applied only to man, and usually only to the part of the covering of the **skull** which normally bears hair (A W L)

SCANDIUM. Symbol Sc Atomic number. 21. Atomic weight; 45 10 Melting point 1200° C Type of compounds Sc_2O_3 Color of salts Colorless Discovered by Nilson in 1879, but predicted by Mendeleeff in 1871 as an element to be discovered with properties resembling **boron.** Occurs in a few uncommon minerals, *e g*, **wolframite,** sometimes to the extent of 2% oxide A member of the **cerium** sub-group of the rare earth metals (R K S)

SCAPHOPODA. The tooth shells A small class of **mollusks** with slender tapering shells open at both ends The foot projects from the larger end of the shell, together with a group of slender tentacles called captacula which arise from the poorly developed head These captacula have sucker tips and are sensory In many details of structure the animals are intermediate between the classes **Gasteropoda** and **Lamellibranchiata.** They are marine, burrowing in the bottom by means of the foot (A W L)

SCAPOLITE. Wernerite.

SCAPULA. The shoulder blade of the vertebrates **Skeletal system.** (A W L)

SCARAB. Insecta, Coleoptera A species of **beetle** which was regarded as sacred by the ancient Egyptains. The term is applied especially to the sculptured likenesses of the beetle From this name the family Scarabeidae has arisen, containing, among the many North American species, the **June bugs** or May beetles, the **tumble bugs,** and the **rose chafer.** (A W L)

SCARLET FEVER. (Scarletina). An acute infectious disease caused by the *Streptococcus scarletinae.* Scarlet fever was first described by Sydenham in 1675. Previous to that time it had been confused with **measles** and **rubella.** In the eighteenth century the severe epidemics of diphtheria were confused with it and it was not until the discovery of the diphtheria organism that the confusion between the diseases was finally cleared up

It is essentially a disease of childhood and the morbidity and mortality decreases with the age of the patient The black race is more immune to the disease than the white race Epidemics are more common in the fall and winter The entry of the disease is usually through the throat, localizing at first in this area Infection occurs by direct contact but may be conveyed individually by infected objects The incubation period varies from one to eleven days The severer the disease the shorter the period

The onset of the disease is acute Vomiting, fever and sore throat are the commonest early symptoms Often there is an area of pallor around the mouth and nose The rash does not appear until twelve to twenty-four hours after the onset, and usually spreads over the entire body The rash is quite characteristic The palate and roof of the mouth are involved in the eruption. The throat symptoms may be severe and swelling of the neck glands may occur The fever usually remains high for three to five days and then decreases gradually Peeling or desquamation begins within three to ten days after the disappearance of the rash and is complete in two or three weeks on the body, longer on the hands and feet

Mild scarlet fever may occur without rash, fever, sore throat or peeling, making diagnosis difficult (R S M.)

SCARLET RUNNER. Bean.

SCARP. The word scarp is an abbreviation of escarpment, and either term may be used to designate a vertical or steep cliff which has resulted from **erosion** or **faulting** If due to the latter cause the term fault scarp is commonly used An erosion escarpment developed upon beds which tilt at a very gentle angle is called a **cuesta.** If the beds are of variable hardness several cuestas, one behind the other may develop Examples of this condition may be seen on the Atlantic and Gulf Coastal plains (R M F)

SCATTERING. When light enters a body of matter, however transparent, part of it is diffusely reflected or "scattered" in all directions This is due to the interposition in the light stream of particles of varying size, from microscopic specks down to electrons, and the deflection of light quanta resulting from their encounters with these small obstacles Similar effects are produced upon infrared, ultraviolet, x-rays, and other forms of **electromagnetic radiation,** and upon streams of particles such as **cathode rays** or alpha rays

The scattering of light was carefully studied by John Tyndall, who used fine suspensions in air and liquids, and also by Ångstrom and by Lord Rayleigh The laws of scattering depend upon the nature of the scattering particles For very fine dust, Rayleigh concluded that the intensity of the light of wave length λ, scattered in any direction making an angle θ with the incident direction, is directly proportional to $1 + \cos^2 \theta$ and inversely proportional to λ^4 The latter point is noteworthy, in that it shows how much greater is the scattering of the short wave lengths Thus the sky is blue, and tobacco smoke appears blue, because blue light is scattered more than red The unscattered light is of course complimentary to blue, that is, orange or yellow, which explains the "warm" hues of the sunset. Scattered light is also distinctly plane-polarized (see **Polarized Light**) By far the largest part of scattered monochromatic light is of the same wave length as the incident, but that scattered by molecules contains faint components of different wave length, this is known as the **Raman effect.** The scattering of electrons and other particles by **atoms** has given important information as to the structure of atoms. (L D W.)

SCAUP. Aves, Anseriformes. A duck. The scaup or blue-bill, *Nyroca marila*, is found throughout the northern Hemisphere and the lesser scaup, *N affinis*, is a common North American species Both are principally black and light gray or white The head of the scaup duck is glossed with green and that of the lesser scaup with purple (A W.L)

SCHEELITE. The mineral scheelite is **calcium tungstate**, $CaWO_4$. It is a **tetragonal** with an **octahedral** habit although also at times tabular, and may occur massive It displays an octahedral **cleavage**, is brittle, hardness, 4 5-5, specific gravity, 5 9-6 1, luster, vitreous, color white to yellowish, reddish, greenish and brownish, white streak; transparent to translucent Scheelite is found in **pegmatite** and ore veins associated with **granites**, also as a contact **metamorphic** mineral It is known from Czechoslovakia, Saxony, Italy, Alsace, Finland, Cumberland and Cornwall in England, Mexico, and in the United States in Connecticut, Colorado, South Dakota, Arizona, Nevada, and California It is an ore of tungsten The Swedish chemist, Karl Wilhelm Scheele, discovered tungsten in this mineral, which later was named for him (E S C S)

SCHICK TEST. A simple and valuable test to determine whether individuals are susceptible or immune to **diphtheria**. The test is made by injecting a minute amount of very dilute diphtheria **toxin** in the skin If an area of redness about one-half inch in diameter appears at the site of the injection the reaction is said to be positive and the individual is susceptible to diphtheria, i e, the patient is deficient in his natural supply of **antitoxin**. The reaction usually appears within one to three days If no reaction shows at the site of the injection the test is said to be negative and the individual has a sufficient supply of antitoxin Only ten to twenty per cent of individuals in the cities show positive Schick reaction This is due to repeated contact to exposure producing a "natural immunity" In a country 85% to 95% may show a positive reaction indicating that immunization treatment is necessary (R S M)

SCHIFF'S REAGENT. Aldehydes.

SCHILLERIZATION. Luster.

SCHIST. The schists form a great group of **metamorphic** rocks chiefly notable for the preponderance of the lamellar minerals such as the **micas**, **chlorite**, **talc**, **hornblende**, **graphite**, etc Quartz often occurs in drawn out grains to such an extent that a **quartz** schist is produced Most schists have in all probability been derived from clays and muds which have passed through a series of metamorphic processes involving the production of **shales**, **slates** and **phyllites** as intermediate steps Certain schists have been derived from fine-grained igneous rocks such as lavas and **tuffs**. Most schists are mica schists, but **graphite** and chlorite schists are common Schists are named for the prominent or perhaps unusual mineral constituent, as **garnet** schist, **tourmaline** schist, **glaucophane** schist, etc The word schist is derived from the Greek meaning *to split*, with reference to the easy separation of these rocks in a direction parallel to that in which the platy minerals lie (E S C S)

SCHIZOPHRENIA (Dementia Praecox). An ill-defined group of mental conditions without known organic basis, characterized by bizarre mental and emotional reactions and oddities of behavior and thought This disorder is exceedingly common and many of the chronic cases in mental institutions come under this grouping

The cause is unknown but difficulties in adaptation to environment, and **endocrine** disorders, in most cases, seem to be the starting point for the disorder The onset is precipitated by physical ailments, shock, emotional and physical strain

The onset is insidious and is characterized by change of mood, irritability, suspicion or accentuation of long standing individual peculiarities of behavior and thought Intellectual functions are quite well retained in contrast to some of the other mental conditions Increased seclusion, unusual religious and subjective experiences, dissociation of thought, visions and hallucinations characterize the disorder The individual may think that queer changes have taken place in various organs. Social and economic difficulties sooner or later arise Queer fads often form part of the picture, also marked experiences and ideas Hebephrenia or catatonia is present in most cases

The prognosis varies, some patients recover, others suffer profound and permanent mental degeneration It is difficult to prognosticate in any case The probability of recovery is better in those cases precipitated by some acute physical or emotional circumstance

Treatment is necessarily institutional with a complete change of enviroment, tending toward withdrawal of the patient from a world of fantasy and unreal emotional values to the world of reality Introspection must be curbed and the patient taught to adapt himself to his present environment even though this can only be achieved in a modified form Hebephrenia is a disordered condition seen in some forms of schizophrenia characterized by unstable and exaggerated emotional reactions, crudity and pretentiousness

Catatonia is a disordered condition seen in schizophrenia characterized by bizarre movements and positions, hallucinations, refusal of food, negativistic attitudes with mutism and rigidity of body muscles (R S M)

SCHLIER. The term for streaky local segregations which occur in coarse-grained, **intrusive igneous** rocks, usually near the contact of the intrusion with the country rock The segregations, themselves, appear to be local concentrations of minerals drawn out as lenses or stringers by the movement of the **magma** while still in the viscous state The term is derived from the German, *Schliere* (singular), *Schlieren* (plural), referring to the streaks produced in artificial cements. (R M F)

SCHORL. Tourmaline.

SCHUMANN REGION. Ultraviolet.

SCHWEITZER'S REAGENT. This is an ammoniacal copper hydroxide solution used to dissolve cellulose (See **Carbohydrates.**) (R K S)

SCIENTIFIC NOTATION FOR NUMBERS IN DECIMAL FORM. Standard Notation for Numbers in Decimal Form.

SCINTILLATION. Radioactive Changes; Spinthariscope.

SCLERENCHYMA. This is a tissue composed of thick-walled **cells** of various forms These cells have small pits and walls so thick that in many cases the cavity of the cell is nearly obliterated Mature sclerenchyma cells are dead, containing no **protoplasm**. They serve to strengthen the part of the plant in which they are found and to protect the more delicate structures within Sclerenchyma cells are of two kinds, stone cells and fibers Stone cells are small, irregular in shape, and only slightly if at all elongated They may be found in the **cortex** of the stem or elsewhere in the plant, but are particularly abundant in fruit and seeds The flesh of immature pears contains many grit particles, which are groups of stone cells Sclerenchyma fibers are very much elongated cells, generally with long pointed ends and with simple pits in the walls **Hemp** and **flax** are bundles of sclerenchyma fibers of great value to man (R M.W)

SCLEROBLAST. Cells of **sponges** which secrete the material of the **spicules.** These cells lie in the middle layer of the sponge (the mesogloea) and are the only source of the hard parts. (A.W.L.)

SCLEROSIS, MULTIPLE (Insular Sclerosis, Disseminated Sclerosis). A disease of the central **nervous system** characterized by degeneration of nervous tissue in multiple areas causing many varied symptoms, mostly of the motor system. It is one of the common organic diseases of the nervous system.

The cause of the disease is not definitely known. Some observers feel that a specific **spirochete** or a **virus** is responsible.

The symptoms of the disease are extremely varied. Some of the more common ones are disturbances of speech, tremor, emotional and mental changes, disturbances of gait.

The disease tends to have periods of remission but eventually leads to a fatal result. No proven case has recovered although a patient may live for many years. There is no efficient treatment. (R.S.M.)

SCOLECITE. This mineral is a **zeolite,** a hydrous **calcium aluminum silicate,** $CaAl_2Si_3O_{10}3H_2O$. It occurs in slender **monoclinic** prisms and in fibrous and nodular masses. Hardness is 5.–5.5; specific gravity 2.16–2.4; luster vitreous to silky; transparent to translucent. When heated, some specimens of scolecite curl up like worms hence its name, derived from the Greek meaning a worm. This mineral occurs with other **zeolites,** at Baden, Switzerland; Iceland, Greenland; the Deccan region of India; and in the United States, at Golden, Colorado, and Paterson, New Jersey. (E.S.C.S.)

SCOLEX. The portion of an adult tapeworm (**Cestoda**) which is attached to the tissues of the host. It usually consists of a small rounded part at the end of a slender neck leading to the series of segments (proglottids), and usually bears hooks, suckers, or both. The suckers are usually two or four in number. In some species they are replaced by projections or grooves called bothria and in some they are accompanied by accessory suckers. Hooks may be located on a terminal prominence called a rostellum, and in one family they are at the end of slender rectractile organs called proboscides. The scolex may be replaced by a modification of the anterior end of the segmented portion of the body (strobila) known as a pseudoscolex. (A.W.L.)

SCOLIOSIS. Abnormal or lateral curvature of the spine. Although the curvature is to one side of the body or the other, there is always an element of twisting of the spine. Often it is not curvature of the spine that is complained of by patients, but instead the complaint is of a high shoulder or hip, or a projecting shoulder-blade. A curvature that is mild and unnoticed in youth may become troublesome due to its increase after middle-age when there is shrinking of the cartilaginous substance between the vertebrae. Often there are no symptoms connected with this condition unless the scoliosis is of marked degree.

Scoliosis is usually divided into postural or functional scoliosis, and organic scoliosis. Many cases of the former condition are due to bad posture. Other factors playing a part are any faulty home or hygienic conditions which interfere with muscular strength. While most of these causes are acquired, congenital factors enter as well as hereditary factors. Other causes may be remote as unequal vision or hearing, wry neck, shortness of one leg, etc.

With true or organic scoliosis there exists structural or pathologic changes in the vertebral body. False scoliosis may develop into true scoliosis at times. The causes of true scoliosis are usually congenital abnormalities of the spine, rickets, lung disease, tuberculosis of the spine, infantile paralysis, injuries to the vertebrate and tumor formation, etc. With rickets the bones lose their strength; with infantile paralysis a group of muscles on one side may become paralyzed leaving the pull of the muscles on the opposite side unopposed.

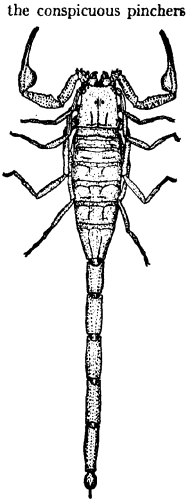
Treatment of scoliosis depends on the severity, duration and damage to the vertebrae. Exercise and correction of posture play a part in the mild functional forms. In the more severe forms, various corrective braces are worn. In other cases, fusion of the spine is the treatment used. (R.S.M.)

SCOLOPHORE. A spindle-shaped organ formed of sensory cells grouped about a nerve ending. It is the fundamental **auditory organ** of **insects,** appearing in a simple form in connection with the body wall and also in the more complex organs of hearing. (A.W.L.)

SCORIA. The term applied to lava which is highly vesicular and slaggy in appearance, due to the escape of the volcanic gases while the lava is still viscous. Scoria may be considered as a very coarse variety of **pumice,** the vesicles occupying approximately the same amount of space as the solid material, and extremely variable in size and shape. (R.M.F.)

SCORPION, SCORPIONIDA. A terrestrial **arthropod** with a conspicuous pair of pinchers and a slender terminal region of the body bearing a clawlike sting, and the order made up of these animals. They are grouped with the **spiders, ticks** and other forms in the class **Arachnida.**

The order is characterized by the conspicuous pinchers and by the sting. The body is divided into **cephalothorax** and abdomen, and the latter consists of a broad anterior portion and a slender postabdomen. The sting, a modified **telson,** bears the opening of the duct of a poison gland. The genital ducts open on the ventral surface of the first abdominal segment, just in front of a pair of comblike pectines of the second segment which are regarded as accessory reproductive organs.



Scorpion.

Scorpions are common in warm dry regions. In the United States they occur as far north as Kentucky. Their poison is not virulent as a rule, although one species found in the region about Durango, Mexico, is said to be dangerous to man. (A.W.L.)

SCORPION FLY. Insecta, Mecoptera. Moderately large **insects** with four membranous wings. They are named from the peculiar modification of the terminal segments of the abdomen, which fairly resembles that of the scorpions. The apparent sting is, however, made up of the external genital organs. (A.W.L.)

SCORPIUS. (The scorpion) (Map, page 306). Scorpio is the eighth sign of the **zodiac.** The **constellation** is rather far south for observation in Europe and North America, but is a beautifully grouped constellation presenting more resemblance to the figure for which it is named than is the case with most of the others.

The brightest star in the group **Antares** (Alpha Scorpii) is one of the most beautiful stars in the sky. It is distinctly reddish in color and gets its name from the fact that it opposes or rivals **Mars,** the red planet,

in color. It is the largest star whose diameter has thus far been measured, having a diameter approximately 450 times that of the sun. The star is so large that if it should replace the sun it would extend out beyond the planet Mars.

Beta Scorpii is a fine **double** for an observer with a small telescope with the two components distinctly different in color. (W.K.G.)

SCOTER. Aves, Anseriformes. A **duck** found chiefly along the seacoasts, and less often on fresh waters. The American scoter, *Oidemia americana,* is a bird of the northern Atlantic, breeding from Alaska to Labrador. The white-winged scoter, *Melanitta deglandi,* breeds from the northern United States northward and is fairly common on the Pacific coast. The surf scoter, *M. perspicillata,* also breeds northward into the Arctic regions and is more generally distributed on both coasts and in inland waters. All of the species are dark colored birds with few lighter areas. (A.W.L.)

SCREAMER. Aves, Ciconiiformes. Peculiar South American birds (**Aves**), with moderately long legs and large feet. The beak is like that of the domestic fowl and the wings are provided with two stout spurs on the front margin. The birds are as large as geese and swim readily, although the toes are not webbed. (A.W.L.)

SCREE. Talus.

SCREW. Machines.

SCREW GEARING. Variously called spiral **gearing,** helical gearing, worm gearing, this general class of gearing is used to transmit motion between nonintersecting, non-parallel shafts. The fundamental principle of screw threads, such as is incorporated in the relative motion between bolt and nut, is present in this gearing. The nut element, however, is replaced by toothed threads on the external surface of a cylinder. The accompanying figure illustrates a screw gear.

Screw gears. (Brown and Sharpe Mfg. Co.)

Included in this general classification is the worm gear, which is used in transmitting motion between two shafts at right angles, but non-intersecting. Worm gearing is very useful, since it offers a possibility of high velocity ratio between the two shafts. If the pitch of the worm is made very small, it has, furthermore, the property of being irreversible, that is, while rotation of the worm will revolve the worm wheel, the worm wheel can not be made to revolve the worm. A particular instance of the usefulness of this is in the drive between steering gear and steering wheel of an automobile. The wheels may be turned by means of the steering wheel with a small effort, but the steering wheel does not have to be held tightly against road shocks transmitted through the steering gear, as would be the case with a reversible gear drive. There is a large amount of sliding action present in screw gearing; a sliding action of the screw transversely over the threads of the wheel, and, although the mechanism possesses the important quality of quietness by virtue of the smooth engagement between teeth, it must be built with hardened, nicely finished surfaces, and operated well lubricated, or wear and loss of power will inevitably be present. The velocity ratio of a worm gear is equal to the number of teeth in a worm wheel, for single-threaded worms. It is half that on double-threaded worms, one-third on triple-threaded worms, etc. (F.T.M.)

SCREW PROPELLER. Air Propeller, Water Propeller.

SCREW THREADS. Fastenings.

SCROFULA. Tuberculosis of the **lymphatic glands.** The glands become enlarged, at times become abscessed and open forming chronically draining sinuses. A favorite site for such infections of the glands is in the neck. They are not seen as frequently as in the past due primarily to the supervision of cows, as the milk from infected cows was in the past one of the prime causes of this form of tuberculosis.

Pulmonary tuberculosis is not often seen in people who have had tuberculosis of the lymphatic glands and been cured before the age of fifteen years. The glandular tuberculosis is usually a mild infection which grants a certain degree of immunity to further tuberculosis infection.

Treatment is by the use of natural or artificial ultraviolet light and surgical excision. (R.S.M.)

SCROLL CASE. Hydraulic Turbine.

SCROTUM. The baglike pouch containing the two testicles, situated behind and below the penis. It is divided into two compartments by a septum in the middle. (R.S.M.)

SCRUBBER. Gases produced in industrial plants, usually originate laden with impurities which render them unfit for the use to which they are to be put. For example, the gas taken from a blast furnace is so dust-laden that were it used directly in gas engines, the cylinders would soon become badly worn and scored. Scrubbers are means for removing such substances from gas. The scrubbing action is one wherein a liquid, commonly water, is brought in contact with the gas in various ways. Chiefly dust and sulfur dioxide are removed by scrubbers. Other substances in gases are removed by equipment in series with the scrubber; for example, tar extractors. The scrubber has competitors such as electrostatic dust precipitators, centrifugal cleaners, and chemical precipitators. Scrubbing is accomplished in a tower through which the gas is made to pass, generally in counter-current arrangement with respect to the water. The equipment available commercially includes rain type scrubbers, spray scrubbers, and hurdle scrubbers, the latter being a maze of staggered slats which are wetted, so that the dust impinging upon them will be retained by the water film. (F.T.M.)

SCULPIN. Pisces, Teleostei. A fish (**Pisces**) of the family Cottidae. They are peculiar fishes, usually small, with a broad depressed head and large pectoral fins. They are of no importance as food fishes. Many of the included species bear other names, including the little miller's thumbs of fresh waters and the sea raven which ranges from Cape Cod to the Arctic. One species of the northern Atlantic coast is called the big sculpin, or daddy sculpin. (A.W.L.)

SCURVY. A deficiency disease due primarily to lack of **Vitamin** C. It was first observed as a disease by Hippocrates. In the thirteenth century it was a curse of Crusaders. In time of war it has killed untold numbers in armies and navies and besieged towns. During the days of sailing ships, often taking months between ports with the resulting lack of fresh food, it affected the crew as a plague. It was even of considerable importance in the World War. In civilized countries its chief importance lies in infant feeding as in adult life it is seldom seen. It is rarely seen in breast fed children but pasteurization of cow's milk destroys the vitamin C and an addition to the diet of this vitamin must be allowed for in infants under one year of age.

Vitamin C is principally found in fresh fruits and vegetables. Dried fruit cantains practically no vitamin C. Citrus fruits which are picked green and allowed to ripen in storage, as many are, contain less vitamin C than tree-ripened fruit.

in color. It is the largest star whose diameter has thus far been measured, having a diameter approximately 450 times that of the sun. The star is so large that if it should replace the sun it would extend out beyond the planet Mars.

Beta Scorpii is a fine **double** for an observer with a small telescope with the two components distinctly different in color. (W.K.G.)

SCOTER. Aves, Anseriformes. A **duck** found chiefly along the seacoasts, and less often on fresh waters. The American scoter, *Oidemia americana,* is a bird of the northern Atlantic, breeding from Alaska to Labrador. The white-winged scoter, *Melanitta deglandi,* breeds from the northern United States northward and is fairly common on the Pacific coast. The surf scoter, *M. perspicillata,* also breeds northward into the Arctic regions and is more generally distributed on both coasts and in inland waters. All of the species are dark colored birds with few lighter areas. (A.W.L.)

SCREAMER. Aves, Ciconiiformes. Peculiar South American birds (**Aves**), with moderately long legs and large feet. The beak is like that of the domestic fowl and the wings are provided with two stout spurs on the front margin. The birds are as large as geese and swim readily, although the toes are not webbed. (A.W.L.)

SCREE. Talus.

SCREW. Machines.

SCREW GEARING. Variously called spiral **gearing,** helical gearing, worm gearing, this general class of gearing is used to transmit motion between nonintersecting, non-parallel shafts. The fundamental principle of screw threads, such as is incorporated in the relative motion between bolt and nut, is present in this gearing. The nut element, however, is replaced by toothed threads on the external surface of a cylinder. The accompanying figure illustrates a screw gear.

Screw gears. (Brown and Sharpe Mfg. Co.)

Included in this general classification is the worm gear, which is used in transmitting motion between two shafts at right angles, but non-intersecting. Worm gearing is very useful, since it offers a possibility of high velocity ratio between the two shafts. If the pitch of the worm is made very small, it has, furthermore, the property of being irreversible, that is, while rotation of the worm will revolve the worm wheel, the worm wheel can not be made to revolve the worm. A particular instance of the usefulness of this is in the drive between steering gear and steering wheel of an automobile. The wheels may be turned by means of the steering wheel with a small effort, but the steering wheel does not have to be held tightly against road shocks transmitted through the steering gear, as would be the case with a reversible gear drive. There is a large amount of sliding action present in screw gearing; a sliding action of the screw transversely over the threads of the wheel, and, although the mechanism possesses the important quality of quietness by virtue of the smooth engagement between teeth, it must be built with hardened, nicely finished surfaces, and operated well lubricated, or wear and loss of power will inevitably be present. The velocity ratio of a worm gear is equal to the number of teeth in a worm wheel, for single-threaded worms. It is half that on double-threaded worms, one-third on triple-threaded worms, etc. (F.T.M.)

SCREW PROPELLER. Air Propeller, Water Propeller.

SCREW THREADS. Fastenings.

SCROFULA. Tuberculosis of the **lymphatic glands.** The glands become enlarged, at times become abscessed and open forming chronically draining sinuses. A favorite site for such infections of the glands is in the neck. They are not seen as frequently as in the past due primarily to the supervision of cows, as the milk from infected cows was in the past one of the prime causes of this form of tuberculosis.

Pulmonary tuberculosis is not often seen in people who have had tuberculosis of the lymphatic glands and been cured before the age of fifteen years. The glandular tuberculosis is usually a mild infection which grants a certain degree of immunity to further tuberculosis infection.

Treatment is by the use of natural or artificial ultraviolet light and surgical excision. (R.S.M.)

SCROLL CASE. Hydraulic Turbine.

SCROTUM. The baglike pouch containing the two testicles, situated behind and below the penis. It is divided into two compartments by a septum in the middle. (R.S.M.)

SCRUBBER. Gases produced in industrial plants, usually originate laden with impurities which render them unfit for the use to which they are to be put. For example, the gas taken from a blast furnace is so dust-laden that were it used directly in gas engines, the cylinders would soon become badly worn and scored. Scrubbers are means for removing such substances from gas. The scrubbing action is one wherein a liquid, commonly water, is brought in contact with the gas in various ways. Chiefly dust and sulfur dioxide are removed by scrubbers. Other substances in gases are removed by equipment in series with the scrubber; for example, tar extractors. The scrubber has competitors such as electrostatic dust precipitators, centrifugal cleaners, and chemical precipitators. Scrubbing is accomplished in a tower through which the gas is made to pass, generally in counter-current arrangement with respect to the water. The equipment available commercially includes rain type scrubbers, spray scrubbers, and hurdle scrubbers, the latter being a maze of staggered slats which are wetted, so that the dust impinging upon them will be retained by the water film. (F.T.M.)

SCULPIN. Pisces, Teleostei. A fish (**Pisces**) of the family Cottidae. They are peculiar fishes, usually small, with a broad depressed head and large pectoral fins. They are of no importance as food fishes. Many of the included species bear other names, including the little miller's thumbs of fresh waters and the sea raven which ranges from Cape Cod to the Arctic. One species of the northern Atlantic coast is called the big sculpin, or daddy sculpin. (A.W.L.)

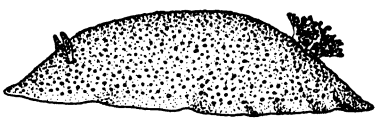
SCURVY. A deficiency disease due primarily to lack of **Vitamin** C. It was first observed as a disease by Hippocrates. In the thirteenth century it was a curse of Crusaders. In time of war it has killed untold numbers in armies and navies and besieged towns. During the days of sailing ships, often taking months between ports with the resulting lack of fresh food, it affected the crew as a plague. It was even of considerable importance in the World War. In civilized countries its chief importance lies in infant feeding as in adult life it is seldom seen. It is rarely seen in breast fed children but pasteurization of cow's milk destroys the vitamin C and an addition to the diet of this vitamin must be allowed for in infants under one year of age.

Vitamin C is principally found in fresh fruits and vegetables. Dried fruit cantains practically no vitamin C. Citrus fruits which are picked green and allowed to ripen in storage, as many are, contain less vitamin C than tree-ripened fruit.

They are killed when they come ashore at their breeding grounds and under present conditions hunting does not interfere with the normal propagation of the species. The Pribilof Islands are an important center for these well-known seals. Fur seals are also called sea bears.

In addition to the fur seals the group includes many other species, among them the harbor seal (*Phoca vitulina*), hair seals, hooded seal (*Crystophora cristata*), and elephant seal (*Mirunga*), in addition to the related **sea-lions.** (A.W.L.)

SEA LEMON. Mollusca, Gasteropoda. A flattened oval marine **mollusk** which feeds on sponges and other



Sea lemon.

sessile animals. The roughened skin and the oval form as seen from above suggest the fruit for which the animal is named. (A.W.L.)

SEA LEOPARD. Mammalia, Carnivora. A large **seal,** *Stenorhynchus leptonyx,* of the southern hemisphere. It is yellowish or tawny with gray spots. Also called the leopard seal. (A.W.L.)

SEA LILY. Crinoidea.

SEA LION. Mammalia, Carnivora. Animals closely related to the seals. They belong to the same family as the fur seals and with them differ from the other seals in having external ears. The common sea lion, *Zalophus californianus,* is found on the Pacific coast of Mexico and California and Steller's sea lion, *Eumetopias stelleri,* ranges from Bering Strait to southern California. (A.W.L.)

SEA MILL. Pot Hole.

SEA MOUSE. Annelida, Polychaeta. A marine **worm,** *Aphrodite hastata,* of compact oval form, covered above and on the sides with a feltlike material. It is recorded from Vineyard Sound on the Atlantic coast. (A.W.L.)

SEA PEACH. Chordata, Ascidiacea. An ovoid **ascidian,** *Halocynthia pyriformis,* found in European waters and along the north Atlantic coast of North America. It is ovoid in form and yellowish to pink or red in color, with a velvety surface. (A.W.L.)

SEA PEN. Coelenterata, Anthozoa. Colonial **polyps** related to the sea feathers but with much shorter lateral branches or none. (A.W.L.)

SEA SERPENT. Reptilia, Sauria. Although the term has come to mean almost invariably a fantastic myth of some great monster, there are true sea **snakes** of several species belonging to a group related to the cobras. They are only moderately large. The body is compressed as an adaptation for swimming and the snakes are so thoroughly aquatic that they are either clumsy or helpless when cast ashore.

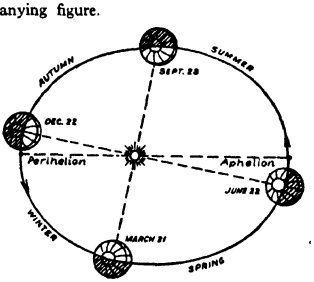
These snakes are poisonous. The short fangs are near the front of the upper jaw and are grooved. The poison acts on the nervous system, like that of the related cobras.

Sea snakes are confined to the tropical oceans, chiefly the Indian ocean and the western Pacific. A single species, *Pelamydrus platurus,* extends to the eastern Pacific. (A.W.L.)

SEASICKNESS. This disorder, and other similar disorders, as car and airplane sickness, are caused by unusual and continuous movements stimulating the equilibrium apparatus of the ear. The unusual stimulation causes reflex symptoms as headache, nausea and vomiting. The susceptibility of persons varies with the individual, and in certain cases is very marked. (R.S.M.)

SEA SLUG. Mollusca, Gasteropoda. Marine **molluska** with compact bodies and without shells. Some species have branching processes on the surface of the body by which they breathe. The creeping habits and general form are similar to those of the terrestrial slugs, although there is no closer relationship between the two. The sea slugs make up the order Nudibranchiata. (A.W.L.)

SEASONS. The fundamental causes of the seasons are the inclination of the **earth's equator** to the plane of the **ecliptic** and the revolution of the earth about the **sun.** Since the equator is inclined at an angle of approximately 23°.5 to the plane of the ecliptic, and this angle remains approximately fixed, the **declination** of the sun varies between 23°.5 north on June 21st and 23°.5 south on December 21st. Intermediate between these two dates, on March 21st and September 21st, the declination of the sun is zero. The general characteristics of the earth's motion about the sun are shown in the accompanying figure.



The seasons in the northern hemisphere. This hemisphere is tipped farthest toward the sun at the summer solstice (June 22), and farthest away at the winter solstice (December 22). About the middle of January the earth arrives at perihelion.

The amount of heat that a particular spot on the earth receives from the sun in twenty-four hours is dependent upon three factors: the angle which the line from the earth to the sun makes with the surface of the earth, the time that the sun is above the horizon, and the distance of the earth from the sun. The first two factors depend fundamentally upon the declination of the sun and are the most important effects in the production of seasonal changes. Neglecting for the moment the slight changes in distance of the earth from the sun due to ellipticity of the orbit, it may be shown that the amount of heat received in one day at any spot on the surface of the earth will be a maximum on that date when the declination of the sun is closest to the **latitude** of the spot on the earth. Points north of latitude 23°.5 north will receive the maximum amount of heat on June 21st while points south of 23°.5 south will receive the most heat on December 21st. The zone on the surface of the earth bounded by the parallels of latitude 23°.5 north and 23°.5 south is known as the torrid zone. The boundaries called the tropics of **Cancer** and **Capricorn,** the names being derived from the signs of the **zodiac** in which the sun is located in June and January. Within the regions north of 66°.5 north and south of 66°.5 south the so-called midnight sun may be observed. The parallels of latitude bounding these zones are known as the arctic and antarctic circles.

Examination of the accompanying figure will show that the earth passes through **perihelion** during the winter season in northern latitudes. In accordance with the **Keplerian law of areas** the motion of the earth is most rapid during this period and the time required for the sun to go from the autumnal to the **vernal equinox**

should be shorter than the remainder of the year Examination of the **calendar** will show that there are 181 days from September 21st to March 21st as compared with 184 days between March 21st and September 21st. Furthermore, at perihelion the sun is closer to the earth than at aphelion and hence the heating effect should be greater While these effects are slight, nevertheless climatic statistics indicate that winter in the northern hemisphere is somewhat milder than the same season in corresponding southern latitude, while the northern summer is somewhat more temperate

In accordance with the theory of the seasons the hottest portion of the year in the northern hemisphere should be about June 21st while the coldest should be about December 21st Examination of temperature statistics indicates that there is a distinct lag in the seasons, the warmest period coming about August 1st and the coldest about February 1st The temperature of a certain region on the earth depends upon two factors the amount of heat received per day, and the amount radiated away The amount received depends upon the factors which we have just discussed while the amount radiated away depends in turn upon the temperature of the radiating substance, the rate of **radiation** being greater the higher the temperature On June 21st the amount received is a maximum, but the temperature of the ground has not yet risen to a point sufficiently high to radiate away as much heat as is received For the next few weeks, the amount received per day decreases, but, since the rate of radiation is not yet as great as the rate of reception of heat, the temperature continues to rise until about the first of August when the balance point is reached From this date the temperature continues to fall On December 21st, the rate of reception is a minimum and the rate of radiation is in excess of the amount received per day In spite of the fact that the amount received per day steadily increases from this date, the rate of radiation continues to exceed the rate of reception until about February 1st when the balance point is reached and the earth begins to warm up

The seasonal conditions in any particular locality are greatly modified by local conditions of altitude, character of the soil, etc Furthermore, the atmosphere serves both as a blanket and also as a method of transporting heat by convection from one portion of the earth to another In this connection it is interesting to refer to an old problem of Professor Young in which he asked students to prove that "If weather was used on the spot where it is made, the hottest place on the earth would be the south pole on January 21st" (W K G)

SEA SPIDER Pycnogonida.

SEA SQUIRT. Ascidiacea.

SEA STAR. Starfish **Asteroidea.**

SEA URCHIN. Echinoidea.

SEA WALNUT. Ctenophora.

SEA WOLF Pisces, Teleostei One of the wolf fishes, a group of species of fishes (**Pisces**) related to the blennies but much larger The common wolf fish, *Anarrhichas,* attains a length of four feet and is an important food fish in Norway and Greenland Its range extends to Cape Cod The name wolf-fish refers to the large teeth with which the jaws of these fishes are armed (A W L)

SEBACEOUS CYST. A cystic structure developing in the skin, due to plugging of a duct leading from the **gland** These progressively increase in size and often become infected They are commonly called wens and are often seen on the scalp and face as well as other parts of the body. They always contain a white cheesy material

Treatment is by surgical excision If the entire cyst wall is not removed recurrence is certain **(B.S.M.)**

SEBACEOUS GLAND. A gland of the skin of mammals which secretes an oily substance (sebum) These glands are usually associated with hair follicles and in man are especially abundant in the scalp, although they occur all over the body with the exception of the palms of the hands and soles of the feet Their secretion keeps the skin pliable and anoints the hair

In structure these glands are of the compound alveolar type Their secretory parts are saccular, discharging to a common duct which often opens in the hair follicle (A W L)

SECOND Time.

SECONDARY Transformer; Induction Coil.

SECONDARY EMBRYO. An individual formed by budding from another that has not yet completed its development The term is applied to the **bryozoans.** A modified chamber, the **ovicell,** forms a brood pouch in which the fertilized ovum develops into a primary **embryo** From this individual the secondary embryos are derived A similar succession of forms occurs in other **phyla,** as in the complex life cycle of the liver flukes, although different terms are used to designate the different stages (A W L)

SECONDARY FLAGELLUM A small branch of the **antenna** of **crustaceans** The whiplike terminal portion of the antenna is called a flagellum In species with more than one of these structures the smaller flagellum is designated as secondary The term is not to be confused with the flagella of one-celled animals (A W L)

SECONDARY SEXUAL CHARACTERS The characters of living things whose appearance is definitely associated with the sex of the individual, although the characters have no direct connection with the process of reproduction

The different colors and patterns of the two sexes in many species of birds and insects are familiar examples of secondary sexual characters Horns of some males, the manes of many male mammals, and the spurs of cocks are also in this category In some species the differences resulting from such characters are so great that the two sexes can scarcely be associated by appearance Cases are on record among the insects of the classification of males and females of the same species in different genera prior to the discovery of their relationship through other evidence (A W I)

SECRETARY BIRD. Aves, Falconiformes A remarkable African bird (**Aves**), *Sagittarius serpentarius,* related to the eagles and vultures The bird is about four feet tall, with long legs, and is largely terrestrial in habits It walks and runs very rapidly, and is also a strong flier on the relatively rare occasions when it takes to the air (A W L.)

SECRETION For the use of this term in geology, see **Concretions.** In biology, secretion is the production and discharge of special products by living **protoplasm.** In the complex body secretion may be carried out by single cells but is more often the function of many associated cells All of these secreting units are called **glands.**

The details of the entire process are not completely understood In many cases the special secretion is formed in the **cytoplasm** of the gland cell in granules, or these granules may consist of a foundation substance which is transformed into the secretion characteristic of the gland at the time of discharge The transformation or the discharge or both may be brought about by a nervous stimulus or by the action of a **hormone.** Thus the salivary glands respond promptly to nerve stimuli resulting from the taste, smell or sight of food, and the pancreas is activated by the hormone secretion produced in the wall of the intestine

The discharge of secretion may take place through the free end of the gland cell, or through the ruptured end of the cell. In some cases the terminal portion of the cell is converted into the secretion. The existence of these processes is accepted, although the action of many gland cells cannot be classed definitely with any particular one.

The secretions of endocrine glands are not discharged in the usual sense, but are taken up by the blood circulating through the gland. (A.W.L.)

SECTION MODULUS. An inspection of **flexure** will reveal that the stress in a member subjected to a transverse bending is directly proportional to the external bending moment, and inversely proportional to the ratio of

$$\frac{\text{moment of inertia}}{\text{distance of the stressed element from the neutral axis}}.$$

It is apparent that this ratio is entirely a property of the shape and size of the cross-section of the structural member. This ratio is known as the section modulus, and is an important property of rolled steel sections and other shapes which are used as structural members. When the bending moment to be withstood by a beam or column is divided by this section modulus, the quotient is the maximum bending stress which will exist in that member. (F.T.M.)

SECTOR DISK. A device much used in physical apparatus to secure an accurately known control of the intensity of a beam of light or other emission. The simplest form is a circular, opaque disk with a sector or sectors of any desired angle cut from it. If the disk is interposed in the path of light rays and rotated rapidly about its center, the resulting intensity, as judged visually, is reduced to a fraction equal to the ratio of the area of the open sectors to that of the whole disk. This arrangement is useful, for example, in a photometer where it is desired to cut down the intensity of one beam to match that of another. By giving the sides of the openings suitable curved shapes instead of cutting them along radii, the intensity may be varied from center to circumference in accordance with any desired law. This affords, for example, a non-selective "wedge" for certain photometric purposes. When a sector disk is used in connection with photographic work, regard must be had for the so-called "intermittency effect," which renders the ratio not strictly accurate. (L.D.W.)

SEDATIVE. Any therapy that decreases excitement or activity. The main sedative **drugs** that are commonly used are **bromides,** chloral (See **Chloral Hydrate**), **opium** derivatives such as **codeine, morphine,** etc., the barbiturates (See **Purine**), such as amytal, "dial," "allonal," "seconal," "allurate," "luminal," etc., and alcohol.

The chief action of sedatives is obtained by depressing the higher brain centers. The chief sedative measures used, outside of drugs, are hot baths and hot drinks which work principally by drawing blood away from the brain. (R.S.M.)

SEDENTARIA. Chaetopoda.

SEDGE FAMILY. Cyperaceae. This family of **monocotyledons** is composed of grass-like plants which are found chiefly in marshy places. Most of its members are perennials with creeping **rhizomes** and grass-like leaves. The basal portion of the leaf is a sheath which completely surrounds the stem. The stem is generally solid and triangular. The **inflorescence** is a **spike** or a **paniele,** composed of one- to many-flowered spikelets. Each flower, borne in the axil of a bract, has three **stamens** and a single **pistil;** in some sedges there is also a **perianth** of six or many bristles. The fruit is an **achene.** All sedges are wind-pollinated.

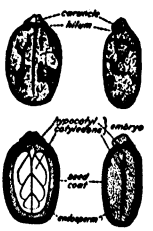
Few of the sedges are of any importance. Some of them yield a coarse hay which may be fed to live stock, and is sometimes used for packing material. **Papyrus,** used as **paper** by the ancient peoples, was made from the stems of *Cyperus papyrus.* The erect stems and leaves of species of *Scirpus* are sometimes dried and woven to form chair seats; chairs finished with this material are called rush-bottomed chairs. The plants are sometimes called bulrushes. Several sedges form tubers which are sometimes used for food. (R.M.W.)

SEDIMENTARY ROCKS. Rocks.

SEDIMENTATION. Filtration.

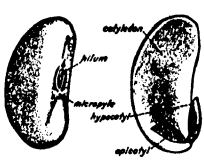
SEEBECK EFFECT. Thermoelectric Phenomena.

SEED. A seed consists of a dormant embryo, together with a quantity of stored food which may be absorbed in the embryo, or may surround it, and one or two seed coats or integuments. The seed develops from an **ovule.** In **Angiosperms** it is completely enclosed by the ovary wall; in **Gymnosperms** it lies exposed on the surface of a scale of the cone.



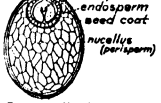
Seed of the castor bean. Above, entire seeds; below, median longitudinal sections.

The fertilized egg develops into the embryo which is a young plant contained in a seed. This embryo may be an undifferentiated mass of cells, as it is in the **orchid** family, but usually is more highly organized. It then consists of a short axis which is called the hypocotyl. At one end of the hypocotyl there is a primitive root called the radicle. At the other end is a terminal bud, called the plumule. This plumule may be nothing more than a small mass of undifferentiated cells, recognizable only as a small bulge at the apex of the hypocotyl, or it may be a well-developed shoot having a short internode and two distinct leaves. Borne laterally at the apex of the hypocotyl there are one or more seed leaves or cotyledons. In many seeds these cotyledons are thin and more or less leaf-like, while in others they are very fleshy, filled with stored food material and form the greater part of the seed. The number of cotyledons varies. In monocotyledons there is usually only one cotyledon, in dicotyledons there are two, and in gymnosperms there are often many.



Bean seed. Left, entire seed; right, embryo with seed coat and one cotyledon removed.

In **Angiosperms** the **endosperm** (See **Flower**) is the tissue which results from the triploid endosperm nucleus. It is a tissue which is rich in stored food materials. The food reserves stored in the seed are **carbohydrates,** especially starches and sugars, **fats** and **proteins.** The latter are present in all seeds, but are particularly abundant in the seeds of the **pea** family. The developing embryo gets its food substance from the endosperm. In many seeds the embryo uses only a part of the endosperm during its development, so that the mature seed contains much endosperm surrounding the embryo. In other plants, the food reserves of the endosperm have been entirely absorbed and re-stored in the embryo, which then becomes very fleshy.



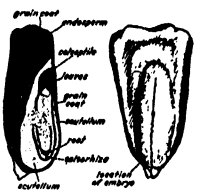
Longitudinal section of a seed of a water lily. (After Conrad from Curtis, *Nature and Development of Plants,* Henry Holt & Co.)

The embryo sac of the ovule is surrounded by a mass of tissue called the nucellus. In most plants this is completely absorbed before the seed reaches maturity.

In some seeds it persists and becomes much enlarged. It is then known as the perisperm, and serves as an additional source of stored food material.

Surrounding all these are the seed coats, which develop from the integuments of the ovule. The outer coat, called the testa, may be variously modified to aid in the dissemination of the seeds. The inner seed coat is the tegmen. In the seeds of many plants there is a fleshy structure called the aril which grows up around and more or less covers the outer integument. In some seeds, the testa produces an outgrowth called the caruncle, which seems to aid in absorbing water from the soil and passing it on to the seed. Passing through the integuments is a minute hole called the micropyle. It is through this that the pollen tube usually enters the seed; the radicle generally points directly towards it. The seed is attached to the ovary wall by a small stalk or funiculus which, when the seed falls off leaves a scar called the hilum on the seed coats.

Once started, the plant must remain fixed in its position throughout its life. In higher plants the vegetative parts are very rarely able to colonize new territories. The fruit, or less frequently the seed, is the part which is carried to new regions. There are several agents affecting this transfer. The most important is the wind. Sometimes the seeds of a plant are very small and light, and so easily carried by the wind. The minute seeds of orchids are carried by this means; in these seeds additional buoyancy is gained by a loose thin case which surrounds the embryo tissue within and acts as a float. In other plants the seeds are carried away by hairs which grow from the seed. Milkweed seeds are provided with a tuft of long silky hairs attached at one end of the thin light seed. Cotton fibers serve the same purpose; they completely cover the cotton seed. In other plants the seed is provided with a wing, a flat thin outgrowth from the seed coats. Catalpa seeds are thus equipped, as also are pine seeds. The distances to which the wind carries seeds is considerable. By this means plants are disseminated over many square miles.



Corn grain. Left, longitudinal section, perpendicular to the broad face of the grain; right, surface view.

Another way in which new land is reached is by ejecting seeds violently from the fruit. When the fruit of the witch hazel is ripe, the dry thick wall of the ovary suddenly snaps and hurls the seeds violently to a distance of many feet. The common Jewel-weed or Touch-me-not scatters its seeds in similar fashion. At maturity the fruit abruptly splits open, and the valves roll back, throwing the seeds many feet away. In similar fashion the pods of many legumes split apart forcefully and scatter the seeds within. Seeds scattered by this means cannot attain the wide dispersal which wind borne seeds do. But they are thrown clear of the region shaded by the parent plant.

A few plants form seeds which float readily on water for some time without harm. Currents of water may carry the seeds, or the latter, floating on the surface, may be blown to new shores. Other seeds are provided with hooks or barbs or have a sticky surface which causes them to adhere to the bodies of passing animals which scatter them. In most plants, however, it is the fruit which is so carried. Such fruits, as beggar's lice, burdock, goldenrod and many others, are commonly mistaken for seeds.

Having reached an environment where suitable conditions exist, the seed germinates. The seeds of many plants must reach such a place in a very short time or perish, since they remain viable but a very short time. Those of the willow, for example, live only a few days after falling from the parent plant. The seeds of most garden vegetables grow best if planted within a year from the time they ripen, though they may retain their vitality for three or four years with decreasing vigor. On the other hand, some seeds lie dormant for a long time before germinating. Seeds of many weeds, including the common ragweed, the cause of misery to many sufferers from hay-fever, may live for years before germinating, making it very difficult to eradicate the plant by pulling it up for a single season. Tests show that the seeds of many plants may remain viable for 20–50 years, though few of them do. It is recorded that the seeds of the Asiatic lotus have germinated after lying dormant for 200 years. But records of viable seeds found in ancient vaults, such as contained the mummies of Egypt, are entirely unfounded.

Certain conditions favor the continued vitality of dormant seeds. Sometimes the seed has a very thick wall which is impervious to water or to oxygen gas, and so excludes the two things necessary to start germination. Until the wall has softened or rotted the seed does not germinate. In other seeds the thick wall resists the pressure of the developing embryo within. Many important crop plants have seeds which germinate slowly because of their thick coats. To hasten germination and to insure a uniform stand of plants the seeds are scarified before planting; that is, the seed coat is rubbed with abrasive substances which break down the impervious wall layers. Often the wall of the seed is sufficiently damaged during mechanical threshing to insure prompt germination when planted. Prolonged soaking sometimes hastens germination.

In other seeds dormancy is inherent in the embryo itself. The embryo may be entirely undeveloped, requiring a long period of slow development before it can break the seed coats. Other seeds germinate only after a period of "after-ripening" which varies from a single winter to many years. The changes occurring during this period are as yet not well understood. The time of "after-ripening" may be considerably shortened by burying the seeds in sand or other suitable material and keeping them cold and moist.

The external conditions necessary to cause germination are adequate water, suitable temperature and oxygen. With some seeds light is an important factor. Most seeds contain very little water, which is one of the reasons why they can survive under adverse conditions such as cold and drought. To germinate they must receive additional water. This added water favors digestion, a process which makes available to the plant the stored food materials. Both water and oxygen are needed by the germinating embryo, because of the great increase in respiration, the process which frees to the plant the energy stored in the carbohydrates and other compounds.

The temperature at which a seed will germinate varies with different plants. For each there is a considerable range of temperature. The lowest temperature at which germination occurs is called the minimum temperature, and varies from 0° to 10° C. or even higher. The maximum or highest temperature at which germination takes place is usually between 45° and 50° C. The most favorable temperature, or optimum, is about 30° C. Light favors the germination of many common plants, such as many grasses and troublesome weeds. Other plants, including many common crop plants, are unaffected by light.

Germination is the development of the embryo into a young plant. It becomes completed when the young plant is independent of the foodstuffs stored in the seed. In most seeds the first visible change is swelling of the seed, which is a result of the increased water content. Often the seed coats are ruptured by the swelling of the contents of the seed. Increased respiration makes available food materials which are carried to those regions where active growth occurs, that is, to the hypocotyl and plumule. The radicle pushes out from the seed coats and attaches itself, by means of root hairs, to the soil

particles It then begins absorbing moisture from the soil In some seeds the hypocotyl elongates considerably, often forming an arch which subsequently straightens, lifting the cotyledons and plumule out of the soil and into the air In other seeds the cotyledons remain permanently underground, the plumule elongating and pushing out into the air There the first leaves of the plant appear With their formation the plant becomes independent

It has been said that man's civilization depended entirely on the seed Until he had learned the value of the seed with its stored food substances man was only a savage wanderer When he learned to use the seed, he was able to adopt a permanent residence, and to devote himself to cultivating crops and storing the products This gave him freedom to think, it also made possible the improvement of his permanent dwellings and their embellishment Even today the main foodstuffs of mankind are seeds, especially those of the cereal grains, rice, **wheat**, **corn**, **barley**, and **oats** But seeds are used in many other ways Many medicinal products are obtained from seeds **Linseed** oil, **soybean** oil, and **coconut** oil are but a few of the many oils which come from seeds **Poppy** seeds, caraway seeds, and mustard add flavor to other foods Clothing is made from the hairy covering of the **cotton** seed Beads, buttons, and ornaments of various kinds are also often made from seeds (R M W)

SEED-FERNS Paleobotany.

SEED SNIPE. Aves, Charadriiformes South American birds (**Aves**) resembling quails but classed as intermediate between the true snipes and the gulls They are closely related to the sheath-bills (A W L)

SEEING. When meteorological conditions are such that the atmosphere is very steady (i e, the atmospheric density decreases with perfect uniformity with increase in height, and there are no strong air currents) the image of a star as seen in a telescope will be a perfectly round disk and very steady The diameter of the disk depends upon the aperture of the **telescope**, being smaller the larger the aperture of the instrument

When the atmosphere is unsteady the variations in the **refraction** produce a number of effects on the star images The images become soft and "fluffy," jump around in the field of view, and are subject to abrupt changes in color These irregularities in the star images are known as bad seeing Bad seeing is evident to the unaided eye in the twinkling of the stars When the stars are twinkling strongly the seeing is bad

The statement is frequently made that the **planets** do not twinkle In a sense this statement is true, for to the naked eye the planets do present much more steady images than do the stars Every point in a planet does twinkle, however, but a planet is made up of a great many such points, since it presents a disk of finite size to the eye The integrated effect of the twinkling of the individual points in the disk is not apparent to the unaided eye In the telescope, when an attempt is made to study individual points on the image of the planet, bad seeing produces such blurring as to make good observations impossible

Bad seeing is almost as fatal to most types of astronomical observing as actual clouds Accordingly, in selecting a site for an observatory, expeditions are dispatched to various sites for the purpose of testing the seeing That site is selected where the seeing averages the best over a long period of time (W K G)

SEGER CONE. A series of substances having different fusion temperatures might serve roughly to measure the temperature of high-temperature regions such as **furnaces**, since, with a series of substances having progressively increasing fusing temperatures, the temperature naturally lies between the fusion temperature of the last substance fused, and that of the next not yet fused. A series of artificially prepared mixtures, mostly of the oxides such as clays, lime, feldspar, have been designed to form a series of "Seger cones" There are sixty mixtures covering a temperature range from 590° to 2000° C. The variation in fusion temperature between cones of adjacent serial numbers ranges from 20° to 30° C Such cones have some pyrometric value as control indices in the ceramic industry, and in any case where exact determination of temperature is not necessary, but some simple, inexpensive means for approximating the temperature is desirable It is apparent that it is necessary to estimate what the temperature to be measured is in order to select the cones for use

The Seger cones are triangular pyramids about ½ inch on each side of the base, and 2 inches high In use, the temperature is estimated, and four cones of consecutive serial numbers which are thought to include the temperature to be measured are placed on a refractory slab and inserted in the high-temperature region If the cones have been properly selected, they will exhibit a range of behavior in the furnace varying from complete fusion of some to others remaining unaffected One will soften until its tip bends over to touch the base, and that one is taken as indicating the temperature (F T M)

SEISMOGRAM. Earthquakes.

SEISMOGRAPH An instrument for recording earth tremors, usually housed for the purpose in a suitable seismological observatory There are two classes of seismograph, one for recording horizontal and the other for recording vertical components of vibration A well-equipped observatory has three, a north-south horizontal, an east-west horizontal, and a vertical recorder The instruments are somewhat complicated, but the principle is that of a heavy mass poised in such a way that a vibration of its support, together with the inertia of the mass, causes a relative motion of mass and support, and this motion, suitably amplified, produces the record In the older forms the recording was done mechanically by a stylus tracing on a revolving drum, in more modern types an electromagnetic current, generated by the motion, operates a **galvanometer** which, by means of a beam of light reflected from its mirror, produces a photographic record of the earth's vibration on a moving film See **Earthquakes.** (L D W)

SEISMOLOGY. Earthquakes.

SEISMOMETER. Earthquakes.

SEISMOSCOPE. Earthquakes.

SEISONIDEA. Rotatoria.

SELACHII. The **sharks** and **dogfishes** A term applied in various classifications to a subclass of the class **Pisces** and to a suborder of the order Plagiostomi as used in this work (A W L)

SELAGINELLA. Lycopodiales.

SELECTED AREAS. To determine the form, extent, and general characteristics of the **sidereal universe** as a whole, knowledge of the **magnitudes**, **spectral types**, and other characteristics of all of the stars would be necessary To solve completely a problem of such magnitude is obviously impossible, and the process of statistical discussion becomes necessary In any problem of statistical analysis a sampling of the material under consideration is necessary For this purpose, Prof J C Kapteyn, a Dutch astronomer, proposed in 1906 a group of 206 "selected areas" distributed all over the sky in accordance with statistical theory, and requested international cooperation in the determination of the characteristics of all stars in these areas During the past thirty years a large amount of work has been done on

these selected areas, and from a stat st cal d scussion of the results most of our information regarding the structure of the sidereal universe has been obtained. (W K G)

SELECTION. A process controlling the reproductive sequence within a **species** either by preserving only a part of the included individuals or by limiting the range of their opportunity for mating The latter process tends to split the species up into different groups

The term applies to certain theories of **evolution**, including natural selection and sexual selection, and to methods of improving domestic animals and plants Most of the varieties of domestic animals have been produced in this way, and the method is supplemented only by hybridization in the production of new breeds

The simplest application of the process is mass selection, consisting merely of the preservation of the more desirable individuals as breeding stock Although mass selection is effective and has, indeed, been the original source of many varieties of domestic animals, modern knowledge of heredity shows that it is a relatively crude method Line selection, based on the study of progenies of single individuals, is a much more exact method of improvement With the refinements made possible by modern genetics it discloses with reasonable precision the hereditary potentialities of the parents and makes possible the establishment of genetically pure strains embodying characters desired by the breeder (A W L)

SELENIUM. Symbol Se Atomic number 34 Atomic weight 78 96 Density red 4 50, gray 4 84 Hardness 2 Melting point gray, crystalline, 220° C Boiling point 690° C Isotopes 74 (0 9%), 76 (9 5%), 77 (8 3%), 78 (24 0%), 80 (48 0%), 82 (9 3%)

Selenium exists in several **allotropic** forms, (1) crystalline red selenium alpha and beta, separating in **monoclinic** crystals from solutions of vitreous or amorphous selenium in **carbon disulfide** The transformation temperature into metallic gray selenium B is 110°–120° C for the alpha and 125°–130° C for the beta, (2) crystalline gray selenium A, formed by heating the vitreous form to 175° C, and changes gradually into metallic gray selenium B, (3) metallic gray selenium B, insoluble in carbon disulfide, and produced when the other forms are heated to 200° C, metallic luster, malleable, a **conductor** of electricity in proportion to the intensity of the incident light **Nitric acid** and **aqua regia** dissolve selenium to form selenous acid, attacked by cold concentrated **sulfuric acid** to form a green solution which precipitates free selenium upon dilution with water Discovered by Berzelius in 1817

Selenium is used as a decolorizer of glass to counteract the green **ferrous** shade, as selenium or sodium selenite to produce clear red glass, and for red enamels on ceramic ware and steel ware, in vulcanized rubber—the presence of 1%–3% selenium notably increased the resistance to abrasion Selenium is not poisonous, but many of its compounds are exceedingly toxic

Selenium occurs as selenide in many sulfide ores, especially those of **copper**, **silver**, **lead**, and **iron**, and is obtained as a by-product from the **anode** mud of copper refineries, and the lead chamber mud of sulfuric acid plants The mud is (1) fused with **sodium** nitrate and **silica**, or (2) oxidized with nitric acid, and the water extract is then treated with **hydrochloric acid** and **sulfur** dioxide, whereupon free selenium is separated Chemically related to **tellurium**.

Acids. Selenous acid (H_2SeO_3), soluble, forms metallic selenites; with hydrogen sulfide forms free selenium and **sulfur** which becomes red on heating, is oxidized by **potassium** permanganate to selenic acid, selenic acid (H_2SeO_4), soluble, forms metallic selenates, less stable than selenites

Chlorides Selenium monochloride, **selenium** dichloride (Se_2Cl_2), brown liquid, boiling point **130°** C, selenium tetrachloride ($SeCl_4$), yellowish-white **solid**, sublimes at 305° C; selenium oxychloride ($SeOCl_2$), yellowish liquid, boiling point 177° C

Hydride Selenium hydride, hydrogen selenide (H_2Se), gas of unpleasant odor, chemically related to **hydrogen sulfide**, hydrogen **telluride**, and **arsenic** hydride (arsine), formed by reaction of selenide with dilute hydrochloric or sulfuric acid

Oxide Selenous oxide (SeO_2), white solid, sublimes at 317° C to yellowish-green vapor, soluble in water to form selenous acid

Selenides Metallic selenides are formed by combination of selenium and the metal, or by precipitation of the metallic salt solutions with hydrogen selenide

Numerous organic compounds of selenium have been prepared (R K S)

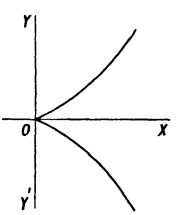
SELENIUM CELL Photoconductivity.

SEMAEOSTOMEAE. Scyphozoa

SEMEN The thick grayish-white secretion of the testicles that contains the **spermatozoa** or fertilizing male cells It is secreted by the testicles, stored in the seminal vesicles, and ejaculated through the penis in intercourse or during nocturnal emissions. (R S M)

SEMICARBAZIDE Amines and Amides.

SEMI-CUBICAL PARABOLA. The semi-cubical parabola is a mathematical curve which is defined as the **locus** of the equation $ay^2 = x^3$ in rectangular coordinates, its form is shown in the accompanying figure (L L S)



Semi cubical parabola

SEMI - LOGARITHMIC PAPER Logarithmic Paper.

SEMINAL VESICLE. An expanded portion of the genital duct of the male, or a pouchlike derivative of the duct, either for the storage of spermatozoa or the secretion of accessory substances Structures of this kind are well developed in the **annelid** worms, the **arthropods**, and the **vertebrates**. Often known by the latinized term *vesiculae seminales* (A W L)

SENILITY. The gradual decrease of physical and mental function that accompanies old age In most cases this is directly due to general diminution in the circulation to organs and tissues of the body This varies according to the degree of hardening of the arteries, which in some people occurs earlier than in others The age at which senile symptoms begin to appear depends on **heredity** and the amount of abuse and illness that the body has been exposed to during life (R S M)

SENSE ORGANS. Structures in the animal body which are influenced by certain factors in the environment Also known as receptors The action of the environmental factor on the living substance is known as a stimulus It results in the transmission of a **nerve impulse** to some nerve center and from this point may influence appropriate reactions of the animal or may be stored in memory Special sense organs are found only in animals with **nervous systems** Their development involves high specialization in some phase of the general property of living matter called irritability, and to some extent this property persists in all living tissue, whether nervous or sensory or not

Stimuli arise from contacts with solid objects, from chemical compounds, either dissolved or in the gaseous state, from the incidence of light rays, and from factors

which damage the body. We know from various evidences that some animals perceive factors to which our own organs are not sensitive, but as far as we can know, the only stimulating factors are in these several groups.

Contact results in variable pressures to which organs of several kinds are sensitive. In vertebrates **tactile corpuscles** and other similar structures located in surface tissues may be classed as organs of touch. They are sensitive to simple pressure and give rise to images of form through the varying pressures due to uneven surfaces and gross contours. Since sound waves are due to rhythmic compression of the air, the ears and other **auditory organs** such as those of insects are also sensitive to pressures, but only to fluctuations of relatively high frequency (in man 30 to 30,000 per second). Between auditory organs and simple organs of touch are the **lateral line organs** of fishes and the **chordotonal organs** of insects, both related in some anatomical details to the auditory organs of the groups to which they belong. These organs are supposed to be sensitive to fluctuating pressures of lower than auditory frequency.

Tactile organs are also closely allied to sensory organs of bats and insects which apparently enable them to avoid obstacles when flying. Supposedly these organs are sensitive to the changes of air pressure, often extremely delicate, resulting from approach to objects. They are located in the wings of insects and in the wings, external ears, and snout of the bats.

Dissolved substances stimulate organs of taste and gases or vapors act on organs of smell (**olfactory organs**). In the vertebrates the olfactory organs are associated with the nasal passages or occupy a similar position; nasal structures of fishes are limited to the olfactory function. Vertebrate organs of taste are known as **taste buds** and are located in the oral cavity principally, although aquatic forms may have them also in the skin. Sensory organs of this class in the invertebrates are extremely varied. Some are known as **sensillae**. In addition to organs of taste and smell a general chemical sense is recognized. It is resident in various surface layers and is the least sensitive of the group. These sense organs are known collectively as chemoreceptors.

The varied integumentary sense organs of the human body are known to include some sensitive only to heat, cold, or pain. These organs may be the free nerve endings found in the skin. It has been suggested that pain may also result from overstimulation of other types of sense organs.

Sense organs that are stimulated by light are familiar to us in our own **eyes**. From this stage of complexity they range downward to simple light-sensitive cells. The transition includes organs capable of perceiving fluctuations of light, the direction from which it comes, and movements, as well as organs which form images in varying degrees of precision.

In contrast with sense organs of the kinds mentioned, which are classed as exteroceptors, the body contains others called interoceptors. They are the source of sensations of hunger, thirst, nausea, and pain. Other interoceptors in the muscles, joints, and tendons are associated with the maintenance of equilibrium and are classed as proprioceptors. They are probably subject to varying pressure due to tension of muscles and shifting of the weight of the body. The semicircular canals of the inner ear of vertebrates are also organs of equilibration.

Organs of many invertebrates, such as the **tentaculocysts** of jellyfishes, can be interpreted only by experimental evidence. By testing the animal with different stimuli definite conclusions can often be drawn from its reactions. In most cases there is evidence of functions like those of our own sense organs.

All sense organs consist of nerve endings associated with various specialized cells or tissues. The nerves are not limited to one type of stimulation but their response may be identical under various stimuli. Thus a mechanical shock to the eye produces a sensation of light. The nerve fibers leading from the sense organ toward the central system are sensory or afferent. (A.W.L.)

SENSILLAE. The sense organs of **insects**. The term is usually applied to the **integumentary** sense organs of the group but it is also extended to include the **scolophores** on which organs of hearing and chordotonal organs are based, and the **ommatidia** and **retinulae** of the eyes.

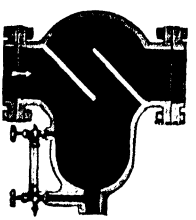
The sensillae of other kinds include some form of cuticular structure, often a projection, associated with a nerve ending and in some cases with gland cells. These organs include some of tactile function and chemoreceptors, both of taste and of smell. In form their external parts are classed as six types: (1) Placoid sensillae end in a thin porous plate or membrane covering a canal. (2) Trichoid sensillae end with a slender **seta**. (3) Basiconic sensillae have a conical protuberance. (4) Styloconic sensillae have a fixed conical base bearing subordinate projections. (5) Coeloconic sensillae end with a depression containing a conical projection. (6) Ampulliform sensillae end with a slender projection in an expanded chamber at the inner end of a long tubule.

Tactile sensillae are distributed over the entire body but are often much more abundant on the legs and sensory appendages such as antennae and palpi. Organs of smell are often abundant on the antennae and in some species appear to be limited to these appendages. There is some possibility that they may occur on other parts of the body. Organs of taste are undoubtedly associated with the mouth parts, but they are supposed to be present in aquatic insects on the outer surface of the body as well. (A.W.L.)

SENSITIVE PLANT. **Movement in Plants.**

SEPALS. **Flower.**

SEPARATOR. The steam separator is used very widely to remove water from steam. Absolutely dry and saturated steam is a rarity. It is desirable in many cases to have saturated steam, as delivered by the boiler to the prime mover, as dry as possible. Wet steam causes **engine** knocks. When accentuated by slugs of water from the **boiler**, or from pockets in the steam line, this trouble may be severe enough to knock out cylinder head blow-out plugs. In a **turbine** the damage is blade erosion, even more serious because the damage usually is done before it is suspected. Wet steam not only erodes blading, but also may deposit on it the solids which it has carried from the boiler water. The steam separator is installed to prevent all this. Even when the boiler normally produces a nearly dry steam the separator may be needed, because were high water accidentally carried, or foaming and priming started, the separator would be indispensable. The principles upon which separation is used are: (a) reverse current, (b) centrifugal force, (c) wet baffles. The separator should provide for an enlarged path for the steam since it has been found that separation is more effective at lower steam velocities.



Separator.

Exhaust steam lines from engines and reciprocating steam pumps contain considerable oil as a result of the method of lubricating such equipment. If this steam is to be used in heating systems, to heat feed water, or for industrial processes, the oil content is objectionable. Therefore the oil

separator, built much on the same principle as the steam separator, should form part of the exhaust line from such equipment (F T M)

SEPIOLITE. The mineral sepiolite or meerschaum is soft, white, light in weight, and occurs in clay-like masses It is a complex, hydrous **magnesium silicate** corresponding to the formula $H_4Mg_2Si_3O_{10}$ It appears to be amorphous, hardness, 2 -2 5, specific gravity, 2 , color, white, grayish white, sometimes a yellowish or bluish green, opaque It is capable of floating on water, hence the name meerschaum or sea foam It occurs in Asia Minor associated with **serpentine** and **magnesite**, and may be derived from the latter Other deposits are in Czechoslovakia, Morocco, and Spain, and in the United States in Pennsylvania and New Mexico. The name meerschaum is from the German Sepiolite is from the Greek, meaning *cuttlefish*, referring to the similarity of the bone of that animal to the light, porous sepiolite (E S C.S)

SEPSIS. Poisoning by **bacteria** and their **toxins** in the **blood**, accompanying an acute infection of some portion of the body. The process is accompanied by fever and severe constitutional symptoms (See **Septicemia**) (R S M)

SEPTARIUM. Concretion.

SEPTIBRANCHIATA. Lamellibranchiata.

SEPTICEMIA. An acute febrile condition in which **bacteria** or other micro-organisms are present in the **blood** stream Septicemia may be due to a variety of organisms The most common organisms producing this condition are one of the varieties of the **Streptococcus**, the **Staphylococcus**, pneumococcus, and colon bacillus Less common are the gonococcus, meningococcus, gas bacillus, bacillus of anthrax, diphtheria, and the influenza bacillus In septicemia the organisms can be isolated from the patient's blood by means of blood cultures.

Septicemia is primary when it occurs as an independent disease, secondary when it occurs as a complication of an infectious disease, such as scarlet fever, erysipelas, etc It is a common disease and one with a very high mortality It usually means that an infectious process is no longer localized to a single part but is spreading The predisposing causes of septicemia are any situation or chronic disease that lowers or weakens the resistance of the body Exposure to cold and wet, fatigue, chronic loss of sleep, and chronic alcoholism are among the most usual predisposing causes The virulence and number of infecting organisms play a definite part as to whether an infection will remain localized or will spread

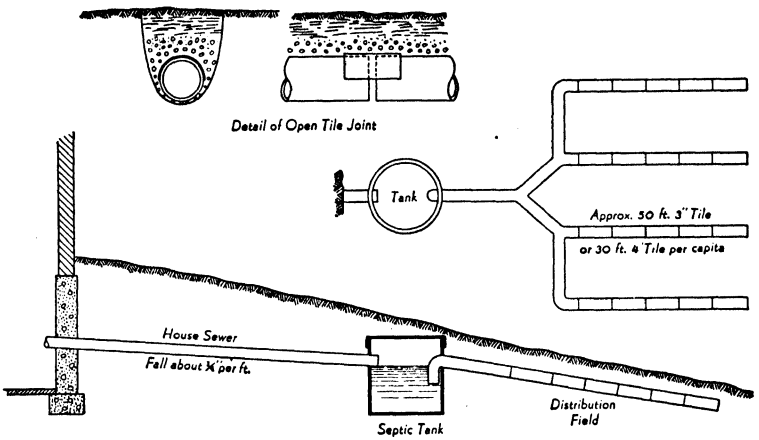
Infection most commonly begins by gaining entrance through the skin Such processes may begin as boils, carbuncles, infected blisters, or any infected wound following injury Next in frequency is **puerperal fever** and septic **abortion** Certain other portions of the body may serve as the portal of entry such as the tonsils, from which septicemia may develop following septic sore throat, scarlet fever, diphtheria, or fulminating cases of acute tonsillitis The lungs may initiate a septicemia in certain forms of pneumonia The ear, as occurs with mastoiditis, the appendix, infected teeth, the veins, as in **phlebitis**, the bones, as in **osteomyelitis**, all may initiate septicemia

The symptoms and treatment of septicemia depend largely on the type of infecting organism The symptoms in general vary according to the acuteness of the disease, thus in the fulminating type, death may occur in a few days The acute form may persist for several weeks, however, and the chronic type of septicemia may last for many months. With sepsis or septicemia, a fluctuating persistent fever is always present Often the temperature may vary as much as six or seven degrees in a day. The patient is acutely ill and weak. Shaking chills and drenching sweats are accompanying characteristics of the disease. If the nervous system is markedly involved, coma, stupor, or even convulsions result The pulse rate increases as weakness develops. There is a tendency in cases of sepsis toward a progressive anemia, necessitating frequent blood transfusions, which are one of the most valuable forms of treatment in this condition Often the joints may become involved, becoming tender and filling with fluid, and at times suppuration occurs, necessitating drainage of the pus The skin is frequently involved in rashes, which may be pustular or hemorrhagic The spleen is constantly enlarged and **albumin** appears in the urine Other complications of septicemia depend on the particular organ or system affected

Treatment in general depends on drainage or removal of the original focus of infection, together with surgical treatment of any secondary foci that may develop Repeated transfusions are very important, sometimes changing the entire course of the disease The use of serums depends on the causative organism Vaccines are of no use in acute sepsis No chemical or drug has, up to the present, proven of general use when injected into the blood stream In certain forms of septicemia, **sulfanilamide** has been used with success

The mortality is often quite high in this grave condition Best results are obtained with early surgical treatment of the original focus of infection, when this is possible (R S M)

SEPTIC TANK. Septic tanks are water-tight compartments generally used for the disposal and purification of residential **sewage** The tanks are made of concrete or steel In the simplest form a septic tank is a circular steel tank of 200 to 600 gallons capacity, fitted with a lid, and with openings for sewage inlet and effluent outlet The outlet will be baffled so that liquids are drawn from below the surface level to prevent floating solids entering the disposal field The operation of a septic tank depends on the action of bacteria which convert the solids into liquids, and purify the liquid The wastes of residences served by septic tanks are conducted to them by soil pipe buried in the ground The septic tank is also buried, in fact, no part of the sewage system need appear above ground The raw sewage enters the tank from the intake and settles to the bottom A thick scum forms on the surface, and effectively shuts off the contents from oxygen **Anaerobic bacteria**, which live and thrive only when shut off from air, act upon the suspended matter and convert it into liquids and gases The gases are discharged either from a septic tank vent, or back through the sewer pipe to the house vent The liquids overflow through the outlet into a disposal field, which is a branching pipe system of drain tile laid with open joints, so that the effluent may be leached into the soil Anaerobic bacteria act upon the effluent here to purify by a process of oxidation The purification of sewage by this method is entirely automatic in character, and the system needs no addition beyond occasional cleaning of indigestible solids from the bottom of the tank, or from the disposal field The septic tank is susceptible of more scientific design than is incorporated in the example just described, but the refinements are not generally considered warranted except for extremely large residences, institutions, or factories However, where built, the large septic tank is usually of a two-compartment type, in one of which the settling and anaerobic action take place, and from the other, the effluent is discharged intermittently by special siphons to the drainage field The intermittent operation permitted by the siphon is much better from the standpoint of disposal of the effluent in a tile field, because when it discharges it floods the field and distributes to all portions, whereas the small outflow from a simple type septic tank is likely to be distributed mainly to one portion of



Septic tank installation.

the field, which is thereby liable to become clogged. The intermittent dosing of the disposal field, and the two-compartment arrangement of the septic tank, permit more sewage to be handled for a given tank volume.

Some of the older municipal sewage disposal plants still make use of the septic tank, which is a horizontal rectangular tank through which the raw sewage is allowed to flow slowly. The solids settle to the bottom, where they are partially reduced to liquids and gases by anaerobic action similar to that which takes place in the residential septic tank. The liquid sewage is discharged at one end while the **sludge** is allowed to accumulate in the bottom of the tank. This sludge is removed periodically by completely emptying the flat-bottom type of septic tanks or by means of sludge discharge pipes in the case of hopper bottom tanks. Occasionally the effluent of septic tanks will contain as much suspended matter as the influent due to the disturbance of the sludge caused by septic action. The Imhoff tank is preferred for modern installations, since it eliminates this unsatisfactory condition. (F.T.M.)

SEPTUM. A thin wall or partition. The term is applied to the radiating plates on the foot of the coral **polyp**, to the transverse partitions which subdivide the body cavity of the **annelid** worms into chambers, and to the partitions between chambers of the shell of **Nautilus**, among the invertebrates. Its most familiar use among the vertebrates is to designate the nasal septum which separates the right and left nasal passages, although it applies also to the partition between the right and left chambers of the heart and to numerous other structures. (A.W.L.)

SEQUESTRUM. A piece of dead bone that separates from the sound bone. This frequently occurs in chronic infections of bone as in **osteomyelitis**. (R.S.M.)

SEQUOIA. Paleobotany.

SERIATE FABRIC. A geological term proposed by Cross, Iddings, Pirsson, and Washington in 1906 for the texture of an **igneous rock** whose granular crystals form a complete gradation in size. (R.M.F.)

SERICITE. Muscovite.

SERICITIZATION. Sericite.

SERIEMA. Aves, Gruiformes. *Cariama.* Peculiar South American birds (**Aves**) of several species. Their relationships are doubtful. They have long legs and moderately long necks, with a broad beak, slightly hooked. These birds live in open country and eat small animals and insects. (A.W.L.)

SERIES, INFINITE. Infinite Series.

SERINE. Aminoacids, Polypeptides, and Proteins.

SEROSA. 1. A thin membrane enveloping the developing **embryo** of terrestrial **vertebrates** (reptiles, birds, and mammals) and all of the other **extraembryonic membranes.** It is covered with ectoderm and lined with mesoderm, and in many species is formed simultaneously with the **amnion** as the outer layer of the amniotic folds. It becomes the outer component of the **chorion** and contributes to the formation of the **placenta** of mammals.

2. The lining membrane of any one of the great splanchnic or **lymph** cavities of the vertebrate body. (A.W.L.)

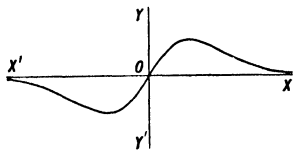
SEROTINE. Bat.

SEROUS GLAND. A gland that produces a watery secretion, in contrast with **mucous glands**, whose secretions are composed of or contain mucus. The term is used in connection with the salivary glands of **vertebrates**, which are partly serous and partly mixed. The serous gland cells are distinguished in part by their more granular **cytoplasm** and rounded **nucleus**, located near the middle of the **cell.** (A.W.L.)

SEROW. Mammalia, Artiodactyla. *Capricornis.* The name of animals of several species peculiar to eastern and southeastern Asia. They occur in hilly or mountainous country, sometimes at an altitude of 12,000 feet, and are related to the gorals and goats. They are also called goat-antelopes. (A.W.L.)

SERPENT. Synonym of **snake.**

SERPENTINE. In mathematics, the serpentine is a plane cubic curve whose equation in **rectangular coordinates** is $x^2y + b^2y - a^2x = 0$



Serpentine

In mineralogy, serpentine is a hydrous **silicate of magnesium** corresponding to the formula $H_4Mg_3Si_2O_9$ It is a secondary mineral resulting from the alteration of magnesium-bearing silicates such as **enstatite, hypersthene, olivine,** etc, and possibly from the reaction between **feldspar** or other such silicates and waters bearing magnesium Serpentine forms granular, fibrous, or **foliated** masses occurring as veins, or as rock masses, the latter often mixed with **calcite, dolomite,** or **magnesite** showing delicate clouded tints of green This variety is known as verd antique or **ophicalcite,** and is used as an ornamental stone Serpentine is found only as **pseudomorphs,** but with **monoclinic** crystalline structure Its fracture is usually conchoidal, sometimes splintery, hardness, 2 5-4 , specific gravity, 2 50-2 65, luster, greasy, pearly dull, color, usually dark green but may be reddish or yellowish brown, translucent to opaque Serpentine is very common and of world-wide distribution There are many localities in Europe and North America Decorative verd antique is obtained from Roxbury, Vermont The name serpentine is derived from the twisting, serpentinous markings of the ophicalcite varieties Besides the use of serpentine as an ornamental stone, much of this mineral is used in the manufacture of heat insulation materials (L L S, E S C S)

SERUM. (1) The clear liquid of the blood, left after separation from the blood of its cells (2) Blood serum of animals or human subjects who have been inoculated against a specific bacteria or their toxins Such serum contains antibodies or **antitoxins** which, when injected into a subject, immunize against a specific disease, or aid in their antibody or antitoxin content in overcoming the disease

Convalescent serum is serum from a patient who has recovered from a disease, which is used in the treatment of the same disease in another person, either prophylactically or during the disease This is specially successful in measles

The serums that are commonly used are diphtheria antitoxin, the pneumonia serums, tetanus antitoxin, meningococcus, and anthrax serum, etc

Pooled serum is mixed serum from a number of individuals

Polyvalent serum is serum obtained by inoculating an animal against several strains or varieties of an organism (R S M)

SERUM ACCIDENTS. Immediate, shock-like reactions which may rarely produce death and occur in individuals highly sensitive to horse serum They are seen most often in individuals who are subject to hay fever or **asthma** Some persons may become sensitized from a previous injection of serum from the same kind of animal (See **Anaphylaxis**)

The active portion of serum that causes the reaction is the **protein** A person who is sensitive to horse serum from a previous injection of the same serum will tolerate, without reaction, an injection of serum from another animal, such as goat serum Recently refined, concentrated serums have been produced from which certain protein substances are reduced to a minimum

The onset is usually immediate upon injection of the serum—generalized **hives, edema** of face, hands, neck, difficulty in breathing, convulsions, circulatory failure—all or any of these symptoms may occur

Before he is given serum a patient should always be tested for sensitivity to it, by a skin test If the patient is sensitive the serum is administered in a special way, starting with fractional dilute doses given in dilute form, gradually increasing the amount This may require twelve to twenty-four days Often it is a good practice to give **adrenalin** by hypodermic injection before giving the serum, as this extract is a specific against serum accidents (R S M)

SERUM DISEASE. An **allergic** reaction that occurs in certain individuals after the administration of foreign blood serum This reaction in some form occurs in about 10% of those treated with small amounts of serum The percentage increases with the amount of serum given

The symptoms of serum sickness begin six to twelve days after the injection of the serum The onset is marked by intense itching and the presence of hives The skin eruption may be varied and lasts from one to three days The temperature may or may not be elevated, the lymph glands are usually slightly enlarged Arthritic symptoms are often present **Edema** of the face, ankles, and hands may occur

This serum reaction cannot be prevented and only symptomatic relief can be given when it occurs, but fortunately the condition is not serious (R S M)

SERVAL Mammalia, Carnivora An African **cat,** *Felis serval* The animal reaches a length of five feet and is light tawny, spotted with black (A W L)

SESAME OIL. **Fixed oils.**

SETA. Any slender bristle-like structure The term is usually limited to the hairlike processes of the integument of invertebrates, of which the setae of **annelid** worms are a good illustration These structures are formed of **chitin** secreted by cells of a pocket in which the base of the seta is lodged They are also called chaetae Setae gain high development among the **insects** Here they are secreted by cells of the **hypodermis** and project from the surface of the cuticula They vary in form from slender hairlike structures to broad flat scales like those of **butterflies** and **moths** In some cases they are associated with sense organs or glands. (A W L)

SETTING. This word is commonly used among **boiler** artisans to refer to the brick work which encloses the furnace, and partially encloses the boiler itself Originally this was probably derived from the fact that the **furnace** walls were built, and the boiler set on the brick work The best modern practice in settings, however, attempts to eliminate boiler supports of that type in favor of independent suspensions because of the unequal rates of expansion of steel and masonry The boiler setting consists chiefly of walls of a compound type, having **refractory** brick on the hot side, and common brick or steel casing on the exterior, or cool, side Many types of setting walls are in use today. There are the solid masonry walls which range from a single homogeneous refractory section to one containing special **insulation** between the refractory lining and the exterior casing This is a common type for steam generating units Some setting walls are hollow The air-cooled wall consists of a thin refractory section backed by an air space through which circulate currents of cooling air Obviously an excellent feature of this construction is that the heat flow which cools the refractory lining may be returned to the furnace by using the cooling air for combustion Often in settings of this type sections of the setting must be independently supported from a steel or iron skeleton, from which the **bricks** are hung Many patented ingenious methods of doing this have appeared, and in the main this is the

field of the proprietary setting In some cases the setting has been partially protected from high temperature by covering a portion of it with water-bearing tubes This tends to maintain the setting at a lower temperature

In brick work settings it is necessary to provide for expansion, horizontally and vertically, with joints in the different layers overlapping so as to avoid cracks and infiltration of air The setting often includes not only the enclosure of the furnace, but virtual enclosure of the boiler itself, which means that different parts of the setting work at widely different temperatures The brick work is laid with thin joints in a refractory mortar The exterior surface should be finished for a minimum of heat radiation from it, while the interior should be able to resist high temperature conditions, thermal expansion, spalling, and the action of slag and clinker (F T M)

SEVENTEEN-YEAR LOCUST. Insecta, Homoptera A **cicada**, *Tibicina septendecim*, which requires seventeen years to complete its development from egg to adult The eggs are deposited in slits cut deep into the wood of twigs After hatching, the young drop to the ground and burrow, feeding on rootlets during their subterranean life When ready for their transformation into the adults, the **nymphs** leave the ground and climb some plant, where their dry skins can be found after the adults have emerged The deposition of eggs weakens the twigs and sometimes causes heavy damage in young orchards Although various broods occur which may overlap, the usual appearance of large numbers is infrequent By consulting local entomologists the orchardist can learn when to plant trees to avoid trouble Otherwise young trees can be protected by covering them with cheap cloth

A variety whose life cycle is completed in thirteen years occurs in the south. It is otherwise similar. (A W L)

SEWAGE. Sewage is a liquid composed of waste from such sources as domestic dwellings, commercial buildings, and factories, together with any ground or surface water which may enter the sewerage system The average composition of sewage is over 99% water, the solid parts being composed of grease, fats, animal and vegetable matter, both dissolved and undissolved, and some inorganic matter It is ordinarily swarming with **bacteria** which, in their ability to destroy dead or organic matter, become active agents in the process of purification Among the bacteria there may be many of a virulent and dangerous nature, making it essential for the sake of general health to practice scientific disposition of the sewage (F T M)

SEWELLEL. Mammalia, Rodentia The mountain beaver or **boomer** A broad stout animal with short legs, found in mountain forests of the western states It is a burrowing species which feeds on bark, twigs, and leaves More closely related to the squirrels than to the beavers (A W L)

SEWEN. Pisces, Teleostei A **trout** found in the rivers of Wales (A W L)

SEWERAGE SYSTEM. The term sewerage system refers to any system for the disposal of sewage A sewerage system usually consists of sewers and the necessary auxiliaries for the purification and disposal of the effluent As sewage is a foul liquid, it must be carried in water-tight underground conduit systems known as sewers A sanitary sewer is one devoted entirely to carrying sewage, and does not receive storm water In a municipality, where a central sewer system serves a large group of homes, industrial buildings, and business houses, the building sewer is connected to a lateral sewer which discharges into a street conduit, called the main or submain The later discharges into an outfall sewer, which carries the sewage to the disposal plant As the average per capita use of water is often assumed to be 50 gallons per day, the sewage load will be from 50 to 70 gallons per capita per day The lateral and main sewers are composed of cast iron or terra cotta pipe with tight joints The outfall sewer, being larger, is often made of masonry Sewerage works are plants which receive sewerage and convert it into an effluent which may be wasted without becoming a nuisance or a focal point of infection

A simple method of sewage disposal is described under the head of **septic tank**, but this system is not suitable for central sewerage works by virtue of its imperfect operation and its bulk per capita Oxygen is a very important factor in converting sewerage into a safe liquid The oxidizing of sewerage takes place either by the **dilution** process or by **aeration** or filtering Often the discharge of a municipal sewerage works takes place into a nearby stream or river, in which case the dissolved oxygen in the water effects the oxidation required for complete breakdown of the solids Disposal to a subsurface drainage field, which constitutes a filter, is illustrated by the tile disposal field, which is an essential part of the septic tank system Aeration of sewage is illustrated by the activated sludge process The principal equipment for sewerage works might be briefly enumerated as follows screens, or racks, for the removal of floating matter, sedimentation tanks for the removal of solids by gravity, **Imhoff** tanks, and activated sludge chambers In the last mentioned system, the conversion of the solids in sewage is carried out by forced aeration Anaerobic bacteria are supplied in large quantities by recirculating to the incoming sewage a considerable amount of sludge, which contains large growths of these bacteria. This system is rather extensively used where dilution cannot be practiced, since the effluent is not foul The operating costs of the activated sludge process are likely to be rather high, because of the necessity for compressing the air for aeration (F T M)

SEX. The state of an individual as determined by its adaptations for a special part in biparental reproduction and modifications of the process Also a category of individuals adapted for a special part in reproduction The usual sexes are male and female Neuter individuals exist among colonial invertebrates, including both sexless forms and abortive females whose limited reproductive powers are not exercised under normal conditions Sex is also expressed in hermaphrodite animals which carry on the usual processes of sexual reproduction but have male and female organs in the same individual

The differentiation of the sexes is associated with the development of two kinds of **gametes** in the process of sexual reproduction Organs and ducts capable of producing the larger egg cells of the female and providing them with quantities of food material make up a **reproductive system** much different from that which produces the minute male spermatozoa and the seminal fluid in which they are discharged The development of the external genitalia for internal insemination also results in conspicuous differences since the male has a projecting penis or other **intromittent organ** while the female has the terminal portion of the genital ducts specialized for the reception of this organ In the mammals the **mammary glands** of the female also constitute a conspicuous sexual distinction These organs may be classed as essential and accessory organs of reproduction, the former category including the **gonads** and ducts and the latter such parts as the external genitalia and the mammary glands.

Sexes also differ in more or less conspicuous **secondary sexual characters** such as the beard of man, which are definitely associated with sex but have no direct part in reproduction

The sexes of most animals are specialized in behavior as well as in structure for the performance of reproductive acts, for accessory functions such as the building of nests, and for subsequent duties of parental care All of these phases of sexual differentiation are intricately variable among the many species of animals (A W L)

SEXAGESIMAL MEASURE OF ANGLES. Degree Measure of Angles.

SEX GLAND. Ovary or testis, the essential organs of the **reproductive system.** These organs are classed as cytogenic glands, or glands which produce cells, but they also have endocrine functions (R S M)

SEX HORMONES. During recent years additional **hormones** have been discovered that are necessary for pregnancy, the menstrual cycle, and associated conditions The literature on this subject is confusing at present since all the functions and the relation of body hormones are not known Preparations of the sex hormones are now being used in the successful treatment of many reproductive, menstrual, and associated disturbances

One such hormone liberated by the **ovary** has been called by various names such as estrin, theelin, folliculin, estrogenic hormone, menformin, female sex hormone An effort has been made to standardize the nomenclature and it is usually referred to as estrone, theelin, or as the follicular hormone The hormone is secreted by the maturing follicle in the ovary (Graffian follicle—small spherical sacs in the ovary, each of which contains an egg-cell or ovum) After a menstrual period, several follicles develop and secrete the follicular hormone into the blood stream Only one of the follicles matures with ovulation of the ripe egg-cell Ovulation occurs between the ninth and seventeenth day of the menstrual cycle. (See **Menstruation**)

During pregnancy an abundance of this hormone is excreted in the urine It is also found in varying amounts in the urine of non-pregnant women—the amount varying with the time of the menstrual cycle It may also be found in male urine

The hormone is obtained for therapeutic and diagnostic procedures from the urine of pregnant women and mares A concentrated form is available which is produced by a partly synthetic process starting with the hormone obtained from pregnancy urine

Doisy and his co-workers first produced this hormone in crystalline form It is believed to exist in several closely related forms The most potent form is known chemically as ketohydroxyestrin $C_{18}H_{22}O_3$ One form that is used therapeutically is made by a partial synthetic process and is a **benzoic acid** ester of dihydroxyestrin.

Various preparations of the follicular hormone are used in treatment, and it may be given by mouth or by injection It has proven to be of value in the treatment of certain menopausal disturbances, menstrual disorders, genital underdevelopment, certain cases of frigidity, painful breasts, functional sterility, and certain senile affections

The production of this hormone by the ovary is controlled by hormones (follicle-stimulating) secreted by the anterior portion of the **pituitary gland.** Production is also stimulated by certain anterior pituitary-like hormones which are believed by some observers to be liberated from other sources than the pituitary gland Such a substance is Antuitrin-S, Prolan, etc Its action is similar to that of the pituitary hormone and it is also obtained from pregnancy urine By means of it, stimulation of the ovarian and testicular hormones can be produced, provided the **gonads** are still able to function It is used in both sexes for certain disorders Among them are menstrual disorders, delayed puberty, genital underdevelopment, habitual abortion, certain forms of **acne,** frigidity, certain types of impotence, undescended testicle, etc.

The other known ovarian hormone which is necessary for menstruation and pregnancy is known as progestin (progesterone) corpus luteal hormone, corporin, etc Actually this hormone seems to be a modified form of the follicular hormone, as both are closely related chemically.

After ovulation with escape of the egg-cell from the ovarian follicle, the follicle begins a second phase developing into the corpus luteum (The corpus luteum in the advent of pregnancy continues its development and hormone production for several months If the ovum is not fertilized, the corpus luteum degenerates and disappears) The corpus luteum secretes progestin besides continuing the secretion of the follicular hormone Some observers believe that the onset of menstruation is due to the withdrawal of progestin rather than withdrawal of the follicular hormone

Progestin is responsible for the secretory activity of the glandular epithelium of the **uterus,** preparing it for implantation of the fertilized ovum Without it pregnancy cannot take place

The formula of this hormone is similar to the follicular hormone The chemical formula is believed to be $C_{21}H_{30}O_2$, and it has been produced in a crystalline chemical form from this formula A similar substance has been synthesized from **sterols** derived from soy bean oil

A male sex hormone named androsterone, which is produced by the testicle under stimulation of a pituitary and/or a pituitary-like hormone has been isolated from the urine This hormone differs from the female sex hormone only by a molecule of water and an atom of carbon. The male hormone is also present in the urine of women

The remarkably similar chemical relationship between the follicular hormone, progesterone, and the male hormone is brought out by the fact that all three of the hormones are built around the same phenanthrene group, made up of three six-membered rings It is also remarkable that their chemistry is similar to the sterol group of chemical compounds, the bile acids, certain **vitamins,** and to various chemicals that under certain conditions may produce certain forms of **cancer** The similarity of the chemical structure of these hormones and the carcinogenic compounds has led some workers toward the view that the cause of certain forms of cancer may in part be due to derivation or deterioration products of certain hormones

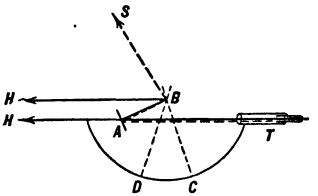
Sex differentiations and maintenance of the sex characteristics is not believed to be due directly to the ovarian and testicular hormones mentioned above They are believed to be due to still other hormones which have not been identified (R S M)

SEX LIMITATION The conditioning of the expression of a hereditary character in the individual according to its sex In many known cases exactly the same determining heritage according to Mendelian **heredity** may give different results in the two sexes A good example is that of color in Ayrshire cattle Males with determiners for the colors mahogany and red develop the former, while females develop the latter, although both colors may appear in both sexes under proper conditions of inheritance (A W L)

SEXTANT. The sextant is a light portable instrument designed for the purpose of measuring the angular distance between two objects It represents the most recent stage in a succession of portable devices for angular measurement advancing from the **astrolabe** through the **cross-staff** down to the modern instrument The immediate predecessor of the sextant was the quadrant (the "hog-yoke" of the sailing ship era), but the design of this instrument is very similar to that of the modern sextant Since the sextant is universally used by navigators for the purpose of measuring the apparent **altitude** of celestial objects, the opinion is prevalent that it is purely a navigational instrument. Such is far from the case, and the instrument is of great value to ex-

plorers, surveyors, or any person who desires to measure angular distance

The optical system of the sextant (and quadrant) is diagramed in the accompanying figure The mirror *A* (called the horizon glass) is divided into two sections by



a line parallel to the plane of the instrument The upper section is unsilvered so that an observer looking through the telescope *T* can see directly through *A* to an object in the direction *H* The mirror *B* (called the index mirror) may be rotated about an axis perpendicular to the plane of the instrument and coincident with the center of the graduated arc *CD* Attached to the index mirror is a vernier arm which sweeps along the arc

With the mirror *B* strictly parallel to *A* the observer will see two superimposed images of the object in the direction *H* One of these is the direct image observed through the upper section of the horizon glass, the other is a reflected image with light traveling along the path *HBAT* Under these conditions the index *C* should read zero, in case this is not so an "index correction" must be applied to all observations with the instrument

In case the angular distance between an object in the direction *H* and another in the direction *S* (angle *SBH*) is desired, the observer moves the index arm along the arc until an image of *S* (light path *SBAT*) is superimposed on the direct image of *H* Application of the laws of reflection of light will show that the angle *CBD* through which the mirror is turned is one-half the angle *SBH* To obviate the necessity of dividing each reading of the instrument by two, the arc is so graduated that when *CBD* is actually 60° the index will read 120°

In measuring altitudes of celestial objects the instrument is pointed toward the horizon at *H* and the index arm moved until an image of the celestial object (in direction *S*) swings just tangent to the image of the horizon as the instrument is rotated slightly about the axis of the telescope The reading of the arc (index correction being applied when necessary) gives the minimum angular distance of the object from the horizon, or the apparent altitude

For use in aviation a modification of the ordinary sextant is made From the definition of horizon the telescope, *T*, must be exactly level when the horizon is seen directly through the horizon glass Frequently the actual horizon is obscured from the aviator and a level is attached to the telescope in such a manner that the bubble may be seen when the telescope is strictly horizontal To measure altitude with this "bubble sextant," the telescope is held with the bubble visible and the index arm moved until the reflected image of the celestial object is superimposed on the bubble

Careful use of a sextant of the type ordinarily used in navigation will permit the measurement of angular distances to an accuracy of about 10″ for a single observation Within recent years improvements in the design of bubble instruments has led to nearly the same accuracy with these instruments. (W K G)

SHA. Mammalia, Artiodactyla. An Asiatic sheep with very wide range It is found from Persia into India and northward through Tibet The name more widely used is urial, sha applying to a large variety ranging from northern Tibet to Afghanistan It is more common at high altitudes, up to 14,000 feet (A W L)

SHACKLE. A shackle is a piece used for connecting together two parts The parts so connected can have some relative motion which is permitted by the shackle, but at the same time the extent of their freedom is limited by the restraining action of the shackle The connections of the shackle to the part is not required to be as exacting a fit as a **bearing**, but often is of a type needing lubrication A common example of shackle is the steel shackle employed to connect the ends of the suspension springs of an automotive vehicle to the frame (P T M)

SHAD. Pisces, Teleostei A marine fish (**Pisces**) found along the Atlantic coast of the United States. It ascends the coastal rivers to spawn This species belongs to the same genus as the herring and is ranked as one of our best food fishes The roe is also regarded as a delicacy. (A W L)

SHAFT. From a technical standpoint, shaft has two principal meanings It may mean the well-like excavation sunk vertically in the ground for subsurface exploration or exploitation, or it may refer to the drive shaft, which is a long cylindrical bar of metal, generally steel, employed to transmit power by torque

A mine shaft is an excavation carried vertically downwards, having a cross-section which is small compared to its length Where the earth is such that it might cave in and fill the shaft, the walls are braced or shored with wood From the shaft, at proper levels, horizontal drifts are driven out to the seams which are to be worked The shaft is usually served by a car which is lifted by a winch located at the head of the shaft Shafts may be sunk for purposes other than mining, as to examine the character of subsoil bearing for a proposed foundation.

Drive shafts are associated with a majority of rotations which are found in machines or in other industrial equipment It is not necessary to have a shaft wherever there is a turning wheel, gear, disk, etc, but such is frequently the case A transmission shaft is that designed to transmit power by torsion in the shaft, and in simple form, could consist of a rolled steel shaft, to which are keyed two pulleys, and which is supported by two or more bearings One pulley is belt-driven from a source of power, while from the other pulley power is taken by a belt to drive some other shaft, or a machine By the use of a shaft upon which several pulleys are mounted, power from one source may be distributed to a number of points A system of power distribution to the separate machines or departments of an industry, or shop, consists of a main shaft and one or more countershafts, which are driven from the main shaft, and which, in turn, drive the machinery, all by means of belts and pulleys Selection of pulleys of proper diameter enables a set-up to be worked out whereby the line shaft may be driven at constant speed by an engine or motor, while the machines themselves may individually operate at the speed for which each is designed This system of power transmission has, in recent years, suffered from considerable competition on the part of electric transmission of power through wires to individual motors mounted on each separate machine

The load upon a transmission shaft is one of torsion and bending, the torsion arising from the torque to be transmitted, and the transverse bending from deadweight and belt tension on pulleys The torque which causes the torsion is a function of the horsepower being transmitted, as is shown by the following equation.

$$\text{H P.} = \frac{T \times 2\pi n}{33{,}000}.$$

T is the torque in foot pounds, and *n* the speed of the shaft in revolutions per minute. (P T M.)

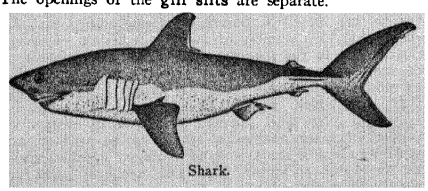
SHALE. Shale is a fine-grained sedimentary rock whose original constituents were clays or muds. It is characterized by thin laminae breaking with an irregular curving fracture, often splintery, and parallel to the often indistinguishable **bedding** planes. (R.M.F.)

SHAMA. Aves, Passeriformes. A jungle birds (**Aves**) of the Oriental region. The several species are found in the Malayan area, in the Philippines, in India, and on various Pacific islands. They are shy birds, but the Indian species is kept as a cage bird for its beautiful song. (A.W.L.)

SHAPER. A machine tool which is used to cut a plane surface on a piece of metal by reciprocating the piece back and forth under a cutting tool which moves slowly parallel to the plane, and perpendicular to the direction of reciprocation, is known as a shaper. The planer might be described in exactly the same way, but there is this difference: the travel of the carriage on a **planer** is much longer than on a shaper, and the planer is rarely used except for work whose dimensions are too large for it to be performed on the shaper. The ordinary type of shaper is the crank shaper, whose mechanism is illustrated in the article on **quick return mechanism.** Power is supplied from a driving belt to a pulley on the machine. This pulley is keyed to a shaft which carries a pinion, which engages a large gear. The crank driving arm rotates with this gear, and drives, on horizontal ways, a table or carriage to which the work is affixed. The travel of this table may be adjusted by altering the length of the crank arm. When a small piece is to be planed, the shaft is adjusted for short throw and the high-speed step of the cone pulley drive is used.

Supported above the reciprocating table is the tool post, to which the cutting edges are fixed. This has a compound motion, horizontally for moving over the surface of the work; vertically, for adjusting the depth of the cut. The horizontal travel is automatic and adjustable, the vertical manual. (See **Machine Tool.**) (F.T.M.)

SHARK. Pisces, Plagiostomi. A carnivorous fish (**Pisces**) of the group with cartilaginous skeletons. The mouth opens on the ventral surface of the head and is armed with many rows of sharp teeth attached to the skin and similar in structure to the placoid **scales** of the body. The tail is of the heterocercal form, having two lobes with the backbone extending into the upper. The openings of the **gill slits** are separate.



Shark.

The **dogfishes** are the most widely known of the sharks. They are common material for the anatomical laboratory and are used to some extent as food. Some members of the group, notably the whale shark (*Rhinodon*), attain a length of thirty or more feet, and others are large enough to be feared by divers. Although they are reputed to attack man freely, this tendency is also disputed by competent observers. There can be little doubt that under some conditions they do attack human beings.

Among the species whose common names do not indicate their association with this group are the thresher (*Alopias*), the **porbeagle**, the hounds, and the tope. The most peculiar species is the hammerhead (*Sphyrna*), whose head is transversely extended into two processes bearing the eyes at their tips. (A.W.L.)

SHARK SUCKER. Remora.

SHEAR. A force which lies in the plane of an area or a parallel plane is called a shearing **force.** It is the force which tends to cause the plane of the area to slide on the adjacent planes.

The vertical shear for any section of a simple beam is the magnitude of the **resultant** of the transverse loads on either side of the section. Transverse loads are those which are at right angles to the length of the beam. If the loads are inclined the vertical components, only, should be used in computing the vertical shear. The resisting shear at any section is the internal force which opposes the shearing action of the external loads. It is numerically equal to the external shear but in the opposite direction. Vertical shear, which is always accompanied by **bending moment** at a section of a beam, is numerically equal to the rate of change of this moment with respect to distance along the beam. This shear is arbitrarily assumed to be positive if the resultant of the vertical loads to the left of a section acts in an upward direction. In a symmetrically loaded simple beam the shear is equal to zero at the center of the beam. (See **Elasticity.**)

In addition to vertical shear in a beam there is always a horizontal shear which is a result of the difference in the flexural stresses (See **Flexure**) between any two vertical planes. The tendency of adjacent horizontal planes to slide upon each other is caused by horizontal shear. The effect may be better understood by visualizing a beam composed of flat planks laid one on top of the other. As the beam bends, due to the applied loads, the bottom of one plank will slide upon the top surface of the one beneath it unless this effect is restrained by friction, nails, bolts, or other **fastenings.**

The unit stresses resulting from vertical shear are called vertical shearing stresses. At any point in a beam these stresses are numerically equal to the horizontal shearing stresses. The variation of the unit shearing stresses over the cross-section of a rectangular beam is parabolic, being equal to zero at the top and bottom surfaces and a maximum at the **neutral axis.** When horizontal and vertical shear, only, act at a point in a body, the body is said to be in a state of pure shear at the point.

Shear is not restricted to beams. It occurs wherever there is bending. The web members of **trusses** and web plates of **plate girders** are designed to carry the shear. Columns, which are subjected to bending caused by eccentric **loads**, or by inclined or **lateral** loads, must be designed to withstand the shearing stresses. **Rivets** and welds (See **Welding**) are also subjected to shear. If the riveted connection is made so that the shear occurs between two plates only, it is called a single shear. When the type of connection is such that the shearing force is opposed by resisting shears acting on two planes, as in the case of three plates riveted together, the condition is called double shear. (See **Rivet.**) (C.W.C.)

SHEARWATER. Aves, Charadriiformes. Puffins. A group of marine birds (**Aves**) related to the auks, with large beaks, high at the base and strongly compressed. The name puffin is commonly applied to the Atlantic species and the name shearwater to those of the Pacific. Together they constitute the genus *Puffinus.* (A.W.L.)

SHEATHBILL. Aves, Charadriiformes. *Chionis.* A bird (**Aves**) related to the oyster-catchers. It is named from the horny sheath enclosing the base of the beak. Two species are known, both found in extreme southern latitudes and the Antarctic. (A.W.L.)

SHEAVE. A pulley wheel which carries grooves on its surface for the purpose of accommodating rope transmission, chains, V-belts, etc., all of which depend for traction upon something besides friction on a smooth surface, is a sheave. Sheaves for rope drive have

V-shaped grooves with sides at an angle of 45° or 60°, and a rounded bottom The diameter of the sheave must bear a certain minimum relation to the diameter of the rope, so that the latter will not be worn too rapidly by being passed over the sheave One authority recommends that the sheave be forty times the diameter of the rope Sheaves for V-belts have grooves with sides sloping at the same angle as the belt Chain sheaves may be cut with grooves which serve simply for guiding the chain over the sheave, or the groove may be pocketed at regular intervals to receive the links of the chain, so that positiveness of drive is secured that is not possible with a plain sheave Sheaves may be either single or multiple groove (See **Chain; Rope Drive; Belt**) (F T M)

SHEEP. Mammalia, Artiodactyla Animals related to the oxen and goats but more sharply distinguished from the former by their smaller size and the usually spiral horns They differ from goats in the absence of strong odor in the males and in the lack of a beard

Aside from the many domestic breeds, *Ovis aries*, sheep are much more highly developed in the Old World They are mountain animals, often found at high altitudes, and are represented by various species in the Old World, while in North America the mountain sheep or **bighorn** (*O canadensis*) is the sole representative Among the other species are the argalis (*O ammon*) of Tibet, Mongolia, and Kamchatka, the urial or sha (*O vignei*), the **mouflon**, the **bharal** or blue sheep of Tibet, and several known as the Armenian, Cyprian, and Barbary sheep (A W L)

SHEEPSHEAD Pisces, Teleostei 1 An excellent salt-water food fish (**Pisces**), *Archosargus probatocephalus*, related to the snappers It ranges from Massachusetts to Texas 2 A fresh-water species, *Aplodinotus grunniens*, one of the drums, found from the Great Lakes to the Gulf of Mexico It is taken for food but must be regarded as inferior The species bears several other names, among them white perch, croaker, and fresh-water drum (A W L)

SHEEP TICK Insecta, Diptera A wingless parasitic **fly**, *Melophagus ovinus*, resembling the true ticks only in its flattened body and leathery texture Like the other flies it has sucking mouth parts, hence it draws blood from the skin of the host It is especially harmful to lambs

Control of the tick requires dipping, preferably twice, after shearing The commercial preparations for dipping stock are effective against such pests (A W L)

SHEET Sill.

SHELDRAKE Aves, Anseriformes 1 A **duck**, *Tadorna tadorna*, of the Old World, marked with green, bay, and white It is a larger species than most of the ducks but has the characteristic broad beak of the group 2 The American **merganser**, *Mergus merganser*, a fish-eating species found throughout North America, although it breeds chiefly north of the United States (A W L)

SHELL. A hard external covering secreted by folds of the body wall of many animals The term applies properly to the shells of **Brachiopoda** and **Mollusca**, although it is sometimes used in reference to the hard exoskeleton of **crustaceans** Also a hard covering of eggs

Brachiopod shells consist of two valves, one upper and one lower They have an outer layer of organic matter known as the periostracum, under it a thin layer of calcium carbonate, and a thick inner layer of mixed organic and calcareous matter, deposited in prismatic form The valves are opened and closed by a complex system of muscles

Molluscan shells are usually spiral in form, like many common snail shells, or bivalve like those of mussels and the oyster The valves of such shells are lateral in position A third rarer form is the shell of **nautilus**, which is spirally coiled in one plane Internal shells of slugs, chitons, and some cephalopods are in the form of plates of calcareous matter

The external shells of mollusks have an external horny layer, the periostracum, a smooth lining of nacre or mother-of-pearl, and a thick calcareous middle layer

Because of their permanence and beauty the shells of many marine mollusks have attracted the attention of collectors, and many have received common names Among them the spiral staircase or wentletrap, periwinkle, conch, finger shell, cowry, coffee-bean, apple-seed, oyster drill, whelk, papal miter, cockle, gem, and others are to be found on the coasts of the United States

The shells of eggs are calcareous or chitinous coverings secreted by a portion of the female reproductive ducts known as the shell gland In the birds they are characteristically and often beautifully colored, and in the insects they may be beautifully sculptured They are sometimes perforated by a minute opening or group of openings called the micropyle for the entry of the sperm The egg shell of insects is also called the chorion, a term not to be confused with the chorion of vertebrate embryos (A W I)

SHELL GLAND A specialized region of the ducts of the female **reproductive system** which secretes a more or less rigid covering about the egg (A W L)

SHICHSHOKIAN DISTURBANCE. Devonian

SHINER. Pisces, Teleostei A small fish (**Pisces**) found in streams east of the Rockies It occurs in almost all of the states of this region and is sometimes very abundant in the smaller streams Steel blue above and silvery on the sides Also called the redfin and dace The name is applied to other species of the same genus and to less closely related minnows (A W I)

SHIPWORM Mollusca, Lamellibranchiata A peculiar marine **mollusc** which bores into submerged wood and apparently is among the few animals that can digest cellulose and related materials The shipworms belong to several genera of which *Teredo* is most often cited All are slender wormlike creatures but they have the characteristic structures of the bivalves The valves of the shell are small separate parts, located at the anterior end of the worm, and are used for excavating the burrow

Shipworms do great damage to wooden hulls and marine piling, consequently they have been subject to detailed studies to determine methods of avoiding their destructive attacks (A W L)

SHOCK A general bodily state characterized by great diminution of the vital functions of the body, producing a profound depression which may prove fatal if not treated or overcome It is characterized by greatly reduced blood pressure, very rapid, thready and feeble pulse, shallow and rapid respiration, sub-normal temperature, and moist cold grayish skin In its early stages there is restlessness and anxiety which changes if untreated, to coma This state is frequently seen after severe injuries, severe prolonged surgical procedure and **anaesthesia**, after severe hemorrhage and following exposure It is called traumatic or surgical shock It is due to a lowered volume of circulating blood reaching the heart, a large portion of the available blood stagnating in the finer vessels or capillaries The exact mechanism concerned in the production of shock is not known Immediate treatment is required This includes artificial warmth to the body, elevation of the foot of the bed, large amounts of fluid intravenously, and often large transfusions

Anaphylactic shock is occasionally seen following the injection of a **protein** substance in the body when a previous injection has made the body sensitive to that particular protein. This is an **allergic** phenomenon and varying degrees of this reaction are sometimes seen when a particular substance is injected into a subject who gives an allergic history, such as the presence of asthma or hay fever. The symptoms are acute in onset and are similar to those described in traumatic or surgical shock. They are relieved by adrenalin given by hypodermic.

Insulin shock occurs when overdosage of insulin is given and is due to a sudden lowering of the **sugar** in the blood. It is immediately relieved by supplying sugar to the patient. This is used as a treatment of certain mental diseases such as dementia praecox.

Shell shock is a war neurosis and is seen following mental and physical strain during times of war. It is seen in some subjects far removed from the field of battle. It is thought possible that some of the cases occurring on the field of battle close at hand to terrific detonations may differ from the functional type of shell shock. In these cases definite organic injuries may be present in the brain due to the shock of suddenly expanding gases accompanying the explosions. (R.S.M.)

SHOCK ABSORBER. A shock absorber is a device which absorbs energy of shock either by storage or dissipation. While there are many instances of the use of such equipment on machinery, the two outstanding uses of mechanical shock absorbers are found in the field of automotive and aeronautical engineering.

An automobile shock absorber is provided to absorb the shocks of road irregularity and prevent their transmission to the frame. Strictly speaking, pneumatic tires and springs are in the nature of shock absorbers, but, supplementing these, automobile manufacturers have added shock absorbers which prevent excessive rebound after unusually large spring deflections, or which set up forces aiding the spring in resisting deflection due to the tires passing over a severe bump. Many shock absorbers are simply snubbers, which tighten up when the spring is in its maximum deflected position, and gradually ease it out on the rebound, absorbing energy in mechanical or hydraulic friction, which might otherwise be used in throwing the vehicle.

Shock absorbers are used on **airplanes** to cushion the impact of landing. Although it is possible to land an airplane without impact, this type of landing is rarely accomplished, even by experts, and the usual landing is a **stall** from three or four feet above the ground. Absorbers are installed to absorb the velocity of descent gradually, and prevent large impact stresses in the framework, as well as the unpleasant jarring of the occupants. They used to be of the type which merely stored this energy and then released it. Illustrative of this shock absorber is the type using rubber cords, in which the energy of shock is absorbed by the stretching of a number of loops of rubber shock cord. In their extended position, these cords contain energy which is liberated by a return to the unstretched position. The effect was usually to throw the aircraft back in the air in a bounce, and such shock absorbers have been largely replaced today by a type in which the energy is dissipated in friction within the absorber.

The **oleo shock absorber**, used on aircraft, is essentially a smooth-fitting piston and cylinder. The cylinder is attached to the wheel, and the piston to a strut which extends to a fitting on the fuselage. The energy is absorbed by compressing this member, thus moving the piston and the cylinder. The cylinder is filled with oil which flows through a small orifice in the piston when the strut is compressed. The energy is absorbed in the friction of the liquid flowing through that orifice. The resistance of such a shock absorber automatically adjusts itself to the degree of shock, being comparatively soft for a smooth landing, where the compression in the strut is low. On a hard landing the compression in the strut is greater, and the action of the absorber is harder, although the oil is of course flowing through the orifice faster under the greater pressure developed. (F.T.M.)

SHOE-BILL. Aves, Ciconiiformes. A large bird (**Aves**) of central Africa, *Balaeniceps rex*, noteworthy for its large beak. The organ is broad and moderately deep, and the upper **mandible** bears a strong hook at the tip. The species stands about five feet high, has a moderately long neck and long legs, and is gray in color. Also called the whale-headed stork. (A.W.L.)

SHONKINITE. An **igneous rock** term proposed by Pirrson, in 1895, for a basic variety of **syenite** or **monzonite** containing both **orthoclase** and **plagioclase** and small amounts of accessory **nepheline.** (R.M.F.)

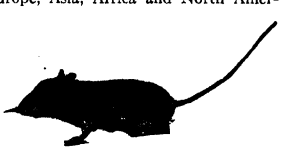
SHOOTING STAR. Shooting star is the popular term used to designate **meteors.** These objects bear little if any relation to the **stars** other than that they are seen as bright, rapidly moving objects against the dark sky and hence apparently among the stars. (W.K.G.)

SHOT EFFECT. A troublesome phenomenon which gives rise to a sputtering or popping noise in **radio** and **amplifier** apparatus. It was called *Schroteffekt* (small shot effect) by Schottky, who first explained it as due to variations in the number of thermions per second emitted from the tube filament. This variation seems to be merely a statistical one, like the variations in the forces acting on particles exhibiting the **Brownian movement.** Its magnitude depends upon several factors, among which is the influence of the space charge (distribution of electrons) within the tube. A somewhat similar effect, produced by random variations in the velocities of the electrons, and depending upon the temperature of the filament, is manifested in what is called thermal noise, and is superposed on the shot noise. There is also a shot effect in the emission of photoelectrons, observable in the operation of **photoelectric cells.** (L.D.W.)

SHOU. Deer.

SHOVELLER. Aves, Anseriformes. A widely distributed **duck**, *Spatula clypeata*, of the northern hemisphere. The male has a dark green head and is beautifully marked with blue, white, chestnut and orange. The female brownish but for the blue wing patch. The species is named from the greatly broadened beak. Also called the spoonbill. (A.W.L.)

SHREW. Mammalia, Insectivora. Small animals closely resembling the mice in general appearance. They are common in Europe, Asia, Africa and North America. Many species burrow and aquatic habits are not uncommon in the group. Another family, confined to Africa, is characterized by the great development of the hind legs; its members are known as the **jumping shrews.** The **tree shrews** or tupaias of the Oriental region constitute a third family of arboreal habits and somewhat squirrel-like appearance. All of these animals subsist on a diet of worms, insects, and some plant products. (A.W.L.)

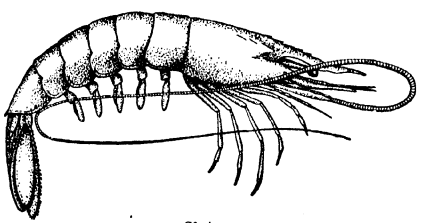


African jumping shrew. (Courtesy of American Museum of Natural History.)

SHRIKE. Aves, Passeriformes. *Lanius.* A bird (**Aves**) which is known chiefly for its habit of catching other birds and small animals and impaling uneaten remnants on thorns. Also known as the butcher bird. The beak is notched and in some species hooked. The numerous species occur on all continents but South America. (A.W.L.)

Shrike.

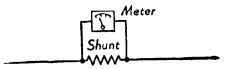
SHRIMP. Crustacea. 1. The edible shrimps of the order **Decapoda**. Closely related to the prawns and less closely related to the lobsters and crayfishes. The body is compressed, the antennae long and slender, and the chelate appendages small, although the related snapping shrimps have moderately large pinchers. A few species of shrimps and prawns are among the important edible crustaceans. They are found chiefly in warmer waters and are the basis of an important industry on the Gulf Coast of the United States. 2. The **mantis shrimp**. The name is also applied in other combinations to many of the small crustaceans, including tadpole shrimps, skeleton shrimps, spiny shrimps, and fairy shrimps. (A.W.L.)



Shrimp.

SHRUBS. Stem.

SHUNT. The shunt is an electrical bypath so arranged that an **electric current** divides and flows partially through the shunt, and partially through the equipment that is shunted. See the accompanying diagram for connections. A shunt may be employed to extend the range of currents measurable by an **ammeter,** since, when an ammeter is connected around a shunt, the currents flowing in the two branches, i.e., the shunt and the ammeter, are inversely proportional to the respective resistances. Thus, if the resistance of an ammeter is 5 ohms, and of the shunt, 1 ohm, the current through the shunt would be five times that through the ammeter. In such a case, the ammeter reading would have to be multiplied by six, and six would be the multiplying power of this shunt. By the use of shunts of different resistances, a fixed range ammeter may be adapted to a wide range of currents.



In the above illustration, the shunt has carried the main part of the current. In the shunt-wound **generator**, the field coils are shunted across the armature circuit, but in this case the shunt resistance is very high, and consequently only a very small portion of the current flows through the shunt winding. (F.T.M.)

SIALID. Insecta, Neuroptera. A member of the family Sialidae, usually applied only to the **alder flies** although the **dobson fly** and the **fish flies** also belong here. The alder flies are small insects whose larvae live in streams. The habit of the adults of perching on the alders lining the banks gives them **their** name. (A.W.L.)

SIAMANG. Mammalia, Primates. A species of **gibbon**. (A.W.L.)

SICHEL. Pisces, Teleostei. A fish (**Pisces**) of eastern Europe, related to the carps. It is of peculiar form, with the upper surface almost straight and the mouth directed upward. (A.W.L.)

SIDEREAL PERIOD. The sidereal period of any object is its period of revolution around its primary. In general, sidereal period may be defined as the time required for an object to move from a particular position among the stars back to the same longitude again, as seen from the sun. (W.K.G.)

SIDEREAL UNIVERSE. Milky Way.

SIDERIOLITE. Meteor.

SIDERITE or **CHALYBITE.** This mineral is a **carbonate** of **iron**, $FeCO_3$. It is **hexagonal** with **rhombohedral** crystals, and also occurs in various massive forms. It has a rhombohedral **cleavage**; uneven fracture; is brittle; hardness 3.5–4; specific gravity 3.83–3.88; luster vitreous to pearly; color gray, yellowish or greenish gray, green, reddish brown and brown. Siderite is found as **concretionary** masses in the **sedimentary rocks**; as a replacement mineral from the action of iron solutions upon limestones; and in metalliferous veins as a **gangue** mineral. It is relatively common. Siderite is found in Austria, Saxony, Czechoslovakia, France, England, Italy, Greenland, Australia, Brazil and Bolivia. In the United States important localities are in Connecticut, Pennsylvania, New Jersey, Ohio and Washington. It is used as an iron ore. (E.S.C.S.)

SIDEWINDER. Reptilia, Sauria. A small **rattlesnake** of the southwestern deserts. It has a pair of hornlike projections between the eyes and progresses by a peculiar sidewise locomotion. (A.W.L.)

SIERRA NEVADA REVOLUTION. Jurassic.

SIEVE TUBES. A sieve tube is an elongate cell occurring only in **phloem**. It has a thin wall of **cellulose**, lined with the **protoplast**, and contains a large central **vacuole**. Through its walls there are many perforations, which are localized in those places known as sieve plates. The function of a sieve tube is the conduction of food materials.

For development, see **cambium**. (R.M.W.)

SIFAKA. Mammalia, Primates. A **lemur** of the genus **Propithecus**. The several species are found in Madagascar. They are related to the indri lemur but have long tails and shorter muzzles. (A.W.L.)

SIGILLARIA. Paleobotany.

SILEX. Flint.

SILICATE. Silicon.

SILICEOUS SINTER. Geysers.

SILICIC ACID. Silicon.

SILICON. Symbol: Si. Atomic number: 14. Atomic weight: 28.06. Density: 2.4. Hardness: 7. Melting point: 1420° C. Boiling point: 2600° C. Isotopes: 28 (89.6%), 29 (6.2%), 30 (4.2%).

Silicon is (1) a dark gray hard crystalline solid, (2) an amorphous brown powder Both forms are unaffected by air at ordinary temperatures, but when heated in air to high temperatures a protective layer of oxide is formed, reacts with **nitrogen** at high temperatures to form nitride, with **chlorine** to form chloride, with several metals to form silicides Crystalline silicon is unattacked by **hydrochloric** or **nitric** or **sulfuric acid**, but attacked by **hydrofluoric acid** to form silicon tetrafluoride gas, soluble in **sodium** hydroxide solution to form sodium silicate and hydrogen gas, reacts with dry chlorine to form silicon tetrachloride Isolated by Berzelius in 1823

Silicon occurs abundantly in all ordinary rocks except **limestone**, is second in abundance of the elements in the earth's crust (27 7% of the solid crust) and exceeded only by oxygen Present in **igneous rocks** and clays as alumino-silicate, as the oxide (SiO_2) in the minerals **quartz**, sand, **flint**, and the gems **amethyst**, **jasper**, **chalcedony**, **agate**, **onyx**, **tridymite**, **opal**, **crystobalite**, as silicates, **zircon** (zirconium silicate $ZrSiO_4$), **willemite** (zinc silicate Zn_2SiO_4), **wollastinite** (calcium silicate, $CaSiO_3$), **serpentine** (magnesium silicate $Mg_3Si_2O_7$) Silicon is obtained from the oxide (1) by igniting with **aluminum** powder, (2) by reduction with **carbon** in the **electric furnace**, and is used to reduce many oxides Silicon is chemically related to **aluminum**, **boron**, **titanium** and **carbon**

Acids Silicic acid (ortho H_4SiO_4 or $SiO_2\ 2H_2O$, meta H_2SiO_3 or $SiO_2\ H_2O$), white gelatinous precipitate, by reaction of solution of silicate and **hydrochloric**, **nitric** or **sulfuric** acid of proper concentrations, forms silicon oxide upon ignition, forms various silicates by fusion methods, hydrofluosilicic acid (H_2SiF_6), colorless solution, by reaction of silicon fluoride, forms fluosilicates by neutralization methods

Aluminates Many complex silico-aluminates or alumino-silicates are formed in nature Of these, clay in more or less pure form (pure clay, kaolinite, **kaolin**, china clay, $H_4Si_2Al_2O_9$ or $Al_2O_3\ 2SiO_2\ 2H_2O$) is of great importance Clay is formed by the weathering of igneous rocks, and is used in the manufacture of bricks, pottery, porcelain, portland cement Sodium aluminosilicate is used in water purification to remove dissolved calcium compounds (See **Calcium** aluminosilicates)

Carbide Silicon carbide (SiC), ("carborundum"), bluish-black iridescent crystals, very hard, used as an **abrasive** and heat refractory material

Chloride Silicon chloride, silicon tetrachloride ($SiCl_4$), colorless fuming liquid, boiling point 58° C, by reaction of silicon, or silicon oxide plus **carbon**, heated in **chlorine**, fumes in moist air, and is used for producing white smoke screens in air

Fluoride Silicon fluoride, silicon tetrafluoride (SiF_4), colorless gas, by reaction of silicon oxide, **calcium** fluoride and hot concentrated **sulfuric acid**, reacts with water to form silicic acid plus hydrofluoric acid, and the latter, with excess silicon fluoride, forms hydrofluosilicic acid, combines with ammonia (e g, $SiF_4\ 2NH_3$)

Fluosilicate Sodium fluosilicate (Na_2SiF_6), white solid slightly soluble, magnesium fluosilicate ($MgSiF_6$), white solid, soluble

Hydrides Silicon tetrahydride, silicon methane, silicane (SiH_4), colorless gas, boiling point 115° C, by reaction of magnesium silicide and **hydrochloric acid**, followed by purification of the gas, reacts with **silver** nitrate yielding silver plus silicon, silicoethane (Si_2H_6), colorless liquid, boiling point 52° C, by reaction of **lithium** silicide (Li_6Si_2) and concentrated hydrochloric acid

Nitrides Trisilicon tetranitride (Si_3N_4), by heating silicon oxide plus **carbon** to 1500° C in a current of **nitrogen** gas

Oxide Silicon oxide, silicon **dioxide**, **silica**, **quartz**, **tridymite**, **crystobalite**, "vitreosil" (SiO_2), white to colorless solid Ordinary quartz (alpha-quartz), density 2 65, melting point 1425° C, changes into beta-quartz at and above 575° C, these have different optical properties and etching marks with hydrofluoric acid Beta-quartz is changed into tridymite, density 2 26, melting point 1670° C, at and above 870° C When silica is maintained some time at the sintering temperature, crystobalite, density 2 32, melting point 1710° C, is formed Different forms of silicon oxide differ in chemical activity, e g, quartz is practically unreactive with **sodium** hydroxide solution, whereas amorphous silica, density 2 20, formed by heating silicic acid, is reactive. Silicon oxide reacts (1) with fused **sodium** carbonate, yielding sodium silicate glass, (2) with sodium and **calcium** carbonate to form ordinary glass, (3) with several metallic oxides to form various colored glasses, (4) with **hydrofluoric acid**, but not with other acids (except hot concentrated **phosphoric acid**) Quartz is commonly found as a mineral in rocks (second in abundance to feldspar among minerals of the earth's crust) Quartz softens gradually like glass when heated somewhat below its melting point, and in the plastic condition may be worked into various shapes like glass (such wares are called by various trade names, e g, "vitreosil") Various preparations of silica gel involve the dehydration of silicic acid to silica containing more or less combined water for special purposes of adsorption of gases and liquids

Silicates Sodium metasilicate, "water glass" (Na_2SiO_3), colorless (when pure) glass, soluble, melting point 1088° C, formed by reaction of silicon oxide and **sodium** carbonate at high temperature, solution reacts with **carbon dioxide** of the air, or with sodium carbonate solution or **ammonium** chloride solution, yielding silicic acid, gelatinous precipitate Sodium silicate solution is used (1) in soaps, (2) for preserving eggs, (3) for treating wood against decay, (4) for rendering cloth, paper, wood non-inflammable, (5) in dyeing and printing textiles, (6) as an adhesive (e g, for paper boxes) and cement Various fused mixed silicates are used in glasses (sodium calcium silicates in common glass) Various colored silicates may be separated in solution by adding the colored soluble solid (e g, cobalt nitrate) to sodium silicate solution See Aluminates above See **Calcium** silicates

Sulfides Silicon monosulfide (SiS), yellow solid, somewhat volatile, formed by heating to redness crystalline silicon in sulfur vapor, reactive with water, silicon disulfide (SiS_2), white crystals, formed by heating amorphous silicon and sulfur, and then subliming, reactive with water

Organic compounds Silicon tetramethyl ($Si(CH_3)_4$), liquid, boiling point 26° C, silicon tetraethyl ($Si(C_2H_5)_4$), liquid, boiling point 152° C, disilicon tetramethyl ($(CH_3)_3Si\ Si(CH_3)_3$), boiling point 113° C, silicon tetraphenyl ($Si(C_6H_5)_4$), solid, melting point 231° C; methyl silicate, tetramethoxy silicon ($Si(OCH_3)_4$), boiling point 122° C, ethyl silicate, tetraethoxy silicon ($Si(OC_2H_5)_4$), boiling point 165° C

In the inorganic world of nature, the element silicon plays a role in the composition of rocks and minerals at least suggestive of the diversity shown by carbon in the organic world of plants and animals (R K S)

SILK. A material produced by many **insects** and **spiders** for the formation of cases in which the **larva** lives, cocoons in which pupation (**pupa**) takes place or eggs are deposited, and webs for the capture of prey Some **caterpillars** form temporary defenses of silk and both caterpillars and spiders use it to lower themselves from elevated supports and sometimes to elevate themselves to such supports

Silk is formed as a liquid secretion which hardens quickly on exposure to the air It is spun by being forced through small apertures which mold it into a thread When so discharged it is a clear, smooth, lustrous material of considerable strength, but spiders form opaque and adhesive threads as well

The silk of commerce is produced by the silk worm, caterpillar of the **moth**, *Bombyx mori* The fine threads of which the cocoon is composed are reeled and spun into threads large enough to be woven Although the use of pure silk has been encroached upon by manufactured rayon and allied products, it is still produced in large quantities in the Orient and in the Mediterranean countries Another product of the industry is catgut, produced by removing the silk gland of the worm and artificially drawing it into a thick thread This product comes chiefly from Spain

The silk of many other insects has been reeled and spun, and even that of spiders has been made into fabrics The latter is too fine for practical purposes although the very fine filaments spun by the spider are used as cross-hairs in optical instruments Pongee silk is the only commercial product of this kind that is derived from another moth than the true silkworm species (For synthetic fibers such as rayon, see **Carbohydrates**) (A W L)

SILK GLAND The gland from which **silk** is produced by the **insects** and **spiders.** Silk glands of most insects are modified salivary glands opening through the mouth parts in the **larvae** alone, but in the order Embiidina some observers report that the silk comes from glands in the front legs, whose ducts open through hairs on the tarsi

The silk glands of spiders are located in the abdomen, opening through a group of special organs called spinnerets on the under surface near the tip of the body They are of several forms Ampulliform glands produce the strong radial lines of the orb webs and aggregate glands secrete the sticky spiral lines Pyriform glands produce disks by which the anchoring lines of the web are attached to its supports When prey is caught it is wrapped in fine silk produced from aciniform glands, and still another type, the tubuliform glands, form the silk of which the egg cocoon is made The last occur only in the female (A W L)

SILKWORM Insecta, Lepidoptera The **caterpillar** of the **moth**, *Bombyx mori*, which produces the silk of commerce Caterpillars of the family Saturniidae also spin cocoons of silk, and are known as the giant silkworms This family includes the common luna, cecropia, and polyphemus moths of North America, as well as many other species (A W L)

SILL. A tabular mass of igneous rock that has been intruded laterally between layers of sedimentary rock, beds of volcanic lava or **ejectmenta**, or even along the direction of the **foliation** in metamorphic rocks The term sill is synonymous with intrusive sheet (R M F)

SILLIMANITE The mineral sillimanite is an **aluminum silicate**, the formula Al_2SiO_5 being like that of **andalusite** and **kyanite** It is **orthorhombic**, usually in slender prisms, but may be fibrous or massive Its hardness is 6–7, specific gravity 3 23–3 24, luster vitreous, color, various shades of gray, grayish green, grayish brown, etc , transparent to translucent It occurs in **granites** and **gneisses** as tiny prisms and aggregates, and is often associated with andalusite, **cordierite** and **corundum** Sillimanite has been found in Bavaria, Czechoslovakia, France, India, Madagascar, Burma and Ceylon, the latter two localities furnishing transparent sapphire blue gem stones In the United States sillimanite has been found in Connecticut, New York, Pennsylvania, Delaware, North Carolina and California, where, in Inyo County is the largest deposit in the world This mineral was named in honor of Benjamin Silliman for many years professor of chemistry and natural science at Yale University Sillimanite is used in the manufacture of spark plug "porcelains" and laboratory ware (E S C S)

SILTSTONE. A term signifying a **clastic** sedimentary rock in which the particles are of silt **grade** (R M F)

SILURIAN PERIOD. A major subdivision of the **Paleozoic Era** Type locality, Wales and Shropshire, England The formations of this system were first studied and described by R I Murchison in 1835 The Silurian Period began 380 million years ago and lasted for 50 million years In Murchison's time, and for some time afterward, the Paleozoic Era, below the **Devonian**, was divided into the **Cambrian** and Silurian This practice still holds in parts of Europe The Silurian formations are well exposed in Eastern North America, especially in New York State, and the length of the **Appalachian geosyncline** where the sediments are principally red **sandstones** and **shales** of delta origin There was little or no volcanic activity except in southeastern Maine The Silurian is also well exposed in nearly all of Western Europe, Northern Siberia, Burma, Central Asia, Himalayas, Morocco, Australia, Peru and Bolivia The system is characterized by all types of sediments, with evidence in certain areas of an arid climate, including thick deposits of salt and **gypsum** The maximum thickness of sediments is 15,000 feet, in Britain The principal types of fossils are **corals**, **bryozoans** (including primitive reefs), spire-bearing **brachiopods**, **graptolites**, **nautiloids**, **trilobites**, and **ostracods** The first air-breather, a fossil scorpion, is reported from both Sweden and England In North America the principal economic products of Silurian Age are rock salt, gypsum, iron ore, petroleum and natural gas In western Europe the Silurian was brought to a close by a period of mountain building called the Caledonian Disturbance (R M F)

SILVER Symbol Ag (argentum) Atomic number 47 Atomic weight 107 880 Density 10 5 Hardness 2 5–2 7 Melting point 960 5° C Boiling point 1950° C Isotopes 107 (52 5%), 109 (47 5%)

Silver is a white metal, softer than **copper** and harder than **gold**, when molten is luminescent and occludes **oxygen** (20 volumes) but the oxygen is released in solidification ("spitting"), the most malleable and ductile of the metals except gold as a **conductor** of heat and electricity superior to all other metals, soluble in **nitric acid** containing a trace of nitrate, soluble in hot 80% **sulfuric acid**, reacts with **hydriodic acid** to yield **hydrogen**, insoluble in **hydrochloric** or **acetic acid**; tarnished by **hydrogen sulfide**, soluble sulfides and many sulfur containing organic substances (e g , **proteins**), not affected by air or water at ordinary temperatures, but at 200° C a slight film of silver oxide is formed, not affected by **alkalis**, either in solution or fused Discovery prehistoric

Silver is used as a useful and ornamental metal, either as silverware or silver-plated goods, in coins (90% Ag with 10% copper as a hardener), and deposited on glass for mirrors

Silver occurs native in Peru, but the chief ores are sulfides (**argentite**, Ag_2S) and it is frequently associated with gold, lead and copper ores Silver is obtainable (1) as a by-product in the **electrolytic** refining of copper in the **anode** mud, (2) as a by-product in crude lead by its differential solubility in zinc metal when molten (silver is 3,000 times more soluble in zinc than in lead), (3) by leaching the ore with **sodium** cyanide solution and recovery by electrolysis

Acetate silver acetate ($AgC_2H_3O_2$), white solid, only slightly soluble in water

Bromide silver bromide (AgBr), pale yellow precipitate by reaction of silver nitrate solution, and **potassium** bromide solution, insoluble in **nitric acid**, only slightly soluble in ammonium hydroxide, soluble in **sodium** thiosulfate solution, turns dark on exposure to light, melting point of silver bromide 434° C

Chloride silver chloride (AgCl), white precipitate by reaction of silver nitrate solution and **potassium**,

ammonium, or **sodium** chloride solution or by **hydrochloric acid**, insoluble in nitric acid, soluble in ammonium hydroxide, and in sodium thiosulfate solution, turns dark on exposure to light, melting point of silver chloride 455° C.

Cyanide: silver cyanide (AgCN), white precipitate by reaction of silver nitrate solution and **potassium** cyanide solution; silver potassium cyanide ($KAg(CN)_2$), soluble, and recovered as white solid by crystallization.

Chromate: silver chromate (Ag_2CrO_4), yellow to red to brown precipitate by reaction of silver nitrate solution and **potassium** chromate solution.

Dichromate: silver dichromate ($Ag_2Cr_2O_7$), red precipitate by reaction of silver nitrate solution and **potassium** dichromate solution, changing to silver chromate upon boiling with water.

Iodide: silver iodide (AgI), yellow precipitate by reaction of silver nitrate solution and **potassium** iodide solution, soluble in concentrated nitric acid, insoluble in ammonium hydroxide solution, and slightly soluble in sodium thiosulfate solution, turns dark on exposure to light, melting point of silver iodide 552° C. with decomposition.

Nitrate: silver nitrate, lunar caustic ($AgNO_3$), white colorless crystals, soluble, the source of most insoluble and some soluble silver compounds, formed by the reaction of silver metal and **nitric acid** followed by crystallization, melting point of silver nitrate 212° C., and at 320° C. begins to decompose.

Oxides: silver monoxide, silver oxide (Ag_2O), brown precipitate, by the reaction of silver nitrate solution and **sodium** or ammonium hydroxide, soluble in **ammonium** hydroxide (upon standing this solution forms a dangerous explosive), appreciably soluble (1 part in 300) in water, giving a solution that turns litmus blue, decomposes at 300° C. into silver metal and oxygen; silver dioxide, silver peroxide (Ag_2O_2), black precipitate by the reaction of silver nitrate solution and **ammonium** persulfate solution, an active oxidizing agent.

Phosphate: silver phosphate (Ag_3PO_4), yellow precipitate, by reaction of silver nitrate solution and disodium hydrogen **phosphate** solution, soluble in nitric acid and in ammonium hydroxide, turns dark on exposure to light.

Sulfate: silver sulfate (Ag_2SO_4), white precipitate, by the reaction of silver nitrate solution and **potassium**, **sodium** or **ammonium** sulfate solution or sulfuric acid, melting point of silver sulfate 652° C.

Sulfide: silver sulfide (Ag_2S), black precipitate, by the reaction of silver nitrate solution and **hydrogen sulfide**.

Thiocyanate: silver thiocyanate (AgCNS), white precipitate by reaction of silver nitrate solution and potassium thiocyanate solution, insoluble in nitric acid, soluble in warm ammonium hydroxide but re-precipitated on cooling.

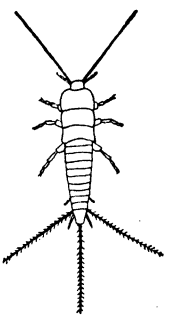
Silver halides (**iodide**, **bromide**, **chloride**) on account of darkening on exposure to light, are applied in photography on the sensitized plate or film, and the solvent action of sodium thiosulfate on silver compounds is applied in the fixing process, the particles of metallic silver remain unattached.

Colloidal silver and some of its insoluble compounds, are used in medicine for antiseptic and antibacterial action on mucous membranes. Silver nitrate is antibactericidal, astringent, and stimulating.

Silver forms more insoluble salts than any other metal (approached in number of salts by lead and mercury). (R.K.S.)

SILVER-FIN. Pisces, Teleostei. A small fish (**Pisces**), *Cyprinella whippli*, related to the shiners. Common in clear streams from New York to Alabama and west to Minnesota and Arkansas. It is silvery with a bluish tinge and the paired fins are pale whitish. (A.W.L.)

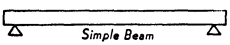
SILVER-FISH. Insecta, Thysanura. *Lepisma.* One of the primitive wingless **insects**. It is about one-half inch long, broad in front and tapering behind, with two long slender antennae and three similar processes at the caudal end of the body. It is covered with lustrous grayish scales, whence the common name. The insect eats starchy materials and sometimes defaces book bindings, wall paper, and laundry, but as a rule it is not sufficiently abundant to be a pest. It is often found in damp buildings. Also called the fish moth. (A.W.L.)



Silverfish.

SILVERSIDES. Pisces, Teleostei. Small slender fishes (**Pisces**), of numerous species, found chiefly along the coasts of the warmer seas but in a few cases in ponds and streams. They make up the family Atherinidae. (A.W.L.)

SIMPLE BEAM. A simple **beam** is one which rests on two end supports in such a manner that the ends of the beam are free to rotate on the supports. Since riveted connections are elastic the end restraint offered by this type of connection is not very reliable. Therefore beams and girders which are riveted to supports are generally assumed to be simply supported unless a special type of moment connection is used. (C.W.C.)



SIMPLE CURVE. Circular Curve.

SIMPLY AND MULTIPLY CONNECTED REGIONS. By a simply connected region is meant a region such that no closed curve drawn in the region contains in its interior a boundary point of the region. All other regions are called multiply connected.

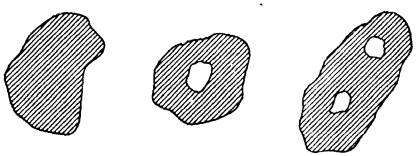


Figure 1 Figure 2 Figure 3

Simply and multiply connected regions.

In a simply connected region, a curve between two points of the region may always be changed by continuous deformation into any other curve between those points, without passing outside the region.

A region bounded by a simple closed curve is a simply connected region (Figure 1). A circular ring is an example of a doubly connected region (Figure 2). A triply connected region is also shown (Figure 3). (L.L.S.)

SIMULTANEOUS EQUATIONS. Systems of Algebraic Equations.

SINANTHROPUS. Paleontology of Man.

SINE CURVE. Trigonometric Curves.

SINEW. A common term applied both to **tendons** and to **ligaments**. (A.W.L.)

SING-SING. Mammalia, Artiodactyla An **antelope** of western and central Africa It is a medium sized species with a white patch on the buttocks (A W L)

SINGLE PHASE. **Phase.**

SINGULAR SOLUTION OF A DIFFERENTIAL EQUATION. **Ordinary Differential Equations of First Order and Higher Degree than the First.**

SINK OR SINK HOLE. **Cave.**

SINTER. The calcareous (See **Calcium**) or **siliceous** material deposited by mineral springs, usually thermal but not necessarily so, is known as sinter or tufa Commonly the term sinter is used for the siliceous variety, tufa for the calcareous kind Siliceous sinter is also known as **geyserite** Rocks formed from calcareous tufa are known as travertine, and frequently used as decorative stones under the name of "**onyx marble**" (E S C S)

SINUS. A pouch or cavity in any organ or tissue, or an abnormal cavity or passage formed by the destruction of tissue The term is applied to a very large number of such structures in the human body, such as, a dilated portion of a vein containing venous blood, a chronically infected tract such as a **fistula**, the air cavities made up of the cranial bones, especially those located near the nose and connecting with it They are called accessory sinuses of the nose They extend from the nasal passages into bones of the skull, and are named according to the bones in which they lie as the frontal, ethmoidal, sphenoidal, and maxillary sinuses The maxillary sinuses are also called antrums The maxillary sinuses are found on either side of the nose They are large in size, and lie between the floor of the eye socket above and the upper teeth below The frontal sinuses lie in the forehead above the roof of the eye socket, one on either side of the midline of the forehead The ethmoidal sinuses are three groups with numerous air cells, situated between the eyes in either side of the midline or septum of the nose The sphenoidal sinuses, two in number, are situated above and behind the nose proper They are all lined with a delicate mucous membrane continuous with the nasal mucous membrane When the sinuses become infected, **sinusitis** is said to be present (A W L, R S M)

SINUSITIS. Acute or chronic infection of the nasal **sinuses** They are most commonly infected during an acute **rhinitis** or cold in the head Abscess of the roots of the teeth directly under the floor of the maxillary sinus may rupture upward, thereby infecting this sinus

The chief symptom of sinusitis is headache, usually limited to some portion of the face near the involved sinus The headache is directly due to obstruction of the opening leading from the sinus cavity to the nose, thereby preventing the escape of infected secretion or the entrance of air into the sinus In chronic sinusitis the discomfort is often present in the forenoon Usually a chronic discharge is present, much of which is swallowed

Treatment of sinusitis is local and general, involving the establishment of correct drainage of involved sinuses, correction of any nasal or dental abnormality and general measures for improving the bodily health The treatment is best given by a rhinologist Sinus infection in children is often relieved by the removal of infected tonsils and adenoids (R S M)

SINUSOID. **Circulatory system.**

SINUSOID. **Trigonometric Curves.**

SIPHON. For the general use of this term in connection with the flow of fluids, see **hydrokinetics** In zoology, it refers more specifically to a passage between the **mantle** folds of **bivalve** mollusks through which water enters or leaves the mantle cavity In some species these passages are developed into long muscular tubes and in others they are no more than poorly marked openings They are two in number, a dorsal or excurrent siphon and a ventral or incurrent siphon Water is taken in through the latter, passes through the gills to the chambers above them, and flows out through the dorsal siphon

A part of the mantle border in some of the marine **gasteropods** also forms a tube through which water can be drawn into the mantle cavity This tube is known as the siphon

The term oral siphon is applied to the canal leading to the mouth of **ascidians** and the opening from the atrial cavity is sometimes known as the atrial siphon

Unlike these organs, all of them associated with respiration, the siphon of sea urchins (**Echinoidea**) is a slender tube associated with the alimentary tract (A W L)

SIPHONAL CANAL. An extension of the lip of the shell surrounding the siphon of many **snails** (A W L)

SIPHONAPTERA. The fleas An order of **insects** characterized by high compressed bodies, sucking mouths, and complete metamorphosis The eggs are dropped in the quarters occupied by the animals on which the fleas live and the larvae live on organic debris The great majority of the known species live as adults on mammals but some are found on birds Species found on the dog and cat are sometimes troublesome to man (A W L)

SIPHONOGLYPH. A ciliated (**Cilia**) groove in the angles of the **stomodaeum** of **sea anemones** It conducts water currents into the enteric cavity for respiratory purposes and as a carrier of food particles, and also carries currents outward In some species excurrent and incurrent siphonoglyphs occur and in others a single one serves both purposes by reversal of the effective beat of the cilia (A W L)

SIPHONOPHORA. **Hydrozoa.**

SIPHONOZOOID. A specialized **polyp** in the colonial **sea feathers**, **sea pens**, and related forms It draws water into the enteric cavity of the colony (A W L)

SIPHUNCLE. A slender tube extending from the visceral hump of the **nautilus** through perforations in the septa of the shell along the entire spiral The siphuncle contains blood vessels and its function is supposed to be the maintenance of the gas content of the closed chambers of the shell By this contained gas the weight of the shell is offset to aid the animal in floating (A W L)

SIPUNCULIDA. **Gephyrea.**

SIREN. **Musical Sounds.**

SIRENIA. The **manatee** and **dugong**, constituting an order of mammals They are marine animals with fore legs modified as flippers and hind legs lacking The manatee is found on the east coast of Florida and southward and the dugong is found near Africa, Australia, and the islands of the Oriental region (A W L)

SIRIUS. Sirius (**α Canis Major**) is the brightest star in the sky and volumes have been written concerning its matchless brilliancy Historically, it is undoubtedly the most interesting star in the heavens and references to it are found throughout all ancient literatures back to the earliest known writings. Aside from its

surpassing brilliancy, the fact that it may be observed from every habitable portion of the earth has served to make it an object of veneration by all peoples. Sirius was worshiped in the valley of the Nile long before Rome was even heard of, and many ancient Egyptian temples were so arranged that the light from this star would penetrate to the inner altars.

Astronomically, Sirius is particularly interesting as being the typical, A, **spectral type**. The companion of Sirius is the first **white dwarf** discovered. (W.K.G.)

SISKIN. Aves, Passeriformes. A quietly colored **finch**. The numerous species are found throughout the temperate part of the northern hemisphere and in South America. The pine siskin of North America, *Spinus pinus*, also called the pine finch, is finely streaked with brownish on a lighter ground and has a few yellow marks on wings and tail. (A.W.L.)

SITITUNGA. Mammalia, Artiodactyla. An **antelope**, *Limnotragus spekei*, found in swampy ground in central Africa. It is grayish brown in color and of medium size. Also called the nakong. (A.W.L.)

SKATE. Pisces, Plagiostomi. Cartilaginous fishes (**Pisces**) characterized by the broad flat body. The pectoral fins are extended at the sides and along the greater part of the head and body and are angled at the outer margin so that the general form is quadrangular. The tail is long and slender and is sometimes armed with spines. The name is applied to the common rays, making up the family Rajidae. Several species are found off the coasts of the United States, including the common skate of the Atlantic coast which also bears the remarkable name, tobacco-box. The family is represented in most of the warm and temperate seas. (A.W.L.)

SKELETAL SYSTEM, SKELETON. An aggregation of rigid or semirigid structures that provide mechanical support for the body and usually a lever system on which the muscles act.

The simplest type of skeletal system is found in the **sponges** (**Porifera**) and some of the **coelenterates**. Sponges have scattered spicules of calcareous or siliceous matter among their loosely integrated tissues or are held together by a meshwork of fibers composed of the material spongin, so familiar in the sponges of commerce. The commercial sponge is, in fact, the skeleton freed of organic matter. Spicules are variously formed bodies, some straight rods, some with radiating axes from three to six in number, and some expanded at the ends. Approximately similar scattered bodies are found also in alcyonarians, and in some of these animals they are united to form a continuous mass in which the polyps are imbedded or a solid core surrounded by softer material. Rock **corals** lay down a calcareous deposit beneath the base to which each **polyp** of the colony adds.

In many invertebrates the body wall is the sole support of the animal. Even though it is soft, the incorporation of muscular layers in it provides for movement without rigid skeletal structures.

The **echinoderms** differ in having calcareous plates (ossicles) throughout the integument. In the sea urchins they are closely joined to form a shell and in the sea cucumbers they are small and scattered. Other groups show an intermediate condition with closely associated but movable ossicles. These structures in the sea urchin also illustrate lever action in the use of the spines for locomotion and in the peculiar chewing organ known as **Aristotle's lantern**.

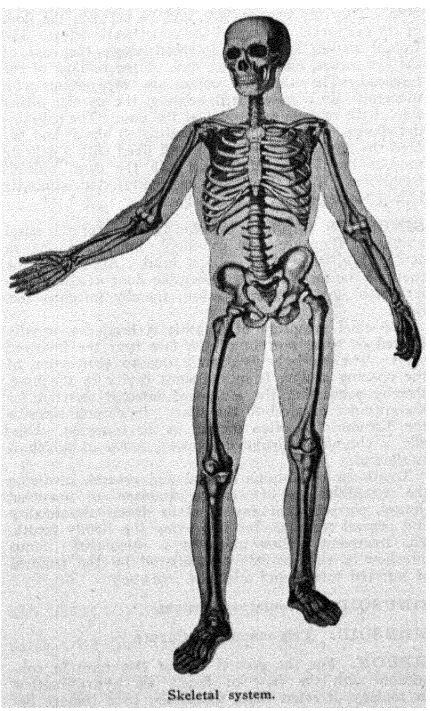
The **arthropods** and **vertebrates** differ in the presence of a complex skeletal system which supports the body and forms the foundation of the jointed appendages. In no other phyla are leverlike appendages found.

The arthropods have an exoskeleton made up of hard plates (sclerites) of **chitin** and calcareous matter, formed in circumscribed areas of the **cuticula**. They are separated by flexible zones which provide for freedom of movement, and are moved by muscles attached to their inner surfaces. The **appendages** are formed of rigid segments attached to each other and to the body by the flexible tissue of the joints. The skeleton forms a sheath enclosing the muscles in such appendages.

Among the half-million species of arthropods wide variation is inevitable. In general the exoskeleton of the head forms a compact capsule. The skeleton of the **thorax** also tends to become compact, although its segments are distinctly recognizable in many species. This portion of the exoskeleton also forms a shieldlike **carapace** in many species. The abdomen retains greater mobility, although its segments may be reduced in number and the exoskeleton of each may be consolidated to a ring surrounding the body. A moderately complex segment of the exoskeleton contains a dorsal, a ventral, and two lateral sclerites known respectively as the tergum or tergite, the sternum or sternite, and the pleura or pleurites. In many cases this plan is simplified by fusion or made more complex by subdivision of the sclerites.

An endoskeleton of limited extent in the arthropods is made up of internal projections from the exoskeleton known as apodemes. They serve as places of attachment for muscles.

One important result of exoskeletal support is the provision of wings in the insects as thin-walled sacs of the body wall. By the apposition of the upper and lower walls of these sacs they become thin membranous planes sufficiently strong and rigid to support



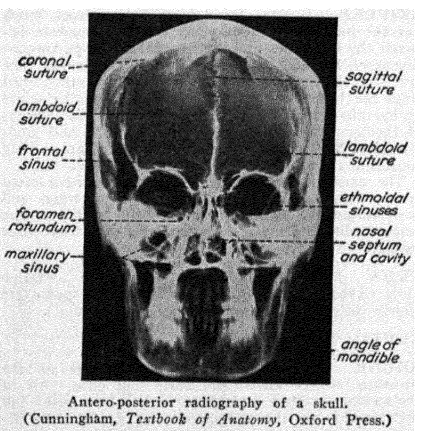
Skeletal system.

the body in flight. Thus the jointed appendages are freed from participation in adaptation for flight.

Exoskeletal structures also appear in the vertebrates but here they are merely hard parts without the usual supporting functions of the skeleton. They are derived from either or both layers of the skin. The category includes teeth and beaks, horns, claws, hoofs and nails, scales, feathers, and hair. Bony plates associated with scales, as in the alligator and armadillo, are also exoskeletal.

The supporting skeleton of the vertebrates is an endoskeleton composed of **bones** and **cartilage**. It is made up of two chief divisions, an axial skeleton consisting of a vertebral column, ribs, and skull, and an appendicular skeleton including pectoral and **pelvic girdles**, each bearing a pair of appendages. The pharyngeal wall of fishes is supported by the visceral skeleton which persists to a limited extent in the more advanced classes. In the elasmobranch fishes now living, the skeleton is composed entirely of cartilage. In most vertebrates it is made up very largely of bone.

The skull in the elasmobranch fishes consists of a mass of cartilage below, behind, and partially enclosing the brain. This structure is called the chondrocranium. In the bony fishes it is replaced by bones in the same position and is supplemented by superficial bony plates enclosing the remainder of the brain. The jaws of the elasmobranchs are also supported by cartilages and in the bony fishes these cartilages are supplemented by bones. Above the fishes a chondrocranium appears in the embryo and is replaced during development by the ethmoid bone and parts of the sphenoid, temporal, and occipital bones, taken in order from front to back. The remaining bones are not preformed in cartilage. They are more numerous in the lower forms than in man. In the human skull they



Antero-posterior radiography of a skull.
(Cunningham, *Textbook of Anatomy*, Oxford Press.)

are the pair of nasal bones in the bridge of the nose, the pair of lachrymals in the orbits, the vomer in the nasal septum, the large frontal bone of the forehead, the parietals in the top and sides of the skull, the upper part of the occipital forming the lower back wall of the skull, and the temporals above the ears. The upper jaw is based on the maxillary bone from which the palatine extends into the hard palate. A slender rod, Meckel's cartilage, supports the lower jaw of the human fetus but the permanent lower jaw is the mandible, a dermal bone formed independently.

The vertebrae that make up the spinal column consist typically of a centrum bearing a neural arch above and a haemal arch below. The neural arch surrounds the spinal cord and is surmounted by a neural spine. In the fishes the haemal arch encloses the dorsal aorta and in the region of the body cavity open haemal arches form ribs known as fish ribs. In other classes and in a few fishes these ribs are replaced by similar slender bones known as true ribs. They develop between the segments of the body lateral to the fish ribs and above them, and articulate with processes of the vertebrae. These ribs join a median ventral structure, the sternum or breast bone, composed of bones and cartilages.

The vertebrae differ in various regions of the body. The first, with which the skull articulates, is the atlas. The second, the axis, is noteworthy for its odontoid process, a solid anterior extension of the centrum. This process is the centrum of the atlas. These two and the remainder of the series in the neck are called cervical vertebrae. The following series with which the ribs articulate are the thoracic vertebrae. The lumbar vertebrae extend to the articulation of the pelvic girdle, where one vertebra or a fused series constitute the sacrum. The following caudal vertebrae lie in the tail or, in the apes and man, are fused to form a mass called the os coccyx.

The pectoral and pelvic girdles are composed of three pairs of bones, two passing downward and toward the median line of the body from the articulations of the appendages and one upward. Of the more constant bones in the pectoral girdle, also called the shoulder girdle, the upper bone is the scapula (shoulder blade), the anterior of the lower bones is the clavicle (collar bone), and the posterior is the coracoid. These two pairs attach to the sternum. They are supplemented in amphibia and reptiles by other bones. The bones of each half of the pelvic girdle are the dorsal ilium, the anterior pubis, and the posterior ischium. This girdle in many forms is firmly attached to the sacrum.

The girdles are modified in various ways. The principal tendency of the pectoral girdle is toward simplification by the loss of bones, so that in many species only the scapula and clavicle remain, as in man. In the hoofed mammals only the scapula persists. In the moles, however, the girdle is large and strong. The pelvic girdle, in correlation with the stresses that it bears in locomotion, becomes compact. The bones of each side tend to fuse and the pubic symphysis, at the ventral union of the two halves, is very firm. The name pelvis or pelvic bone is often applied to this composite structure.

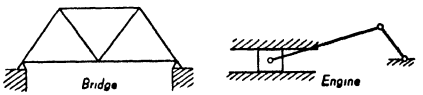
The primitive appendages are the paired fins of the fishes. These structures are precursors of the **pentadactyl appendage** of terrestrial vertebrates. From this basic plan the structure of appendages in various groups has come by modification of the proportions and relations of the bones, by loss of digits, and to a limited extent by the fusion of separate bones. Both loss and fusion have occurred in the wings of birds, and maximum loss is found in the legs of the horse and allied species, where a single functional digit remains.

The appendages also contain sesamoid bones, small rounded bones developed in the tendons spanning movable joints. The most constant of these bones is the patella or knee cap.

The visceral skeleton in its primitive condition consists of a series of small bones and cartilages supporting the branchial arches between the gill slits. In the existing vertebrates the embryonic primordia of the hinged jaws are derived from these arches but the visceral skeleton is otherwise greatly reduced except in the fishes. It persists in part as the small bones (ossicles) of the middle **ear**, the hyoid bones supporting the **tongue**, and the cartilages of the **larynx** and upper part of the **trachea**. (A.W.L.)

SKELETON DIAGRAM. A skeleton or line diagram is a graphical representation of the members of a

machine or structure A simplified diagram of a machine or of some static structure, can be as useful for certain purposes as a complete drawing In fact, a



Skeleton diagrams

skeleton diagram is often more useful than a drawing of the actual equipment it represents, because of the elimination of unnecessary detail which might be confusing Generally speaking, a skeleton for a static structure is a series of lines which might be thought of as being the center lines of the different structural members In the case of a machine, a skeleton diagram could be one which would represent the machine kinematically (See **Mechanics**) Such diagrams are useful for study of motions and analysis of stresses (F T M)

SKEW CURVES. Curves in Space.

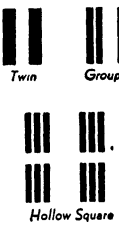
SKIMMER. Aves, Charadriiformes A bird (**Aves**) related to the terns and gulls but distinguished by its peculiar beak The entire beak is long and compressed and the lower mandible is much longer than the upper The bird dips this lower mandible into the water as it flies Of the few species only one, the black skimmer, *Rhynchops nigra*, is North American (A W L.)

SKIN. The covering of the body of **vertebrates** It consists of two parts, an outer epidermis and an inner dermis or corium The former develops in the embryo from the outer **germ layer**, the ectoderm, and the latter from the middle germ layer, the mesoderm

The epidermis is composed of many layers of cells in two principal strata, the stratum corneum and the stratum germinativum The flattened cells next the surface are hardened by deposits of pareleidin, a substance related to keratin, and are said to be keratinized They make up the stratum corneum Below them are several layers of thicker cells whose active proliferation gives rise to the cells of the stratum corneum These layers constitute the stratum germinativum In the outer cells of this stratum granules of keratohyalin appear as forerunners of the pareleidin of the stratum corneum, forming the thin stratum granulosum A thin clear zone just outside of the granular layer, known as the stratum lucidum, is regarded as the basal layer of the stratum corneum In its cells the granules of keratohyalin become a diffuse intermediate substance, eleidin

The corium is a dense connective tissue layer extending from the fatty subcutaneous tissue It is obscurely divided into an inner stratum reticulare and an outer stratum papillare which rises in papillae beneath the epidermis Epidermal derivatives including hair follicles, sweat glands, and sebaceous glands extend into the corium and it contains nerve endings, tactile corpuscles, and blood vessels Smooth muscle fibers attached to the hair follicles lie in it and in some parts of the skin it contains other muscle fibers The voluntary muscles of the face by which expression is controlled end in it (A W L)

SKIN EFFECT. Ordinarily the **resistance** of an electrical conductor depends only on the **material**, temperature, cross-sectional area, and **length of** that conductor On this basis, a conductor **would** have the same resistance for both alternating and direct current However, it is a fact that the **resistance** of a conductor carrying alternating current **is greater** than one carrying direct current The **reason for this** is to be found in the fact that the continuous cutting of a conductor by **flux** from an **alternating current circuit** sets up internal **electromotive forces** which oppose the flow of current near the center of the conductor, and assist it near the circumference As a result of this, the current density in the conductor is greater near the skin This phenomenon is known as skin effect Conductors for large currents, such as buses, will exhibit the most economical disposition of metal if they are shaped with due regard to this skin effect The metal is arranged so as to eliminate any solid core For alternating current buses, the tube is excellent, however, bus bars may be grouped, as shown in the accompanying diagram, to yield economical disposition of copper (F T M)



SKINK Reptilia, Sauria A **lizard** of the family Scincidae These animals vary greatly in structure but are usually small with short legs and long tails The scales are underlaid with bony plates The several species of the United States are widely distributed but are more common in the south One of the most remarkable species of the family is the Australian stumptailed lizard, a thick-bodied species with a very short blunt tail (A W L)

SKIPJACK. Pisces, Teleostei A common fresh-water fish, *Pomolobus chrysochloris*, of moderate size, related to the herring and shad It is found throughout the Mississippi valley to the Gulf of Mexico and in Lake Erie and Michigan The back is blue and the sides silvery Of no value as a food fish (A W L)

SKIPPER Insecta, Lepidoptera An **insect** much like the butterflies but in many ways intermediate between the butterflies and moths Most species are distinguished by their knobbed and hooked antennae The few that lack the hook are less easily distinguished from the butterflies except by the veins of the wings or by other details of structure Most of the skippers of the temperate zones are of moderate size and modest colors but many tropical species are brilliant They constitute the superfamily Hesperioidea

The name skipper refers to the vigorous and often erratic flight of these insects Their small wings and powerful muscles accompany rapid flight Many species perch readily and make short darting flights from place to place (A W L)

SKUA Aves, Charadriiformes *Catharcta* Marine birds (**Aves**) related to the gulls The few species are widely distributed in both hemispheres. (A W L)

SKULL Skeletal system.

SKUNK Mammalia, Carnivora Animals of the Americas, widely known for their foul odor All of the species are black and white, with a long bushy tail under which are the two glands that produce the defensive secretion

The skunks of North America have been divided into fifteen species and a number of varieties These species are grouped as the striped or common skunks and the small spotted skunks, belonging respectively to the two genera, *Mephitis* and *Spilogale* Both genera are widely distributed

The fur, especially of the larger striped skunks, is commercially desirable (A W L)

SKUNK CABBAGE. Aroids.

SLAG. Slag is a fused product occurring in connection with metallurgical and **combustion** processes It is composed of the **oxidized** impurities in a metal, and

of a fluxing substance, and of ash. In the steel industry, slag is the neutralized product of anhydrous compounds entering into the process. Slag is of great importance to the operator of a steel **furnace** or a cupola, in that, through the slag, impurities are separated and removed from the metal. By floating as a molten covering on the pool of metal, slag protects it from oxidation, and serves to keep it clean. By controlling the character of slag, and continuous observation, the metallurgist insures that the metal is of the quality desired.

Molten ash is one of the products of **combustion** of coal in certain high capacity boiler furnaces. It is also called slag. In some plants, the ash is removed from the furnace in this fluid form. Such furnaces are known as slag tap furnaces. Slag has some commercial value as **ballast**, coarse **aggregate** for **concrete**, road metal, etc. (F.T.M.)

SLATE. A fine grained homogeneous sedimentary rock composed of **clay** or volcanic ash which has been metamorphosed (foliated) so as to develop a high degree of fissility or slaty cleavage which is usually at a high angle to the planes of stratification. This high degree of fissility makes the better grades of slates an extremely useful roofing material which, however, has been somewhat replaced in recent years by synthetic and manufactured substitutes. The finest slates in the world come from Wales, Britain. (R.M.F.)

SLEEPER. Dormouse.

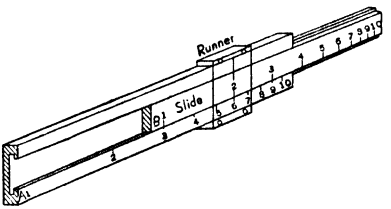
SLEEPING SICKNESS. Trypanosomiasis.

SLEET. When raindrops enter a layer of intensely cold air, they become supercooled, that is, cooled below the freezing point but without freezing. In this state they are highly unstable, and upon coming in contact with any object, even a speck of dust, they suddenly freeze into white, spherical pellets of sleet. Larger objects such as twigs or telephone wires, when touched by these supercooled drops, receive a coating of ice, which may result in a landscape of marvelous beauty when the sun appears, but which often proves very destructive if the ice is heavy. Sleet is quite commonly mixed with snow or with rain; but it is always a cold-weather product, and is not, as many suppose, a small form of **hail**. (L.D.W.)

SLIDER. Reptilia. Chelonia. **Turtles** related to the painted turtles and land tortoises. The several species are brownish or greenish, marked with yellow and in some cases also with red. They constitute the genus *Pseudemys*. Most of the species are confined to the southern states but one, known as the red-bellied terrapin, is found near coastal rivers from Florida to Cape Cod and another lives in the Mississippi valley as far north as Iowa. Both of these species are edible. Also called cooters. (A.W.L.)

SLIDE RULE. The slide rule is an instrument for multiplying, dividing, extracting roots, and obtaining powers of numbers mechanically by logarithmic means. In construction, the simple slide rule consists of two adjacent logarithmic scales which may be so set that a reading on one is added to a reading on another. This represents the addition of logarithms when multiplying numbers. The slide rule for general use is found in several different forms, and there are many special slide rules such as stadia rules, electrical rules, hydraulic computing rules, etc.

The accompanying figure illustrates the principle of multiplication by the slide rule. Two logarithmic scales, A and B, are arranged on a slide rule so that they may be mechanically added. In the illustration given, the process of multiplying three by two is shown. The end of the B scale is aligned over the 3 on the A scale, so that to 3 on the A scale may be added 2 on the B scale. Now if these scales were uniformly divided, the result, of course, would be five units on the A scale,

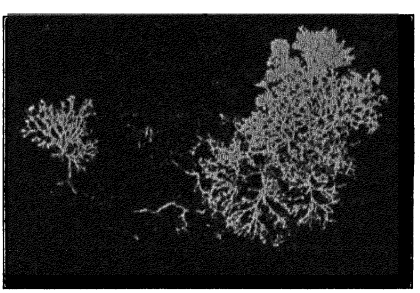


Simple slide rule.

but since they are logarithmically divided, the result on the A scale is the product rather than the sum. Thus, under the 2 on the B scale, one reads the product of $3 \times 2 = 6$ on the A scale. A glass runner is provided so that the alignment of the numbers of the two scales may be facilitated. By halving the divisions, two complete scales could be placed on the rule. Using a full scale, such as A of the figure, and a double scale, one can extract square roots. A triple scale can be used for cube roots. Other scales contained on the ordinary slide rule are a uniform division scale for logarithms, and scales for reading the value of the trigonometric functions of an angle known as the sine and tangent. (F.T.M.)

SLIME MOLDS. Myxomycetes. Slime molds are **saprophytes** found growing on wood, on rocks, or on grass, or wherever there is sufficient moisture to prevent them from drying up. There are some 300 species.

Claimed and rejected by both botanists and zoölogists, this group of organisms occupies a doubtful position in either kingdom. They are simple organisms which have certain characteristics which place them in the plant kingdom and others which make them animals. Perhaps they are best treated as organisms which



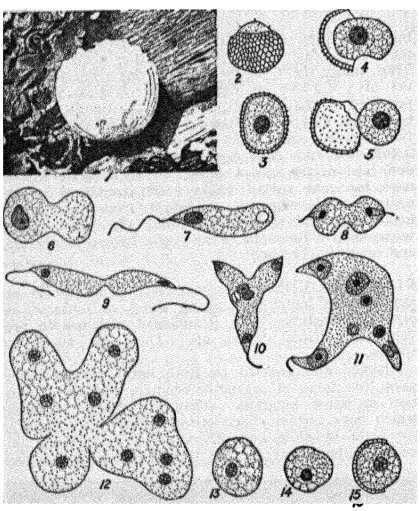
A slime-mold (Myxomycete), *Fuligo septica*, growing on the inner surface of a glass jar. About natural size. (From Gager, *General Botany*, P. Blakiston's Son & Co.)

are in a separate kingdom from both plants and animals.

The vegetative phase of the life history of a slime mold starts with the germination of the **spores**. The spores are unicellular non-motile bodies. When sufficient moisture is available the wall of the spore bursts and the **protoplast** escapes. It becomes a uninucleate bit of naked **protoplasm** which moves about in an amoeboid (See **Amoeba**) manner. Soon it forms a single **cilium** at one end and by means of this moves more rapidly in the water. It is now known as a swarm spore. After a time the cilium is lost and it

becomes once more like an amoeba, crawling about by forming extensions of its protoplasm, called pseudopodia, and "flowing" into them. In this stage it is called a myxamoeba. Both swarm spores and myxamoebae can increase by simple division.

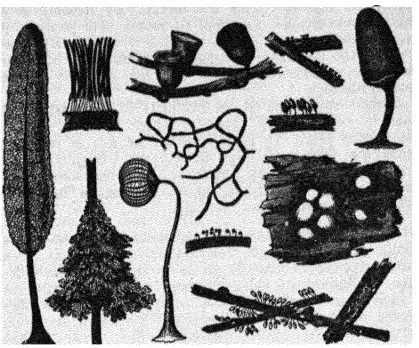
After a time the myxamoebae move together and coalesce, forming **zygotes**. Coalescence continues until considerable masses are formed. In these nuclear divisions occur repeatedly, forming a multinucleate mass of naked protoplasm which is not separated into cells. This mass of protoplasm is usually colorless, but sometimes white or yellow or brownish. It has a consistency very similar to that of raw egg white. It is called a plasmodium. The plasmodium is a formless mass which creeps or flows about over the substratum. This



Reticularia Lycoperdon. 1, mature fruiting body on a log; 2, spore, external view; 3, spore, internal view; 4, spore germinating; 5, protoplast which has escaped from spore wall; 6, simple myxamoeba; 7, zoospore; 8, dividing zoospore; 9, fusion of two gametes; 10, 11, three zygotes uniting to form a plasmodium; 12, portion of protoplasm dividing by cleavage to form spores; 13, young spore before wall is formed; 14, spore with young wall; 15, nearly mature spore. (From Malcolm Wilson, *Transactions* of the Royal Society of Edinburgh, Volume 55.)

movement is not a slow regular progress but a series of surges. As it moves about, the plasmodium engulfs food substances such as bacteria, spores of fungi and other organic substances, which are digested in the plasmodium.

In time the plasmodium is ready to reproduce. At this time it changes its reactions and turns toward the light. It heaps itself up in certain places. These heaps become the **sporangia**. In some species a long slender stalk is formed by the plasmodium and at the top of the stalk the sporangium is formed. A membrane is formed around the heaped-up mass of protoplasm. The protoplasm and wall form a sporangium. Within this wall the protoplasm becomes separated into numerous small units, each containing a single nucleus. Spores result when walls are formed around each bit of protoplasm. Dispersed among the spores are many slender threads which may be simple or branched in different species. These threads are the capillitia. They give strength to the sporangium and also because of their reaction to changes in humidity, which causes them to coil or straighten out, they aid in loosening the spores and pushing them from the sporangium. The spores are capable of resisting prolonged desiccation, as well as low and high temperatures. Eventually the spores germinate and the life-cycle is repeated.



Fruiting bodies of different kinds of Myxomycetes. (From Kerner's *Natural History of Plants,* Blackie & Son.)

The sporangia of slime molds show a variety of forms. In some species they are small brown balls appearing singly or in clumps on rotten wood. In other species they are long-stalked structures of great beauty and delicacy. Some resemble small mazes of irregular shape. A few suggest spots of thick brown grease deposited on leaves and stems. The size of the sporangia varies from coarse fusiform bodies an inch and a half to two inches long and an inch thick, to minute objects scarcely a millimeter in diameter.

Slime molds are of no importance to man. (R.M.W.)

SLIP. For the meaning of slip in geology, see **Fault.**

Slip is a characteristic of the induction **motor. Alternating current** is used in the field windings of an alternating current motor to produce a revolving field. The speed of this revolving field is the synchronous speed, and depends on the frequency of the system. The rotor of the induction type of alternating current motor revolves at a speed less than synchronous. The percentage by which the rotor speed falls below synchronous speed is called the slip, and this varies from practically zero at no-load up to maximum at the stalling torque.

The slip of a propeller is the difference between its actual forward motion and that which it would have if it were revolving in a solid medium analagous to a bolt in a nut. The slip of water propellers is less than that of air propellers, because of the relative densities of the two media in which these propellers rotate.

The slip of a pump arises in the following way: A positive displacement type **pump,** such as a piston or plunger pump, should, theoretically, discharge a volume of liquid equal to the piston displacement. Leaky valves, defective piston rings, and other faults, can cause the delivery to be less than the piston displacement. This difference, stated as a percentage, is called slip, and may have a value of about 5% when the pump is in good condition. (F.T.M.)

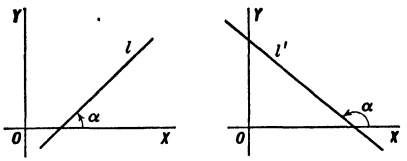
SLOPE OF A CURVE. Derivative of a Function of One Variable.

SLOPE OF A LINE. The inclination of a straight line is the least positive angle α from the X-axis to the given line.

The slope of a straight line is the tangent of the inclination angle α of the line: $m = \tan \alpha$.

The slope of a horizontal line is 0, but a vertical line has no slope

If a line rises from left to right, its slope is positive,



but if the line falls from left to right, its slope is negative

The slope of the line through the points (x_1, y_1) and (x_2, y_2) is given by the formula

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

when **rectangular coordinates** are used

If two lines are parallel, their slopes are equal If the lines are perpendicular to each other, their slopes are negative **reciprocals** of each other (L L S)

SLOTH. Mammalia, Edentata Animals of Central and South America, highly specialized for arboreal life Their claws are large hooks by which they suspend themselves from branches, and they are so thoroughly adapted to this inverted position that the hair runs from belly to back, opposite to its direction in animals of the usual position They eat the foliage of cecropia trees by preference Apparently in coordination with the total lack of competition and risk in their lives, these strange creatures are extremely dull-witted

The sloths are of two forms two-toed and three-toed, each including several species The two-toed sloths (*Choloepus*) are also called unaus, and the native name for the three-toed species (*Bradypus*) is ai (A W L)

SLOW-WORM. Blind-worm.

SLUDGE The suspended matter which is deposited after **sewage** has undergone sedimentation is known as sludge This sludge must be removed from the sewerage system at regular intervals to make room for new deposits The disposal of sludge is accomplished in a number of different ways It may be discharged in waters containing enough oxygen to prevent putrification, buried in trenches, used to fill land, burned or utilized in the manufacture of fertilizer The moisture content must be removed in order to burn sludge or use it for fill or fertilizer This may be done by machinery or by depositing the sludge on filter beds where it is allowed to drain and dry out (C W C)

SLUG. Mollusca, Gasteropoda **Mollusks** of the family Limacidae, related to the land snails but without an external shell The name also appears in the term sea slug, applied to members of the marine group, Nudibranchiata, which are also without external shells. (A W.L)

SLUICE. A **channel** through which water issues is, in some cases, called a sluice A sluice may be a pressure conduit, or it may be an open flume For instance, the word may be applied to an artificial channel to lead water from one point to another, especially a temporary wooden channel Sluices are often incorporated in **dam** structures A sluice through a dam is a conduit cast in the concrete, and equipped with controls called sluice gates The purpose of the sluice is to empty the reservoir if necessary, to control the water level, and to aid in passing floods. (F T.M)

SMALL ERRORS. **Differentials.**

SMALLPOX (Variola). An acute highly contagious disease caused by a filterable virus. The disease is characterized by fever and a peculiar skin eruption which leaves scarring upon healing

The disease has been known since antiquity and lesions have been seen on the skin of an Egyptian mummy of the twentieth dynasty The disease originally spread from India and Central Asia to Europe and became especially prevalent at the time of the Crusades in the eleventh century It was first introduced in America by a negro slave of Cortez in 1520, producing an epidemic that killed several million people One century later it appeared in New England It was first called smallpox in Europe, to differentiate from grand-pox (**syphilis** of the skin)

Only a small percentage of people have natural immunity Permanent immunity usually develops after an attack of smallpox Epidemics vary greatly in severity In recent years the disease has been of a mild type

The incubation period averages between eight to twelve days in the majority of cases The onset of the disease is usually sudden and may begin with a chill The temperature soon becomes high and headache, generalized pain and vomiting are frequently all present

As the skin eruption appears the symptoms and fever abate and the patient feels quite well The eruption first appears as reddish spots which become elevated. After a few days the elevated area is capped by a small blister On the seventh or eighth day this blister contains pus During this period, secondary fever develops, gradually disappearing as healing and desquamation, or peeling, progress This begins around the twelfth or fourteenth day

Black smallpox is a virulent fulminating type of smallpox which invariably causes death in two to six days

Smallpox that may occur in those who have been vaccinated is called varioloid, and is usually a mild disorder

The deaths in smallpox are usually due to complications The most common are laryngeal **edema**, pneumonia, septicemia, nephritis, gangrene, and blindness

There is no specific treatment for smallpox, and the general treatment is similar to that of any severe acute infection In modern times the advent of **vaccination** has reduced the incidence of this disease tremendously, so that in civilized countries it is of rare occurrence (R S M)

SMALTITE-CHLOANTHITE. The mineral smaltite-chloanthite is an **isomorphous** mixture of **cobalt diarsenide**, $CoAs_2$ (smaltite), and **nickel** diarsenide, $NiAs_2$, (chloanthite), the proportions varying widely It occurs in tin-white **isometric** crystals, but is also found massive It is brittle, hardness 5 5–6, specific gravity, 6 4–6 6, luster, metallic, color, tin-white to steel-gray, streak, nearly black, opaque It is associated with other nickel and cobalt minerals as well as with **silver** and **copper** ores It is found in Bohemia, Saxony, Baden, Alsace, Spain, England and New South Wales In the United States it has been found in Connecticut, New Jersey; and in Canada at Cobalt, Province of Ontario It is used as an ore of both metals (E S C S)

SMELL. A chemical sense by which the animal perceives substances in the gaseous state and sometimes in exceedingly small quantities It is valuable to the individual because the rapid transmission of many volatile substances over long distances permits the recognition of foods or enemies prior to close meeting with them. The sense is resident in **olfactory organs.** (A W.L)

SMELT. Pisces, Teleostei. The small fishes (**Pisces**) of the family Osmeridae, including the **candlefish** and the common smelt, *Osmerus eperlanus*, of the Atlantic.

Both of these species are marine, ascending the streams to spawn, and both are important food fishes. (A.W.L.)

SMELTING. The process of heating ores to a high temperature in the presence of a **reducing** agent, such as **carbon** (coke), and of a **fluxing** agent to remove the accompanying rock gangue is termed smelting. Iron ore is the most abundantly smelted ore. It contains about 20 per cent gangue (clay and sand). The ore is heated in an air **blast furnace** with coke and **limestone** (fluxing agent) at a temperature above the melting point of iron and **slag** (fusion mixture of impurities and flux). The molten iron (the more dense material) and molten slag (the less dense material) are removed separately from the furnace. (R.K.S.)

SMEW. Aves, Anseriformes. A European name for a small **merganser,** *Mergellus albellus*. Sometimes also applied to widgeons and pochards, and said to be used for the pintail duck, although pintail is by far the more common name. (A.W.L.)

SMILAX. Asparagus.

SMILODON. Pleistocene.

SMITHSONITE. Smithsonite is **zinc** carbonate, $ZnCO_3$, a **hexagonal** mineral with a **rhombohedral** cleavage. It is a brittle mineral, hardness 5, specific gravity, 4.3–4.5; luster, vitreous to dull; color, usually white, but may be colored yellowish or brownish or perhaps blue or green due to impurities. It is translucent to opaque. Smithsonite is a secondary mineral after **sphalerite** or may replace **limestone** or **dolomite.** It is sometimes called calamine (but true calamine is a **zinc silicate**) and often associated with it. Smithsonite occurs in Siberia, Greece, Rumania, Austria, Sardinia, Cumberland and Derbyshire, England; New South Wales, South West Africa, and Mexico. In the United States it is found in Pennsylvania, Wisconsin, Missouri, Arkansas, and Utah. This mineral was named in honor of James Smithson, whose generous legacy founded the Smithsonian Institution at Washington, D. C. (E.S.C.S.)

SMOKE. Smoke is the colored product of incomplete combustion, consisting chiefly of particles of unburned carbon. The discharge of smoke to the atmosphere can be considered nothing but an evil—and an unnecessary evil at that. The evil effects of smoke may be considered under three headings, viz., (1) effect on health, (2) financial loss due to incomplete combustion, deleterious effect on plant growth, and begriming of buildings, (3) effect on standard of living.

The smoke nuisance is at its worst, of course, in metropolitan districts. The smoke is produced from both industrial and domestic fires. Smoke-abatement workers have found it much easier to render the former class smokeless than the latter.

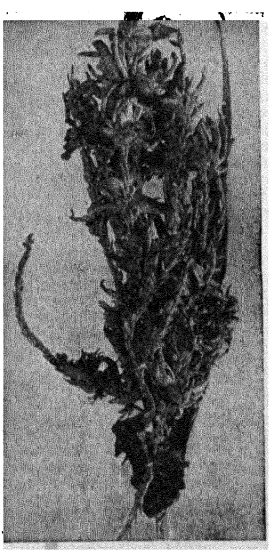
There has been no definite coordination discovered between diseases of the respiratory tract and **smoke density;** however, common sense would say that a smoky atmosphere was bound to be less healthful than air alone. Chronic sinus and nose troubles seem to be prevalent in extremely smoky atmospheres. It is a well-known fact that the effect of smoke is deadly to vegetation. One unit of sulfur in the coal gives about three units of **sulfuric acid,** a substance most poisonous to plant life; indeed, the sulfur dioxide content of flue gas has caused more than one large lawsuit to be brought against central station operators. Sulfuric acid plus rain has a detrimental effect upon the limestone of buildings. Smoke corrodes metals, darkens paints, and in many other ways creates a tremendous economic loss other than that due to loss of heating value of fuel. It is well known by those who have lived in smoky cities that a much lower standard of cleanliness is prevalent. Neither building interiors nor exteriors, clothing, hangings, furniture, etc., can be kept clean.

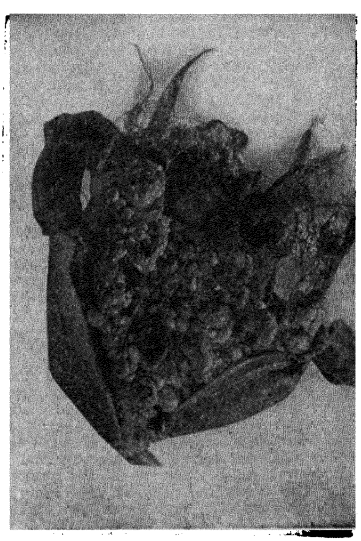
One of the oldest methods of gaging the smoke emitted by a chimney involves use of the Ringleman smoke comparison chart.

The Ringleman chart is composed of four sets of gratings. When these are placed about 25 feet from the observer the gratings merge to a solid color ranging from light gray to a dense black. The chart enables a smoke inspector to rate the character of smoke emission from a chimney by comparison. Smoke ordinances are often based on the Ringleman chart, as, for instance, prohibiting the emission of smoke to exceed "No. 2 Ringleman" more than a certain period of time, say one minute. (F.T.M.)

SMOOTH-HEAD. Pisces, Teleostei. A fish (**Pisces**) related to the salmons. The head is entirely without scales and the median fins, both dorsal and ventral, are located just before the tail. All of the species live in the deep sea. (A.W.L.)

SMUTS. Ustilaginales. Smuts are parasitic **Basidiomycetes** which are so named because of the conspicuous masses of sooty black spores which they form externally on the host plant. Infection by smuts is seldom fatal to the host plant but does seriously reduce its size

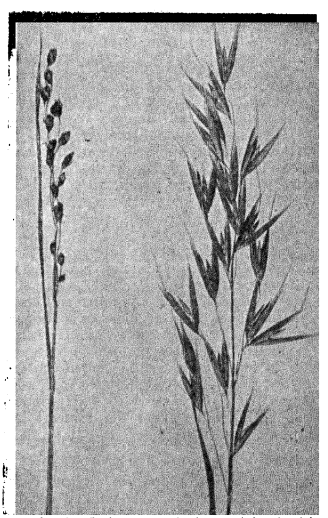




Corn smut. Left, smutted tassel; right, smutted ear.

and may even prevent seed formation completely. The fungus grows as a septate **mycelium** which penetrates between the cells of the host plant; into these cells it sends **haustoria**, which obtain nourishment therefrom. Presently this septate mycelium gives rise to immense numbers of **spores**. Often the presence of the mycelium causes the host tissue to enlarge tremendously, producing irregular tumor-like growths. These are particularly conspicuous in Corn Smut. The spores are thick-walled unicellular objects capable of surviving for some time under unfavorable conditions. On germinating, each spore develops a short germ tube, or promycelium, which becomes from one to four cells long. Each of these cells produces a spore. The promycelium becomes a basidium; and the spores, basidiospores. These spores are capable of infecting new host plants, producing therein a mycelium. Conjugation between cells of the mycelium occurs so that each cell comes to have two nuclei. As growth continues, the two nuclei of any cell divide simultaneously so that every cell continues to have two nuclei. When spore formation occurs, the two nuclei fuse, dividing again when the spore germinates. Many variations of this process are found; in many smuts the promycelium buds off from its apex many cells. Often fusion between two of these cells occurs immediately, even before they are separated from the promycelium.

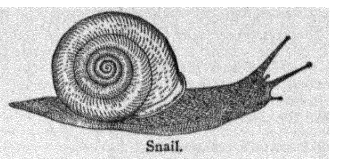
Because of the rapidity with which smuts may spread and the great reduction of seed production which their presence may cause, smuts are of great economic importance. One species, Corn Smut (*Ustilago zeae*), causes the loss of millions of bushels of corn yearly. Oat smut, *Ustilago avenae*, may cause a 30% reduction in yield, while other smuts are equally important. Control



Smutted oat head. Left, smutted plant; right, healthy plant.

of the parasites may be obtained by rotating crops; but due to the resistant nature of the spores, at least three years should elapse before replanting an infected field to the same crop. Other methods of control consist of soaking seeds in various solutions, such as formaldehyde (See **Aldehyde**) solution in water, or dusting infected seeds with copper compounds. (R.M.W.)

SNAIL. Mollusca, Gasteropoda. A name properly applied to most members of this class but usually given only to the small fresh-water and terrestrial species with coiled shells. The term does not correspond with any part of the scientific classification of mollusks beyond this general application.



Snail.

Snails are eaten in several countries of Europe, where they are regarded as a delicacy. (A.W.L.)

SNAKE. Reptilia, Sauria. A slender elongate **reptile** with no trace of external appendages and only in a few species with vestiges of the appendicular skeleton. The snakes differ from the lizards also in the large scales of the ventral surface. They are widely distributed and many species are poisonous.

Among the large number of snakes that bear distinctive names are the adders, racers, **vipers** and **pit vipers**, constrictors, including the **python, boa**, and **anaconda, cobras, craits, asp, bushmaster, fer-de-lance**, and many others. The poisonous North American species aside from the relatively unimportant coral snake of the southeast, are the **copperhead**, the **moccasin**, and the **rattlesnakes**. (See also **Fossil Reptiles.**) (A.W.L.)

SNAKE FLY. Insecta, Neuroptera. A peculiar **insect** found only in the far West. It has four membranous wings and the body is prolonged at the anterior end. They are insect eaters and are found commonly on the bark and foliage of trees. (A.W.L.)

SNAKE VENOM POISONING. Snake venom is a mixture of **protein** substance, cellular debris, fatty matter, and salts such as **calcium** chloride and phosphate, **ammonium** and **magnesium**. The venom of all snakes contains two toxic elements, a hemotoxin and a neurotoxin. The hemotoxin causes destruction of red **blood** and tissue cells with extensive swelling and discoloration of the soft parts. The neurotoxin attacks nerve centers causing **paralysis.**

Various venoms differ in the relative amounts of each of these toxins and in their strength. In the American tropics the **fer-de-lance**, the **mapepir balsagn**, the **barba amarilla** and the **jararaca** all have a venom that contains a powerful hemotoxin which causes rapid death in untreated cases. The venom of the **cobra** of India consists for the most part of the neurotoxin, and death results from paralysis of respiration. Venoms of other snakes contain a combination of the two toxins. The North American snakes, such as **rattlesnakes, copperheads, moccasins,** inject a venom which contains a considerable amount of the hematoxin, but it is not as rapid in its action as that of some of the tropical snakes.

Venom is injected through fangs which are a type of highly specialized tooth, and resemble in construction a hypodermic needle.

The mortality from snake bite is very high. In India the annual mortality is around 20,000. Anti-venom serum has been prepared and is easily accessible for use in many countries. In Brazil the Institute at Sao Paulo under the auspices of the Government, has made a study of the various venoms and anti-venom serums are widely distributed. Thus the mortality from snake bites has been reduced from several thousand to less than fifty. The annual mortality from this source in the United States is around 150. The Antivenom Institute of America is located at Glenalden, Penna., with subsidiary stations in different sections of the country.

In the treatment of snake bite cauterization should not be used The use of potassium permanganate crystals is condemned, as harm rather than good follows their use Proper treatment consists of application of a tourniquet where possible, or ligation of the vessels leading from the wound, and deep incisions at the site of the fang punctures with the use of some suction device Often the venom is absorbed slowly from the site of the bite, and this procedure should be carried out even several hours after the accident has occurred Antivenom serum should be injected as soon as possible to neutralize the poison (R S M)

SNAPDRAGON. Figwort.

SNELL'S LAW. Refraction.

SNIPE. Aves, Charadriiformes Long-legged and long-beaked wading birds (**Aves**) related to the sandpipers and woodcock They are found in marshy ground and occur on all continents North America has one species, the Wilson snipe (*Capella delicata*) or jack snipe, which is regarded to a limited extent as a game bird Certainly its erratic flight makes it a severe test of marksmanship This species breeds from the northern states northward and migrates to South America (A W L)

SNIPE FLY. Insecta, Diptera Two-winged **flies** with long legs and a conical abdomen They belong to the family Rhagionidae, sometimes called Leptidae Some of the species suck blood and in the western mountains are very annoying to human beings They receive the name **deer fly** in the west, a term applied to a small horse fly in the east (A W L)

SNOW. Snow crystals when freshly formed are often almost perfect and exhibit an endless variety of detail They are commonly flat, six-sided polygons, stars, or spangles, often of very complicated and beautiful design, but always with the 60° and 120° angles characteristic of the hexagonal system Sometimes they are needle-like, resembling miniature six-sided lead pencils, or needle-like with a hexagonal head, like a pin The finer spicules are sometimes suspended high in the atmosphere, and are the cause of **halos** Snow differs from **frost** chiefly in being formed in the air instead of upon solid objects near the ground, the crystallization nuclei being particles of dust Partly melted crystals often cling together to form snowflakes of varying size, and may melt into raindrops before reaching the ground Snow appears white only because of the multitude of reflecting surfaces, the individual crystals are of transparent ice In the United States, a heavy snowfall is commonly followed by intense cold, partly because of the low absorptivity of snow for solar radiation, and partly because of the cyclonic character of the snowstorm, which brings a change of wind to the north on the westward or following side of the storm (L D W)

SNOW LEOPARD. Ounce.

SOAP. Esters.

SOAPSTONE. Talc.

SOCIETY. A group of individuals of the same **species** living together for mutual benefit, with some division of labor The society is a high expression of colonial organization in the animal kingdom, and is not sharply separated from simpler forms of colonies

In the simplest type of colony, as found among the one-celled animals, the associated individuals are similar and each is capable of complete existence in itself In the same group a slight division of labor appears, accompanied by structural differentiation of the individuals for different tasks This form of organization persists in the **coelenterates, bryozoans,** and **ascidians,** with varying degrees of structural continuity in the colony and varying degrees of differentiation and division of labor.

Among the more highly organized animals the possibility of association of individuals in a complex society involving division of labor is expressed only among the social insects and man The insect society, or colony as it is often called, continues the associated principle of structural specialization of the individual for its particular duties, with the resulting castes exemplified in a simple form by the queen, drone, and worker honeybees Among the **termites** and **ants** the differentiation is much more extreme and complex. To a moderate degree the **honey-bee** colony also shows specialization of behavior among the workers, which may engage in various activities within their powers according to the requirements of the colony at different times.

The human society differs from that of insects in the restriction of inherent fitness for special duties to less evident details of organization While inherent fitness undoubtedly exists among men, they are structurally of approximately the same form and their specialization is largely a result of training In other words, specialization of the individual in human society is conspicuously a specialization of behavior Lack of structural specialization is compensated by the use of tools

In all cases the society is an extension of the prevailing biological principle that biological units of any degree of complexity can be associated together as component parts of a larger coordinated unit (A W L)

SODA Term applied to **sodium** compounds Soda ash, sodium carbonate, washing soda, sodium carbonate decahydrate, baking soda, sodium hydrogen carbonate, caustic soda, sodium hydroxide Percentage of soda expressed in analyses of chemicals is for sodium oxide (Na_2O) (R K S)

SODALITE. An **isometric** mineral, a **sodium aluminum silicate** containing **sodium chloride,** with the chemical composition $3NaAlSiO_4$ NaCl, **potassium** sometimes replacing a small amount of sodium It is commonly found as **dodecahedrons** or simply massive When observed sodalite has a dodecahedral **cleavage;** conchoidal to uneven fracture, brittle, hardness 5 5–6, specific gravity, 2 14–2 30, luster, vitreous to greasy, color grayish to greenish or yellowish, may be white It is often a beautiful blue and may sometimes be red It is transparent to translucent, streak, white Sodalite is found in **igneous rocks** of **nephelite-syenite** type which have been produced from soda rich **magmas.** It has also been found in the lavas of Vesuvius Common minerals associated with it are **nephelite** and **cancrinite.** It occurs in the Ilmen Mts of Russia, at Vesuvius and Monte Somma, Italy, in Norway and Greenland In Canada, in British Columbia and in Ontario, beautiful blue sodalite is found, and in the United States similar material comes from Kennebec County, Maine It derives its name from the fact of its soda content Attempts have been made to use this mineral for ornamental purposes. (E S C S)

SODA NITRE. The mineral soda nitre or Chile saltpeter is naturally occurring **sodium nitrate,** $NaNO_3$ Its **hexagonal** crystals are rare, this mineral usually being found in crystalline aggregates, crusts or masses It is soft, hardness 1 5–2 , specific gravity 2 24–2 29, vitreous, luster, colorless or white to yellow or gray, transparent to opaque Soda nitre is a most important mineral commercially, being used in the manufacture of nitric acid, other nitrates and fertilizers The chief soda nitre deposits of the world are those found in the Atacama and Tarapaca deserts of northern Chile, although others exist in the Argentine and Bolivia Some small deposits have been found in California, New Mexico and Nevada The origin of these **nitrate** deposits is far from being well understood. They have been regarded as nitrates formed originally by oxidation of organic matter and

subsequently leached out Guano, the excrement of birds might be the original source of the nitrates. Ground water and ancient marine deposits have been suggested as well as the possibility of derivation from nitric acid produced in the atmosphere during electrical storms Some investigators have felt that the nitrates may have come from volcanic sources (E S C S)

SODIUM. Symbol: Na (natrium) Atomic number· 11. Atomic weight. 22 997 Density: 0 97 Hardness· 0 4 Melting point. 97 5° C Boiling point. 880° C No isotopes, but of single atomic form 23

Sodium is a silvery-white metal, can be readily molded and cut by knife, oxidizes instantly on exposure to air, and reacts with water violently, yielding sodium hydroxide and hydrogen gas, consequently is preserved under kerosene, burns in air at a red heat with yellow flame Discovered by Davy in 1807

Sodium occurs as sodium chloride in the ocean (1 14% Na), in salt deposits (salt, **halite,** NaCl), e g , in Michigan, New York, Louisiana, in Great Britain, in Germany, in salt lakes, e g , the Dead Sea (3% Na), Great Salt Lake, in common rocks (average of the solid shell of the earth 2 75% Na) as sodium nitrate (Chile saltpeter, $NaNO_3$) in Chile, as sodium borate (**rasorite, kernite,** $Na_2B_4O_7$ $4H_2O$, in California, **tinkal,** $Na_2B_4O_7$ $10H_2O$, in Thibet), as sodium carbonate (Na_2CO_3) and sulfate (Na_2SO_4) in certain salt lake areas

Sodium metal is obtained by **electrolysis** of fused sodium chloride or hydroxide out of contact with air. Its uses are limited in extent, but important in particular cases, as in the liberation of a metal from its chloride by reaction of sodium to form sodium chloride, and in certain reactions of organic chemistry

Acetate Sodium acetate ($NaC_2H_3O_2$ $3H_2O$), white solid, soluble, formed (1) by reaction of sodium carbonate or hydroxide and **acetic acid,** and then evaporating, (2) by precipitation of **calcium** acetate solution and sodium carbonate solution, followed by filtration, and evaporation of the filtrate Used (1) as a source of acetate, (2) in the dye industry Reacts (1) with sulfuric acid, upon heating, yielding sodium hydrogen sulfate non-volatile and acetic acid volatile and condensable, (2) with sodium hydroxide solid, upon heating, yielding sodium carbonate and methane

Alum Soda alums are those alums such as **aluminum** sodium sulfate ($Al_2(SO_4)_3$ Na_2SO_4 $24H_2O$) where sodium sulfate is used instead of the more common potassium or ammonium sulfate

Aluminate Sodium aluminate ($NaAlO_2$), white solid, (1) by reaction of **aluminum** hydroxide and sodium hydroxide solution, (2) by fusion of aluminum oxide and sodium carbonate, the solution reacts with carbon dioxide to form aluminum hydroxide Used as a mordant

Aluminosilicate Sodium aluminosilicate is used as a water softener ("Permutite") for the removal of dissolved calcium compounds

Amide Sodamide, sodamine ($NaNH_2$), white solid, formed by reaction of sodium metal and dry **ammonia** gas at 350° C Reacts with **carbon** upon heating, to form sodium cyanide

Arsenate Sodium arsenate (Na_3AsO_4 $12H_2O$), white solid, soluble, formed by oxidation of sodium arsenite Used (1) as a source of arsenate, (2) as a mordant in dyeing and printing, (3) as an insecticide

Arsenite Sodium arsenite ($NaAsO_2$), white solid, soluble, formed by reaction of **arsenic** trioxide and sodium hydroxide or carbonate solution, and boiling Used as an antiseptic, insecticide, weed-killer, hide preservative, and in dyeing

Benzoate· Sodium benzoate ($NaC_7H_5O_2$), white solid, soluble, formed by reaction of **benzoic acid** and sodium carbonate solution, and then evaporating. Used as a food preservative to a limited extent, an antiseptic, in pharmacy, and in dyeing

Borate: Sodium borate, sodium tetraborate, borax ($Na_2B_4O_7$ $10H_2O$), white solid, soluble, formed (1) by reaction of sodium carbonate or hydroxide and **boric acid,** (2) by reaction of sodium carbonate and **calcium** borate (**colemanite**), followed by filtration, and then evaporating the filtrate, or (3) by use or purification of the mineral Used as a flux in soldering, in ceramics, in textiles and tanning, in laundering and soaps, as a food preservative to a limited extent, and in medicine

Bromide: Sodium bromide (NaBr), white solid, soluble, melting point 755° C. Used in photography, and in medicine

Carbonates Sodium carbonate (anhydrous), soda ash (Na_2CO_3), sodium carbonate decahydrate, washing soda, sal soda (Na_2CO_3 $10H_2O$), white solid, soluble, melting point 851° C , formed by heating sodium hydrogen carbonate, either dry or in solution Commonly bought and sold in quantity on the basis of oxide (Na_2O) determined by analysis (58 5% Na_2O equivalent to 100 0% Na_2CO_3) Used (1) as a source of carbonate, (2) in laundering, dish-washing, cleansing, and soaps, (3) in water purification for the precipitation of dissolved **calcium** compounds, as for boiler water supplies, (4) in the preparation of sodium salts (a) in solution, (b) upon fusing, at high temperature, for the manufacture of salts, such as sodium silicate from silicon oxide, sodium chromate from chromite, sodium manganate from **manganese** dioxide, sodium hydrogen carbonate, sodium bicarbonate, sodium acid carbonate, baking soda ($NaHCO_3$), white solid, soluble, when heated, dry or in solution, yields sodium carbonate, formed (1) by precipitation of sodium chloride and **ammonium** hydrogen carbonate cold concentrated solutions, and then **filtering** (ammonia soda process), (2) by reaction of sodium hydroxide or carbonate solution and excess **carbon dioxide.** Used (1) as a leavening agent (with an acid material) for carbon dioxide in baking, (2) in **baking powder,** (3) in effervescent beverages (with an acid material), (4) in fire extinguishers (with **sulfuric acid**), (5) in medicine as an antiacid Both sodium carbonate and sodium hydrogen carbonate are relatively cheap and satisfactory mild alkalis

Chlorate Sodium chlorate, chlorate of soda ($NaClO_3$), white solid, soluble, melting point 260° C , powerful oxidizing agent and consequently a fire hazard with dry organic materials, such as clothes, and with sulfur, upon heating oxygen is liberated and the residue is sodium chloride, formed by electrolysis of sodium chloride solution under proper conditions Used (1) as a weed-killer (above hazard), (2) in matches, and explosives, (3) in the textile and leather industries

Chloride Sodium chloride, common salt, rock salt, halite (NaCl), white solid, soluble, melting point 804° C. Source in nature is widely distributed Formed by reaction of sodium carbonate or hydroxide and **hydrochloric acid.** Used (1) in foods for man and animals, (2) as the original source of most sodium containing substances, and of chlorine and **hydrogen chloride** (therefore, of most **chlorine** containing substances)

Chromate. Sodium chromate (Na_2CrO_4 $10H_2O$), yellow solid, soluble, formed by reaction of sodium carbonate and **chromite** at high temperatures in a current of air, and then extracting with water and evaporating the solution Used (1) as a source of chromate, (2) in leather tanning, (3) in textile dyeing, (4) in inks

Citrate Sodium citrate ($Na_3C_6H_5O_7$ $5\frac{1}{2}H_2O$), white solid, soluble, formed (1) by reaction of sodium carbonate or hydroxide and **citric acid,** (2) by reaction of **calcium** citrate and sodium sulfate or carbonate solution, and then filtering and evaporating the filtrate Used in soft drinks, and in medicine

Cyanide Sodium cyanide ($NaCN$), white solid, soluble, very poisonous, formed (1) by reaction of sodamide and **carbon** at high temperature, (2) by reaction of calcium **cyanamide** and sodium chloride at high temperature, reacts in dilute solution in air with gold or silver to form soluble sodium gold or silver cyanide, and used for this purpose in the cyanide process for recovery of gold The percentage of available cyanide is greater

than in potassium cyanide previously used. Used as a source of cyanide, and for **hydrocyanic acid.**

Dichromate: Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$), red solid, soluble, powerful oxidizing agent, and consequently a fire hazard with dry carbonaceous materials. Formed by acidifying sodium chromate solution, and then evaporating. Used (1) in matches and pyrotechnics, (2) in leather tanning and in the textile industry, (3) as a source of chromate, cheaper than potassium dichromate.

Dithionate: Sodium dithionate, "sodium hyposulfate" ($Na_2S_2O_6 \cdot 2H_2O$), white solid, soluble, formed from **manganese** dithionate solution and sodium carbonate solution, and then filtering and evaporating the filtrate.

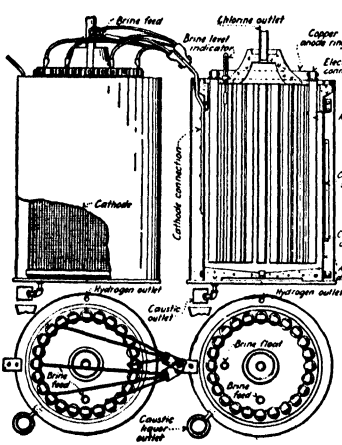
Ferricyanide: Sodium **ferricyanide,** red prussiate of soda ($Na_3Fe(CN)_6 \cdot H_2O$), red solid, soluble, formed by reaction of sodium **ferrocyanide** solution and chlorine, and then evaporating.

Ferrocyanide: Sodium ferrocyanide, yellow prussiate of soda ($Na_4Fe(CN)_6 \cdot 12H_2O$), yellow solid, soluble, formed by treating "spent oxide" of coal gas works with **calcium** hydroxide to extract ferrous cyanide as soluble calcium ferrocyanide, and then treating with sodium carbonate, filtering, and evaporating the filtrate. Used (1) as a source of ferrocyanide, (2) in **blue print** paper, (3) in tanning, (4) in tempering steel.

Fluorides: Sodium fluoride (NaF), white solid, soluble, formed by reaction of sodium carbonate and **hydrofluoric acid,** and then evaporating. Used (1) as an antiseptic and antifermentative in alcohol distilleries, (2) as a food preservative, (3) as a poison for rats and roaches, (4) as a constituent of ceramic enamels and fluxes; sodium hydrogen fluoride, sodium difluoride, sodium acid fluoride ($NaHF_2$), white solid, soluble, formed by reaction of sodium carbonate and excess hydrofluoric acid, and then evaporating. Used (1) as an antiseptic, (2) for etching glass, (3) as a food preservative, (4) for preserving zoological specimens.

Fluosilicate: Sodium fluosilicate (Na_2SiF_6), white solid, very slightly soluble in cold water, formed by reaction of sodium carbonate and **hydrofluosilicic** acid. Used (1) in ceramic glazes and opal glass, (2) in laundering, (3) as an antiseptic.

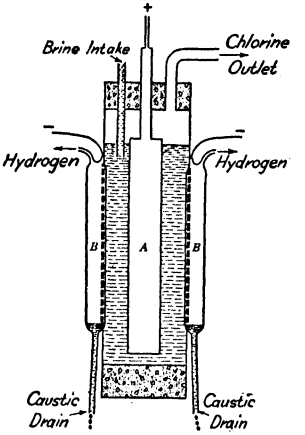
Formate: Sodium formate ($NaCHO_2$), white solid, soluble, formed by reaction of sodium hydroxide and **carbon monoxide** under pressure at about 200° C. Used (1) as a source of formate and **formic acid,** (2) as a reducing agent in organic chemistry, (3) as a mordant in dyeing, (4) in medicine.



Electrolysis of sodium chloride solution. Vorce cell. (Courtesy of L. D. Vorce.)

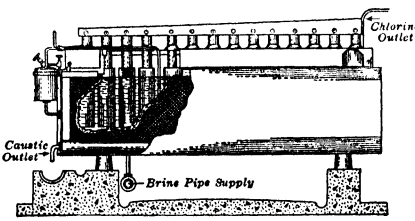
Hydride: Sodium hydride (NaH), white solid, reactive with water yielding **hydrogen** gas and sodium hydroxide solution, formed by reaction of sodium and hydrogen at about 360° C. Used as a powerful reducing agent.

Hydroxide: Sodium hydroxide, caustic soda, sodium hydrate, "lye" (NaOH), white solid, soluble, melting



Electrolysis of sodium chloride solution.
Section of Allen-Moore cell showing: A, graphite anode; B, unsubmerged cathode consisting of iron grid supporting asbestos diaphragm.

point 318° C., an important strong alkali, not as cheap as **calcium** oxide (a strong alkali) nor sodium carbonate (a mild alkali), but of wide use. Formed (1) by reaction of sodium carbonate and calcium hydroxide in water, and then separation of the solution and evaporation, (2) by



Electrolysis of sodium chloride solution.
Nelson electrolytic cell.

electrolysis of sodium chloride solution under the proper conditions, and evaporation. Commonly bought and sold in quantity on the basis of oxide (Na_2O) determined by analysis (77.5% Na_2O equivalent to 100.0% NaOH). Used (1) in the manufacture of soap, rayon, paper ("soda process"), (2) in petroleum and vegetable oil refining, (3) in the rubber industry, in the textile and tanning industries, (4) in the preparation of sodium salts, (a) in solution, (b) upon fusion.

Hypochlorite: Sodium **hypochlorite** (NaOCl), commonly in solution by (1) electrolysis of sodium chloride solution under proper conditions, (2) reaction of **calcium** hypochlorite suspension in water and sodium carbonate solution, and then filtering. Used (1) as a bleaching agent for textiles and paper pulp, (2) as a disinfectant, especially for water, (3) as an oxidizing reagent.

Hypophosphite: Sodium hypophosphite ($NaH_2PO_2 \cdot H_2O$), white solid, soluble, formed (1) by reaction of **hypophosphorous acid** and sodium carbonate solution,

and then evaporating, (2) by reaction of sodium hydroxide solution and phosphorus on heating (poisonous phosphine gas evolved)

Hyposulfite. Sodium hyposulfite, sodium hydrosulfite (not sodium thiosulfate) ($Na_2S_2O_4$), white solid, soluble, formed by reaction of sodium hydrogen sulfite and zinc metal powder, and then precipitating sodium hyposulfite by sodium chloride in concentrated solution Used as an important reducing agent in the textile industry, e g , bleaching, color discharge

Iodide Sodium iodide (NaI), white solid, soluble, melting point 651° C , formed by reaction of sodium carbonate or hydroxide and **hydriodic acid**, and then evaporating Used in photography, in medicine and as a source of iodide

Manganate Sodium manganate (Na_2MnO_4), green solid, soluble, permanent in alkali, formed by heating to high temperature **manganese** dioxide and sodium carbonate, and then extracting with water and evaporating the solution The first step in the preparation of sodium manganate and permanganate from **pyrolusite**

Nitrate Sodium nitrate, nitrate of soda, Chile saltpeter, "caliche" ($NaNO_3$), white solid, soluble, melting point 308° C , source in nature is Chile, in the fixation of atmospheric **nitrogen** nitric acid is frequently transformed by sodium carbonate into sodium nitrate, and the solution evaporated Used (1) as an important nitrogenous fertilizer, (2) as a source of nitrate and nitric acid, (3) in pyrotechnics, (4) in fluxes

Nitroprusside Sodium nitroprusside ($Na_2Fe(CN)_5NO \cdot 2H_2O$), red solid, soluble Used in testing soluble sulfides.

Nitrite Sodium nitrite ($NaNO_2$), yellowish-white solid, soluble, formed (1) by reaction of nitric oxide plus **nitrogen** dioxide and sodium carbonate or hydroxide, and then evaporating, (2) by heating sodium nitrate and **lead** to a high temperature, and then extracting the soluble portion (lead monoxide insoluble) with water and evaporating Used as an important reagent (diazotizing) in organic chemistry

Oleate Sodium oleate ($NaC_{18}H_{33}O_2$), white solid, soluble, froth or foam upon shaking the water solution (soap), formed by reaction of sodium hydroxide and **oleic acid** (in alcoholic solution) and evaporating. Used as a source of oleate

Oxalates Sodium oxalate ($Na_2C_2O_4$), white solid, moderately soluble, formed (1) by reaction of sodium carbonate or hydroxide and **oxalic acid**, and then evaporating, (2) by heating sodium formate rapidly, with loss of hydrogen Used as a source of oxalate, sodium hydrogen oxalate, sodium binoxalate, sodium acid oxalate ($NaHC_2O_4 \cdot H_2O$), white solid, moderately soluble

Oxides Sodium oxide, sodium monoxide (Na_2O), white solid, reactive with water to form sodium hydroxide, formed by reaction of sodium hydroxide or peroxide and the requisite amount of sodium metal upon heating, sodium peroxide (Na_2O_2), yellowish-white solid, soluble in water with some evolution of **oxygen** at 30°–40° C , complete at 100° C Reacts (1) as an oxidizing agent, e g , nitric oxide converted to sodium nitrate, (2) as a reducing agent, e g , salt solutions of silver or mercury converted to silver or mercury metal, and oxygen Formed by heating sodium metal and dry air at 300° C. Used as an important bleaching and oxidizing agent for various materials, and as a source of oxygen

Palmitate· Sodium palmitate ($NaC_{16}H_{31}O_2$), white solid, soluble, froth or foam upon shaking the water solution (soap), formed by reaction of sodium hydroxide and **palmitic acid** (in alcoholic solution) and evaporating Used as a source of palmitate

Perborate· Sodium perborate ($NaBO_3 \cdot 4H_2O$), white solid, soluble, stable in air, but in water solution loses oxygen, formed (1) by the **electrolysis** of sodium borate solution (in the presence of sodium carbonate), (2) by reaction of sodium borate solution, in the presence of sodium hydroxide and excess hydrogen peroxide

Permanganate· Sodium permanganate, permanganate of soda ($NaMnO_4$), purple solid, soluble, formed by oxidation of acidified sodium manganate solution with chlorine, and then evaporating Used (1) as disinfectant and bactericide, (2) in medicine

Phenate Sodium phenate, sodium phenoxide, sodium phenolate ($NaOC_6H_5$), white solid, soluble, formed by reaction of sodium hydroxide (not carbonate) solution and **phenol**, and then evaporating. Used in the preparation of sodium salicylate

Phosphates Trisodium phosphate, tribasic sodium phosphate ($Na_3PO_4 \cdot 12H_2O$), white solid, soluble, formed (1) by reaction of sodium hydroxide and the requisite amount of **phosphoric acid**, and then evaporating, (2) by reaction of disodium hydrogen phosphate plus sodium hydroxide, and then evaporating Used (1) as a cleansing and laundering agent, (2) as a water softener, (3) in photography, (4) in tanning, (5) in the purification of sugar solutions, disodium hydrogen phosphate, dibasic sodium phosphate ($Na_2HPO_4 \cdot 12H_2O$), white solid, soluble, formed (1) by reaction of dicalcium hydrogen phosphate and sodium carbonate solution, and then evaporating the solution, (2) by reaction of sodium carbonate and the requisite amount of phosphoric acid, and then evaporating Used (1) in weighting silk, (2) in dyeing and printing textiles, (3) in fireproofing wood, paper, fabrics, (4) in ceramic glazes, (5) in baking powders, (6) to prepare sodium pyrophosphate, sodium dihydrogen phosphate, monobasic sodium phosphate ($NaH_2PO_4 \cdot H_2O$), white solid, soluble, formed (1) by reaction of sodium carbonate and the requisite amount of phosphoric acid, and then evaporating, (2) by reaction of **calcium** monohydrogen phosphate and sodium carbonate solution, and then evaporating the solution Used (1) in baking powders, (2) in medicine, (3) to prepare sodium metaphosphate, sodium pyrophosphate ($Na_4P_2O_7 \cdot 10H_2O$), white solid, soluble, melting point about 900° C , formed by heating disodium hydrogen phosphate to complete loss of water, followed by crystallization from water solution Used (1) in electroanalysis, sodium metaphosphate ($NaPO_3$), white solid, soluble, melting point 617° C , formed by heating sodium dihydrogen phosphate or sodium ammonium phosphate to complete loss of water, is an easily fusible phosphate forming colored phosphates with many metallic oxides, e g , **cobalt** oxide

Phosphites Disodium hydrogen phosphite ($Na_2HPO_3 \cdot 5H_2O$), white solid, soluble, formed by reaction of **phosphorous acid** and sodium carbonate, and then evaporating at a low temperature, melting point of anhydrous salt is 53° C , at higher temperatures yields sodium phosphate and **phosphine** gas, sodium dihydrogen phosphite ($NaH_2PO_3 \cdot 2\frac{1}{2}H_2O$), white solid, soluble, formed by reaction of phosphorous acid and sodium hydroxide cooled to —23° C when the crystalline salt separates

Salicylate Sodium salicylate ($NaC_7H_5O_3$), white solid, soluble, formed by reaction of sodium phenate and **carbon dioxide** under pressure. Used as a source of salicylate and for **salicylic acid.**

Silicate Sodium silicate, sodium metasilicate, "water glass" (Na_2SiO_3), colorless (when pure) glass, soluble, melting point 1088° C , formed by reaction of **silicon** oxide and sodium carbonate at high temperature, solution reacts with carbon dioxide of the air, or with sodium carbonate solution or **ammonium** chloride solution, yielding silicic acid, gelatinous precipitate Sodium silicate solution is used (1) in soaps, (2) for preserving eggs, (3) for treating wood against decay, (4) for rendering cloth, paper, wood non-inflammable, (5) in dyeing and printing textiles, (6) as an adhesive (e g , for paper boxes) and cement Sold as granular, crystals, or 40° Baumé solution

Silicoaluminate See aluminosilicate, above

Silicofluoride See fluosilicate, above

Stearate· Sodium stearate ($NaC_{18}H_{35}O_2$), white solid, soluble, froths or foams upon shaking the water solution (soap), formed by reaction of sodium hydroxide and **stearic acid** (in alcoholic solution) and evaporating. Used as a source of stearate

Sulfates: Sodium sulfate (anhydrous), "salt cake"

(Na_2SO_4), sodium sulfate, decahydrate, "Glauber's salt" ($Na_2SO_4 \cdot 10H_2O$), white solid, soluble, formed by reaction of sodium chloride and **sulfuric acid** upon heating with evolution of hydrogen chloride gas Used (1) in dyeing, (2) along with **carbon** in the manufacture of glass, (3) as a source of sulfate, (4) to prepare sodium sulfide, sodium hydrogen sulfate, sodium bisulfate, sodium acid sulfate, "nitre cake" ($NaHSO_4$), white solid, soluble, formed by reaction of sodium nitrate and sulfuric acid, upon heating, with evolution of nitric acid. Used (1) as a cheap substitute for sulfuric acid, (2) in dyeing, (3) as a flux in metallurgy, sodium pyrosulfate ($Na_2S_2O_7$), white solid, soluble, formed by heating sodium hydrogen sulfate to complete loss of water

Sulfides Sodium sulfide (Na_2S), yellowish to reddish solid, soluble, formed (1) by heating sodium sulfate and **carbon** to a high temperature Used (1) as the cooking liquor reagent (along with sodium hydroxide) in the "sulfate" or "kraft" process of converting wood into **paper** pulp, (2) as a depilatory, (3) in sheep dips, (4) in photography, engraving and lithography, (5) in organic reactions, (6) as a source of sulfide, (7) as a reducing agent; sodium hydrogen sulfide, sodium bisulfide, sodium acid sulfide (NaHS), formed in solution by reaction of sodium hydroxide or carbonate solution and excess hydrogen sulfide

Sulfites Sodium sulfite (Na_2SO_3), white solid, soluble, dilute solution readily oxidized in air, but retarded by mannitol (**carbohydrates**), formed by reaction of sodium carbonate or hydroxide solution and the requisite amount of **sulfur** dioxide, at high temperatures yields sodium sulfate and sodium sulfide Used (1) as a source of sulfite, (2) as a reducing agent, (3) to prepare sodium thiosulfate, (4) as a food preservative, (5) as a photographic developer, (6) as a bleaching agent and antichlor in the textile industry, sodium hydrogen sulfite, sodium bisulfite, sodium acid sulfite ($NaHSO_3$), white solid, soluble, formed by reaction of sodium carbonate solution and excess sulfurous acid Uses similar to those of sodium sulfite

Tartrate Sodium tartrate ($Na_2C_4H_4O_6 \cdot 2H_2O$), white solid, soluble, formed by reaction of sodium carbonate solution and **tartaric acid**. Used in medicine, sodium potassium tartrate, Rochelle salt ($NaKC_4H_4O_6 \cdot 4H_2O$), white solid, soluble Used (1) in medicine, (2) as a source of tartrate

Thiosulfate Sodium thiosulfate, "Hypo" ($Na_2S_2O_3 \cdot 5H_2O$), white solid, soluble, formed by reaction of sodium sulfite and **sulfur** upon boiling, and then evaporating Used (1) in photography as fixing agent to dissolve unchanged silver salt, (2) as a reducing agent and antichlor

Tungstate· Sodium tungstate ($Na_2WO_4 \cdot 2H_2O$), white solid, soluble, by reaction of sodium hydroxide solution and **tungsten** trioxide upon boiling, and then evaporating Used (1) in fireproofing fabrics, (2) as a source of tungsten for chemical reactions

Uranate· Sodium uranate, **uranium** yellow (Na_2UO_4), yellow solid, insoluble, formed by reaction of soluble uranyl salt solution and excess sodium carbonate solution Used (1) in the manufacture of yellowish-green fluorescent glass, (2) in ceramic enamels, (3) as a source of uranium for chemical reactions

Vanadate· Sodium vanadate, sodium orthovanadate (Na_3VO_4), white solid, soluble, formed by fusion of **vanadium** pentoxide and sodium carbonate Used (1) in inks, (2) in photography, (3) in dyeing of furs, (4) in inoculation of plant life

All sodium containing substances impart a characteristic yellow color to the bunsen flame (R K S)

SOFTENER. An apparatus devised to remove the salts producing hardness dissolved in water, is known as a softener. Hardness of water is due to dissolved salts which make it difficult to obtain soap suds in the water. Hardness of water is also indicative of the scale-forming quality of that water as a boiler feed Consequently, in the power generation field, in the laundry trade, and in many industries making use of water in one way or another, raw water must be treated in softeners Water softeners are of two types—precipitation and base exchange There are several types on the market, but practically all are included in the following classification:

I Precipitation softeners
  A Cold lime and soda
    1 Intermittent
    2 Continuous
  B Continuous hot lime and soda
  C Lime and barium (cold)
    1 Intermittent
    2 Continuous
  D Lime and sodium aluminate
II Base exchange (artificial and natural zeolites)

A precipitation softener embodies the principle of using calculated quantities of soluble reagents to react with the hardness in raw water

A base exchange softener removes the hardness by a simple filtration of the water through a bed of active material which exchanges its sodium base for the magnesium and calcium in the water Natural and artificial zeolites are used as the active material When its softening characteristics are nearly exhausted the zeolite is regenerated by backwashing it with a brine solution The base exchange softener is simple and effective in that no proportioning of chemicals is required and practically zero hardness is obtained Base exchange softening may give dangerously high alkalinity when the raw water itself contains large amounts of sodium bicarbonate in addition to calcium and magnesium salts (F T M)

SOIL. A complex sediment, exceedingly variable as to texture, inorganic and organic composition Difficult to define except in terms of practical fertility or mode of origin From the purely geologic point of view, soil is usually the relatively thin upper layer of the unconsolidated mantle of disintegrated and decomposed rock material or regolith which overlies the consolidated bedrock The upper portion of the regolith is divided into topsoil and subsoil The topsoil is usually a relatively thin zone of the more highly decomposed mineral constituents of the regolith and contains a varying proportion of organic material called humus This soil zone is the habitat of the shallow rooted plants, such as most grasses and cereals The topsoil usually passes gradationally into the subsoil which supplies some of the moisture and food for the deeply rooted plants and trees. The subsoil may or may not pass gradationally into the underlying bedrock It is important to note that the topsoil is easily destroyed by erosion, when not protected by a mantle of vegetation Classification of soils founded entirely on the origin of the regolith has been found to be impractical Since the important topsoils are primarily the result of the interaction of rainfall, temperature and organisms with the regolith, the soil specialist recognizes over 7500 types of soils, irrespective of textural differences, and with particular reference to age and to the climatic and other physical conditions under which each soil has been developed Soils are therefore usually classified as follows (1) Young Soils These usually show their relationship to the parent material and are typical flood plain and hilly land deposits, when the soil surfaces are constantly being replenished or disturbed (2) Mature Soils These usually cover relatively flat lands where there are good drainage conditions but relatively little erosion. The development of these soils has gone so far in some cases, particularly in semi-arid regions, that little relation is shown to the parent material and their nature has therefore been principally determined by climatic and organic factors. (3) Old Soils. These usually cover old flat surfaces which have not been disturbed by erosion or sedimentation for a long time Such soils, due to the dominance of climatic factors in their formation, have lost many of their

original characteristics and have, therefore, developed abnormal features When soils are intensively cultivated their mineral and organic constituents are rapidly depleted and must be replenished by rotation of crops and the application of natural fertilizers. The method of allowing the land to remain fallow is now known to be inefficient The complete removal of the vegetable cover, such as may result from over-grazing, deforestation, or dry farming, exposes the soil to rapid erosion and destruction It has been estimated that already 35 million acres of good soil have already been destroyed in the United States, and that 225 million acres will soon be destroyed if immediate and adequate steps are not taken to conserve them (R M F)

SOLANINE. Alkaloids.

SOLAR CONSTANT. The rate at which the earth is receiving energy from the sun is known as the solar constant Technically defined the solar constant is the quantity of **energy** that falls in unit time on a unit area placed perpendicular to the direction of the sun at the mean distance of the earth from the sun It is usually expressed in units of **heat** energy and many hundreds of observations give a mean value of 1 938 **calories** per square centimeter per minute Converted into more familiar units this amounts to 1 8 horse-power falling upon each square meter of the earth, neglecting the effects of atmospheric absorption If this solar energy had to be paid for at the extremely low rate of one cent per kilowatt hour, it would cost the earth about 478,000,000 dollars each second

Observations of the solar constant are made by means of the **pyrheliometer** and, of necessity, must be made from the surface of the earth Corrections must be made to all determinations to allow for variations in the distance of the earth from the sun, due to the **eccentricity** of the earth's **orbit,** and also for the effects of the earth's **atmosphere.** The Smithsonian Institution has established, under the direction of Dr C G Abbot, a number of stations scattered over the northern and southern hemispheres, at which daily observations of the solar constant are made The determination of the absorptive effects of the earth's atmosphere have been very carefully investigated in a number of painstaking researches

The results of long series of observations indicate that the solar constant is not a constant, but that it varies by several percent from the mean value The variations are not the same for all regions of the solar **spectrum,** being much greater in regions of short wave **radiation** than in the wave-lengths greater than 5,000 **Ångstroms.** The variations apparently have a very complicated series of periodicities superimposed upon an eleven year cycle which is directly correlated to the **sun spot** number At the time of sun spot maximum the solar constant is two or three per cent above the mean value

It would be natural to suppose that, since the temperature of the earth is fundamentally dependent upon **solar radiation,** variations in the solar constant would be directly correlated with climatic changes upon the earth In spite of a tremendous amount of research upon this important subject, the results do not justify a definite statement that such correlation has been found, although there are many indications in that direction (W K G)

SOLAR MOTION. We know that the so-called fixed stars are actually moving in space and in many cases the **space velocity** has been determined By 1783, the **proper motions** of thirteen stars had been determined and Sir William Herschel noticed that they seemed to have a preferential character In the direction of the constellation of **Hercules** he noticed that the stars seemed to be moving apart, while in the opposite direction they appeared to be closing in He interpreted this phenomenon not as a characteristic of the sidereal system as a whole, but rather a perspective effect caused by the actual motion of the sun in the direction of the constellation of Hercules During the next fifty years the proper motions of many more stars were determined, and in 1837 Argelander discussed the results statistically and confirmed Herschel's determination With the rapidly increasing number of proper motion determinations during the past century, numerous statistical discussions of proper motions have been made and all have yielded the same conclusion

With the application of the **Doppler-Fizeau principle** to the determination of the **radial velocities** of the stars a method for determining the solar motion independently from the proper motions became available With increasing number of radial velocity determinations, it is found that stars in the general direction of the constellation of Hercules seemed to have a preferential motion toward the sun, while in the opposite part of the sky the preferential motion was one of recession

Since all methods for the determination of solar motion are purely statistical in character, it must not be expected that results from different methods will agree exactly The point toward which the sun is apparently moving is known as the solar apex, while the opposite point on the celestial sphere is known as the solar antapex Results of statistical analysis of proper motions give the position of the solar apex as **right ascension** 18 hr 03 1m and declination $+27^\circ$ 0, while an independent discussion from radial velocities yields 18 hr 02 4m and $+29^\circ$ 2 The value of the velocity with which the sun is moving toward this point in the constellation of Hercules is 19 65 kilometers per second (12 3 miles per sec)

Up to the present time there is no conclusive evidence other than that the sun is moving toward the solar apex in a straight line Many attempts have been made to employ the solar motion for the determination of the distances of the stars The complete discussion of the problem is far too complex for discussion here but the results which have been obtained, while not of great accuracy for individual stars, are, nevertheless, of great importance for statistical investigations in problems concerned with the discussions of the structure of the **galactic** system. (W K G)

SOLAR PARALLAX. The mean distance of the earth from the sun is one of the most important constants in astronomical measurement Known as the **astronomical unit,** it forms the standard of measurement throughout the **solar system;** it is also the base line for the determination of **stellar parallax.** To measure the distance from the earth to the sun directly is obviously impossible and some indirect method must be used The most common method for the determination of this distance is to determine the angle subtended by an equatorial radius of the earth at the mean distance of the earth from the sun, and this angle is known as the solar parallax

To measure the solar parallax directly is a very difficult problem for a variety of reasons· the sun is very large and very bright, and, furthermore, when the sun is visible there are no stars visible with reference to which the position of the sun can be measured Even with these difficulties overcome there remains the smallness of the solar parallax (8″80) which is practically impossible to determine directly with great accuracy

The most common method for the determination of the solar parallax makes use of the fact that, from the **orbital elements** of planetary **orbits,** the distance of any of the planets from the sun at any instant can be accurately expressed in terms of the earth's mean distance from the sun as unity Furthermore, a plane triangle may always be passed through the earth, sun, and any planet and the angles and sides of this triangle may be computed from the orbit, with distances expressed in terms of the astronomical unit If any one of the sides of the triangle can be determined in terms of the earth's equatorial radius then the other two may be so expressed

and one of these sides will be the distance of the earth from the sun Hence the problem of determination of solar parallax reduces itself to the determination of the **geocentric parallax** of the planet For increased accuracy in the determination of the parallax of the planet the object should be stellar in appearance, and should be as close as possible to the earth in order that it may have a large geocentric parallax The **asteriod Eros** is well suited for this purpose and extensive campaigns for determinations of its geocentric parallax have been carried out at the close oppositions in 1900 and again in 1931. At the time of the close approach in 1931 Eros was only about 16,200,000 miles from the earth and hence the parallax was about 6 times as great as the solar parallax

Several other indirect methods for the determination of the solar parallax have been devised, but the details of their methods are too complex to be included here Prior to the discovery of Eros in 1898 the planets **Mercury** and **Venus** were used for the determination of solar parallax The method of using these objects was to measure the time required for these planets to transit across the disk of the sun and expeditions were dispatched to all parts of the earth to observe this phenomenon

At present the value 8".80 has been adopted for solar parallax by the International Astronomical Union but it is expected that the discussion of the observations taken on Eros in 1931 will give one more decimal place with sufficient accuracy for adoption (W K G)

SOLAR RADIATION. The **radiation** from the sun comprises a very wide range of wave lengths from the long **infrared** rays to the short **ultraviolet** rays, with a maximum intensity in the visible green at about 5000 **Ångstroms.** However, since the **air** strongly absorbs the wave lengths toward either end of the **spectrum,** the solar radiation received on the surface of the earth is confined, largely, to the visible and near infrared regions, with a very small proportion of the ultraviolet This is fortunate, for human beings and many other organisms could not endure the full range of solar radiation The absorption of the ultraviolet radiation takes place largely in the higher stratosphere, where it probably contributes to the atmospheric ionization (See **Ionosphere**) The longer infrared is absorbed only by dust and water vapor at lower levels, which accounts for the low temperature of the air at high altitudes

The intensity, or radiant flux density, of the solar radiation is measured by means of various forms of **pyrheliometer** or solarimeter Its value is known as the **solar constant** and averages about 1.34×10^6 ergs per square centimeter per second The direct **illumination** from the sun approximates 6500 foot candles. (L D.W)

SOLAR SYSTEM. That group of objects which are moving through space with the **sun** is known as the solar system. The following classes of objects are listed as members of the solar system, and the details regarding them as individuals will be found elsewhere: **planets, satellites, asteroids, comets, meteors,** and meteorites, and the zodiacal light and gegenschein The **orbital** and physical data regarding various members of the system may be found tabulated on page 865 In this article we shall confine ourselves to consideration of the system as a whole

Examination of the tabular material will indicate several interesting correlations between the various orbital and dynamical factors in the solar system The mass is overwhelmingly concentrated in the sun, this parent member of the system having nearly 750 times as much mass as all of the rest of the members combined The distribution of the **moment of momentum,** another important dynamical factor, is interesting in that the four major planets, **Jupiter, Saturn, Uranus,** and **Neptune,** have about 98% of the total for the whole system With very few, but nevertheless important, exceptions, the members of the solar system rotate on their axes and revolve, either about the sun or their primary in the case of satellites, in the same directional sense Furthermore, the orbital planes of the great majority of the members lie within an inclination angle of 20° to the plane of the ecliptic. In so far as we have been able to determine the relative percentages of the various chemical elements which go to make up the various members, the compositions of the different objects bear a remarkable similarity to each other

For centuries the belief has existed that the solar system is not merely an accidental arrangement of objects in space, but is rather the product of some process of evolution The mere fact of the common direction of orbital motion of the more than 1300 planets and asteroids is in itself sufficient evidence against any chance arrangement However, in spite of the labors of the large number of eminent scientists and philosophers who have worked on the problem during the past three centuries, the origin of the solar system is by no means completely understood

Since the sun is a typical **star,** which appears abnormally bright to us merely because of its relatively short distance from the earth, the theories regarding its evolution will be found in the material dealing with the stars The earliest hypothesis, which is worthy of scientific recognition, is to be found in the writings of Thomas Wright, the theologian Swedenborg, and the philosopher Kant, during the 18th century None of these gentlemen had much scientific training, with the result that their theories can be regarded as pure hypotheses which violate many of the fundamental principles of dynamics In the middle of the 19th century the astronomer Laplace attempted to put these hypotheses on a scientific foundation and advanced the so-called Nebular Hypothesis

In spite of the fact that the Laplacian nebular hypothesis has failed to stand the tests of rigorous analysis and even that Laplace himself gave evidence that he did not regard the theory very seriously, nevertheless, the theory has had such a large popular appeal that a few words regarding it will not be out of place The theory presumes the existence in space of a large nebulous mass slowly rotating and slowly cooling and condensing As the mass contracts the angular velocity will increase, since the moment of momentum must be conserved and, with the increase in angular velocity, the centrifugal force at the equator will increase until it becomes greater than the gravitational forces holding the mass together At this point a ring of matter is split off from the equatorial region of the parent mass. The parent mass continues contracting and increases both the angular velocity and equatorial centrifugal force until another ring is split off In this way successive rings of matter are produced, each surrounding the equatorial part of the central parent mass These successive rings of matter split and condense into the major planets with, perhaps, their satellites then formed from the cooling masses in much the same way that the planets themselves were formed Eventually, the central mass condenses to form the present sun. The common forward motion of all of the planets and their satellites, and the approximately coplanar features of the planetary orbits can all be explained on this theory and it was highly satisfactory to those who did not analyze the mathematics too critically A careful analysis, however, proves conclusively that the rings thrown off from the primary would not condense into single planets, but would form swarms of small bodies, such as the **asteroids** or the rings of **Saturn.**

Other considerations regarding the distribution of angular momentum, etc, completely removed the Laplacian theory from the realm of possibility as an evolutionary process for the solar system. Nevertheless many modifications of the Laplacian theory were

proposed during the latter part of the nineteenth century in the vain attempt to satisfy the dynamics of the observed solar system

With the dawn of the present century a new idea regarding the birth of the solar system was advanced and the three present theories which are worthy of brief consideration are based upon this new conception It is known that all of the stars are in motion through space relative to each other and more or less at random. From the observed velocities of the stars, their number, and the volume of space which they occupy, it may be calculated that a close approach, and possibly an actual collision is a probable occurrence during the long life history of the average star The tidal friction theory of Jeans and Jeffries, and the planetesimal theory of Chamberlin and Moulton both assume the close approach of two stars, while the newer theory of Jeffries postulates a "side swiping" collision In either case, one of the stars, or what remains after the side swiping collision, passes off in a hyperbolic orbit, but either the close approach or the collision, will have caused the ejection of material from the star which we shall now refer to as the sun Three different things may happen to this ejected material much of it will fall back into the sun due to gravitational attraction, some of it will follow the other star out into space, and some of it will remain revolving about the sun This latter material is the raw substance of which the planets are constructed

The fundamental difference between the planetesimal theory and the tidal theory is concerned with what happens to the material ejected from the sun very shortly after it was left behind revolving about the sun Chamberlin and Moulton in their planetesimal theory postulate that the material condensed and solidified relatively quickly into small objects known as planetesimals, while Jeans believes that the material gathered together in the large masses which now form the major planets The planetesimal theory then postulates that the planets were formed by the gathering together of the small planetesimals about nuclei and the building up of the planets by a process of accretion The tidal theory, on the other hand, assumes that the planets were formed by the condensation of large masses of hot diffused material There are other differences in the theories regarding the distribution of the material about the sun immediately following the catastrophe, but these are too highly technical to be discussed here The collision theory of Jeffries follows the tidal theory very closely differing only in the method by which the material was ejected from the sun None of the theories can be said to be perfect and a great deal of work remains to be done before any positive statement can be made In the meantime, it is unfortunate to find supporters of any particular theory attempting to discredit all of the others (W K G)

SOLDER. Alloys; and Brazing.

SOLE. Pisces, Teleostei A term applied to **flatfishes** of numerous species widely distributed in temperate and tropical seas Some species ascend rivers The term is properly applied to members of the group, ranked as a family or as a subfamily, of which the genus *Solea* is typical Since many other flatfishes are edible, the sole of the inland fish markets is often not true sole. (A W L)

SOLENIA. Tubes of endoderm that pass between the various **polyps** through the middle layer (mesogloea) of **alcyonarians.** (A W L)

SOLENOCYTE An excretory cell from which a **cilium** extends into the associated excretory tubule These cells are superficially like the flame cells of **flatworms** but they are smaller and simpler They occur in connection with the excretory organs of **annelid** worms and in Amphioxus of the lower chordates (A.W.L)

SOLENODON. Mammalia, Insectivora. An animal of about the size of a rabbit but with a long slender nose and a long naked tail The claws are strong, those of the fore feet being much larger than those of the hind feet The two species occur in the West Indies (A W L.)

SOLENOID. The solenoid is an electric winding of superimposed layers of **insulated** electrical conductor in alternating right and left hand pitch The solenoid may be wound on a non-magnetic core or upon a soft iron **core.** The latter type is the basis of electromagnets Solenoids are employed in automatic equipment such as the oil circuit breaker, to interpret electrical impulse in terms of a mechanical movement To do this, the solenoid is equipped with an iron plunger, and is wound on a non-magnetic support **Relays** are often employed to close the solenoid circuit upon any abnormality in the main circuit, and the energizing of the solenoid attracts the soft iron plunger until its magnetic center corresponds with the magnetic center of the solenoid This plunger movement is very positive in action, and may be employed to operate the equipment to correct a fault (F T M)

SOLENOIDAL VECTOR. If the **divergence** of a **vector function** of position vanishes everywhere in a certain region, the function is said to be a solenoidal vector in that region

If a vector function **v** is the **curl** of a vector function **F,** then **v** is solenoidal (L L S)

SOLFATARA. **Fumarole.**

SOLID OF REVOLUTION. A solid of revolution is a solid bounded by a **surface of revolution,** or by a surface of revolution and certain planes

Suppose that the curve whose equation in **rectangular coordinates** is $y=f(x)$ is revolved about the X-axis, generating a surface of revolution The volume of the solid bounded by this surface and the planes $x=a$ and $x=b$ is given by the **definite integral**

$$V=\pi\int_a^b y^2dx$$

If the curve whose equation is $x=F(y)$ in rectangular coordinates is revolved about the Y-axis, the volume of the solid bounded by this surface of revolution and the planes $y=c$ and $y=d$ is given by

$$V=\pi\int_c^d x^2dy. \qquad \text{(L L S)}$$

SOLID EXPANSION THERMOMETER Many devices have employed the expansion of solid bodies as an indicator of temperature change Wedgwood, a celebrated eighteenth century potter, used small blocks of burned clay to estimate, by their expansion, the temperature of his kilns Because of the low expansion coefficient, any such direct application of solids is necessarily very insensitive, on the other hand the requirement of durability favors their use in certain cases One rather crude arrangement, sometimes used, is a long wire passing over pulleys, its length being sufficient to insure a measurable expansion

More commonly, use is made of the warping produced by the differential expansion of two solid strips fastened together The Breguet spiral is composed of two spiral strips, like watch springs, made of different metals and securely welded together throughout their length. A change in temperature causes the combination to coil or uncoil, a motion which, communicated through gears to a pointer-shaft, serves to give temperature readings on a dial (L D.W)

SOLIDS. **States of Matter; Statics; Kinetics; Elasticity.**

SOLID SOLUTION. For the general meaning of this term, see **Solution** and **Alloy.** In geology, as defined by A Holmes this term is applied to compounds which form minerals and is a crystalline and homogeneous solid, representing a mixture of two or more substances, sometimes composed of isomorphous compounds The proportions of the mixture may vary within certain critical limits without destroying the homogeneity of the solid solution Most of the common **silicate** minerals which form the **igneous rocks,** such as the **feldspars, amphiboles** and **pyroxenes,** are complex, solid solutions Compare with **isomorphous.** (R M P.)

SOLITAIRE. Aves 1 Passeriformes A bird (**Aves**) found in the western mountains from the Black Hills to British Columbia and south into Lower California It is related to the thrushes and is known for its beautiful song The full name of this species is Townsend solitaire, *Myadestes townsendi* 2 Columbiformes A giant flightless pigeon, *Pezophaps solitarius,* of Rodriguez Island, extinct since the late eighteenth century. Related to the **dodo.** (A W L)

SOLPUGIDA. The sun **spiders,** a small order of rare arachnids found chiefly in warm and arid regions The few North American species have been recorded from Florida and from the region between Kansas, Oregon, and the Rio Grande Although their appearance is rather formidable they are harmless creatures, noctural in habits and very shy (A W L)

SOLUBILITY Solutions and Solubility

SOLUTIONS AND SOLUBILITY. Solutions are conveniently classified thus

A True Solutions
- 1 Ordinary — Sugar (sucrose) in water, ethyl alcohol in water
- 2 Non-ordinary — **Sodium** chloride in water, sodium hydroxide in water, **hydrochloric acid** in water Salts, acids, bases

B. Pseudo-solutions (colloidal) — Starch emulsion; Silicic acid gel; Casein in milk; Soap in water

Pseudo-solutions are discussed in the article on **Colloidal State.**

It is to be noted that salts, acids, bases are classified as non-ordinary, although commonly encountered, for the reason that such substances in solution are dissociated into two kinds of entities, positively and negatively charged ions (See **Reactions Involving Recombination of Ions; Reactions Involving Water; Chemical Changes; Reactions Involving Oxidation-Reduction; Electrochemistry.**) A solution consists of one substance (the solute) dispersed in another substance (the **solvent**) in such a fine degree of comminution that the product is homogeneous, has a greater or less range of concentration of solute, is optically void Pseudo-solutions differ from true solutions in not being optically void when examined in the ultra-microscope, and suspensions differ from both of these in not being optically void when examined by the naked eye or ordinary microscope Particles in suspension may be separated from a liquid medium by the mechanical processes of filtration or of sedimentation and decantation

Solute may be gas, liquid or solid, and solvent liquid or solid Where there exists a solubility range between solids, that is, there is a series of concentrations of two or more solids, the substances are described as forming a solid solution, as for example in the following systems, namely, (1) **silver-gold,** (2) **cobalt-nickel,** (3) **antimony-bismuth,** (4) **magnesium** sulfate heptahydrate-**zinc** sulfate heptahydrate, (5) **iodine-benzene** crystals Most solutions exist in the liquid state, and water is the most common solvent encountered (See **Water; Solvents**)

The solubility of substances is expressed in various units (See **Concentration**) Some illustrative examples of the extent of solubility with various solute-solvent systems and resulting generalizations follow

SOLUBILITIES OF REPRESENTATIVE GASES

Solute (Gas)	Solvent (Liquid)	Temperature °C	Pressure Atmospheres	Solubility ml of gas (at 0° C, 760 mm) in 100 ml solvent, when the pressure of the gas itself is 760 mm (with exceptions noted)
Ammonia	Water	0	1	105,000
Hydrogen chloride	Water	0	1	50,000
Sulfur dioxide	Water	0	1	8,000
	Water	20	1	4,000
	Water	40	1	1,900
Hydrogen sulfide	Water	0	1	467
	Water	20	1	258
	Water	40	1	166
Chlorine	Water	20	1	226
Carbon dioxide	Water	0	1	171
	Water	20	1	88
	Water	40	1	53
	Water	0	2	342
	Water	0	0 5	86
	Alcohol (49%)	20	1	98
	Alcohol (99%)	0	1	440
	Alcohol (99%)	20	1	300
	Alcohol (99%)	40	1	220
Nitrous oxide	Water	0	1	130
Acetylene	Water	0	1	173
	Water	20	1	103
	Acetone	0	1	37 grams per liter solution
	Acetone	18	1	21 grams per liter solution
	Acetone	15	1	2,500 ml per 100 ml acetone
	Acetone	15	12	30,000 ml per 100 ml acetone
	Acetone	−80	1	200,000 ml per 100 ml acetone
	Acetone (50%)	0	1	5 7 grams per liter solution
	Acetone (50%)	18	1	1 2 grams per liter solution

SOLUBILITIES OF REPRESENTATIVE GASES

Solute (Gas)	Solvent (Liquid)	Temperature °C	Pressure Atmospheres	Solubility ml of gas (at 0° C, 760 mm) in 100 ml solvent, when the pressure of the gas itself is 760 mm (with exceptions noted)
Ethylene	Water	0	1	23
	Water	20	1	12
	Alcohol	0	1	360 vol per 100 vol alcohol
	Alcohol	20	1	270 vol per 100 vol alcohol
Nitric oxide	Water	0	1	7 4
Methane	Water	0	1	5 5
Oxygen	Water	0	1	4 9
	Water	20	1	3 1
	Water	40	1	2 3
Carbon monoxide	Water	0	1	3 5
	Water	20	1	2 3
	Water	40	1	1 8
Nitrogen	Water	0	1	2 4
	Water	20	1	1 5
	Water	40	1	1 2
Hydrogen	Water	0	1	2 1
	Water	20	1	1 8
	Water	40	1	1 6

At a constant temperature, the solubility of a given gas in a given solvent is proportional to the pressure, if the gas is of moderate to low solubility (Henry)

In a mixture of gases, the solubility of each gas is determined by its partial pressure (Dalton)

The solubility of gases decreases with increase of temperature Most gases are expelled gradually but completely from the solvent upon boiling, or by bubbling an inert gas through the solution, or when allowed to remain exposed to the atmosphere **Hydrogen chloride** is an exception Boiling hydrochloric acid of any strength gives ultimately a distillate of boiling point 108 58° C at 760 mm pressure and of 20 24 percent HCl At other pressures the boiling point and concentration are different but definite

SOLUBILITIES OF REPRESENTATIVE LIQUIDS

Solute or Solvent (Liquid)	Solvent or Solute (Liquid)	Temperature °C	Solubility
Alcohol	Water		Miscible in all proportions
Benzene	Water	3	0 030 g H_2O per 100 g
		23	0 061 g H_2O per 100 g
		40	0 114 g H_2O per 100 g
	Carbon tetrachloride	0	85 3 g C_6H_6 per 100 g solution
		5 5	Miscible
	Chloroform	0	88 g C_6H_6 per 100 g solution
		5	Miscible
	Ethyl alcohol	0	85 g C_6H_6 per 100 g solution
		5 5	Miscible
	Phenol	0	78 3 g C_6H_6 per 100 g solution
		5 1	Miscible
Aniline	Water	30	3 7 g $C_6H_5NH_2$ per 100 g water layer 5 4 g H_2O per 100 g aniline layer
		90	6 4 g $C_6H_5NH_2$ per 100 g water layer 9 9 g H_2O per 100 g aniline layer
		150	17 g $C_6H_5NH_2$ per 100 g water layer 24 g H_2O per 100 g aniline layer
		168	Miscible
	Ethyl alcohol		Miscible
Phenol	Water	20	8 3 g C_6H_5OH per 100 g water layer 27 9 g H_2O per 100 g phenol layer
		50	12 g C_6H_5OH per 100 g water layer 37 3 g H_2O per 100 g phenol layer
		68 3	Miscible
	Ethyl alcohol		Miscible
Carbon tetrachloride	Water	20	0 08 g CCl_4 per 100 g water
Carbon disulfide	Water	20	0 18 g CS_2 per 100 ml solution
	Ethyl alcohol (97%)	17	100 ml CS_2 per 100 ml alcohol
Bromine	Water	0	4 0 g Br_2 per 100 g solution
		20	3 5 g Br_2 per 100 g solution
		40	3 3 g Br_2 per 100 g solution

SOLUBILITIES OF REPRESENTATIVE SOLIDS

Solute (Solid)	Solvent (Liquid)	Temperature °C	Solubility
Sucrose	Water	0	64
		20	67
		40	70 } g $C_{12}H_{22}O_{11}$ per 100 g solution
		70	76
		100	83
	Ethyl alcohol (97%)	14	0 36
	Ethyl alcohol (50%)	14	47 } g. $C_{12}H_{22}O_{11}$ per 100 ml solution
	Water	14	87 5
Sodium chloride .	Water	0	26 3
		20	26 4
		40	26 7 } g NaCl per 100 g solution
		70	27 3
		100	28 1
		118	28 5
	Hydrochloric acid 182 g HCl per liter of solvent	25	7 0
	36 5	25	22 3
	18 2	25	25 4 } g NaCl per 100 g solution
	9 1	25	25 5
	Water	25	26 5
Anthraquinone	Benzene	20	0 26 } g $C_{14}H_8O_2$ per 100 g benzene
		60	0 97
	Chloroform	20	0 61 } g $C_{14}H_8O_2$ per 100 g chloroform
		60	1 58
Anthracene ..	Methyl alcohol	20	1 8 g $C_{14}H_{10}$ per 100 g alcohol
	Benzene	25	1 9 g $C_{14}H_{10}$ per 100 g benzene
	Toluene	16	0 9 } g $C_{14}H_{10}$ per 100 g toluene
		100	13
	Carbon disulfide	25	2 6 g $C_{14}H_{10}$ per 100 g carbon disulfide
	Sulfur dioxide liquid	40	2 1
		65	4 } g $C_{14}H_{10}$ per 100 g sulfur dioxide
		99	10
Azobenzene	Methyl alcohol	10	3 8
	Ethyl alcohol	10	5 6 } g $(C_6H_5N)_2$ per 100 g solution
	Propyl alcohol	10	5 7
Sulfur	Carbon disulfide	0	18
		20	30 } g sulfur per 100 g solution
		40	50
	Benzene	15	1 5
		26	1 0 } g sulfur per 100 g benzene
		71	4 4
	Chloroform	20	1 0 g sulfur per 100 g chloroform
	Carbon tetrachloride	25	0 9 g sulfur per 100 g carbon tetrachloride
	Sulfur monochloride	0	6
		18	10 } mol % sulfur in mixture
		55	28
Phosphorus.	Carbon disulfide	0	81
		10	90 } g phosphorus per 100 g solution
	Benzene	0	1 5
		20	3 2 } g phosphorus per 100 g benzene
		40	5 8

Increase in temperature generally increases the solubility of a solid in a liquid Loss of liquid solvent by evaporation at ordinary or elevated temperatures, from a given solution of solid generally results in the recovery of the pure solid as crystals, except when supersaturation occurs

SATURATED SOLUTIONS The maximum amount of solute dissolvable in a given amount of a stated solvent, under definite conditions of temperature and pressure (pressure is important when dealing with gases, otherwise the effect of pressure is minor) and *in the presence of excess* of the solute, is the solubility of the solute in that solvent The resulting solution is a saturated solution (See **Concentration.**)

UNSATURATED AND SUPERSATURATED SOLUTIONS. When less than the saturation concentration of solute is present in a solvent, the solution is unsaturated. When more than the saturation concentration of solute is present in a solvent, the solution is supersaturated The latter condition is brought about in the case of solids by lowering the temperature of a sufficiently concentrated solution in the absence of solute as such, of dust, of mechanical shock, and of nuclei for **crystallization. Sodium** thiosulfate ($Na_2S_2O_3$ $5H_2O$) is a favored substance for producing supersaturated solution, but many other substances exhibit the phenomenon, e g , sugar solutions, **calcium** gluconate and many organic compounds In the case of gases dissolved in liquids, super-

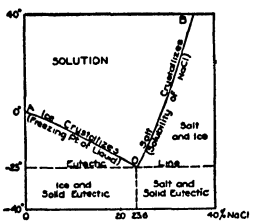
saturation may be present upon raising the temperature in the absence of rough solid surfaces of gases and of agitation Water saturated with air at 7° C is reported as having been kept in this way at 18° C for six days

PHYSICAL PROPERTIES OF SOLUTIONS Certain physical properties of solutions are of predominant importance Among these are.

1 The change of **vapor pressure** of a liquid solvent by addition of solute The vapor pressure is lowered 170 millimeters per 1 gram mol of solute in 1000 grams of water for "ordinary solutions," and up to values of about 2 or 3 times this amount for "non-ordinary solutions" For solvents other than water a characteristic value for each is observed

2 The change of **boiling point** of a solution with the thermometer bulb in the *solution* The freezing point is lowered 1 85° C per 1 gram mol of solute in 1000 grams of water for "ordinary solutions," and up to values of about 2 or 3 times this amount for "non-ordinary solutions" For solvents other than water a characteristic value for each is observed

3 The change of **freezing point** of a solution—with the thermometer in the *solution* The freezing point is lowered 1 85° C per 1 gram mol of solute in 1000 grams of water for "ordinary solutions," and up to values of about 2 or 3 times this amount for "non-ordinary solutions" For solvents other than water a characteristic value for each is observed



Solubility and freezing point diagram of sodium chloride water mixtures.

These three observations were contributed by Raoult (1878)

4 The **osmotic pressure** of a dilute solution (0 5 molar or less) The osmotic pressure at a concentration of 0 1 mol of solute in 1000 grams of water at 0° C is 2 2 atmospheres, and also proportional to the absolute temperature at constant concentration This, as was pointed out by van't Hoff (1885), is not only analogous to but identical with the behavior of gases

Equation which expresses the behavior of gases (the more "perfect" the gas, the more exact is the relation)

$\frac{PV}{T} = R$ where P equals pressure, V volume, T absolute temperature, R constant

Equation which expresses the behavior of solutes in dilute solutions $\frac{P}{TC} = R$ where P equals osmotic pressure, C concentration of solution, T absolute temperature, R constant

SOLUBILITY OF A SUBSTANCE IN THE PRESENCE OF TWO IMMISCIBLE LIQUIDS Distribution or partition of a third substance between two immiscible liquids is illustrated by the following data for several concentrations in each case The ratio of concentrations of the third substance in each of the two layers is practically constant over a wide range of concentrations

FORMIC ACID, DISTRIBUTION (13°-15° C) IN

WATER LAYER	BENZENE LAYER
1 016 g HCOOH per 25 ml	0 016 g HCOOH per 150 ml.
1 539	0 023
2 112	0 031
3 826	0 062
7 83	0 138

PHENOL, DISTRIBUTION (20° C) IN

WATER LAYER	BENZENE LAYER
0 945 g phenol per liter	2 073 g phenol per liter
0 711	1 553
0 475	1 036
0 238	0 518

ANILINE, DISTRIBUTION (25° C) IN

WATER LAYER	BENZENE LAYER
0 0135 g per 100 ml	0 1312 g per 100 ml
0 0122	0 1282
0 0065	0 0656

OXALIC ACID, DISTRIBUTION (20° C) IN

WATER LAYER	BENZENE LAYER
0 306 g. $(COOH)_2$ per 100 ml	0 0653 g $(COOH)_2$ per 100 ml
1 064	0 326
3 015	1 148
4 511	1 934

(R K S)

SOLUTIONS OF A DIFFERENTIAL EQUATION. Ordinary Differential Equations.

SOLUTION OF ALGEBRAIC EQUATIONS BY FACTORING. If an **equation** is in the form of a **polynomial** in one unknown equated to zero, it may frequently be solved by **factoring** the polynomial and using the principle if a product of two or more factors is zero, either one or more of its factors must be zero (L L S)

SOLUTION OF EQUATIONS. The process of finding the particular values of the unknown for which the two expressions of an **equality** have identical numerical values is called the solution of the **equation.**

The process of solution of an equation is therefore the operation of finding the **roots of the equation.**

The term "solution of an equation" is also sometimes used to mean the same thing as the roots of the equation (L L S)

SOLUTRIAN. Paleontology of Man.

SOLVAY PROCESS Ammonia-soda process for making **sodium** carbonate

SOLVENTS The most common solvent is water Water dissolves a great many gases, liquids, and solids, and is much used for this purpose (See **Solutions**; and **Water.**) Other liquids similarly dissolve many substances without reacting chemically with them Important considerations in connection with the choice of solvent for a given case are (1) **vapor pressure** and **boiling point,** (2) solvent power under stated conditions of temperature, (3) ease and completeness of recoverability by **evaporation** and **condensation,** and completeness of separation from dissolved material by evaporation, (4) **heat of vaporization,** (5) miscibility with water or other liquid, if present, (6) inertness to chemical reaction with the materials present, and with the apparatus, (7) inflammability, and explodibility, (8) odor, and toxicity, (9) cost of solvent, loss in process, cost of recovering

Many classes of substances are available as solvents It is convenient to classify these in the following manner

1. **Water**
   Various water solutions, e g, sucrose, glycerol, ethyl alcohol, zinc chloride, zinc bromide, stannous chloride, ammonio-cupric hydroxide, sulfuric acid concentrated
2. **Hydrocarbons**
   Petroleum fractions
   Petroleum ether
   Ligroin
   Higher boiling fractions
   Normal-heptane

(*Continued on next page*)

2 **Hydrocarbons**—*Continued*
- Terpenes
  - Turpentine
- Benzenoid
  - Benzene
  - Toluene
  - Xylenes
  - Mesitylene
  - Cumene
  - Cymene
- Tetrahydronaphthalene
- Decahydronaphthalene

3 **Alcohols**
- Methyl alcohol
- Ethyl alcohol
- Normal-propyl alcohol
- Iso-propyl alcohol
- Normal-butyl alcohol
- Amyl alcohol
- Normal-hexanol
- Ethylene glycol
- Propylene glycol
- Diethylene glycol
- Glycerol

4 **Phenols**
- Phenol
- Cresols

5 Ethers (See **Alcohols and Ethers**)
- Dimethyl ether
- Diethyl ether
- Dipropyl ether
- Di-iso-propyl ether
- Di-normal-butyl ether
- Ethylene glycol monomethyl ether
- Ethylene glycol monoethyl ether
- Diethylene glycol monomethyl ether
- Diethylene glycol monoethyl ether
- Ethylene oxide
- Propylene oxide
- 1, 4-Diethylene oxide

6 **Aldehydes**
- Normal-butyl aldehyde
- Crotonaldehyde

7 Ketones (See **Aldehydes and Ketones**)
- Acetone
- Methyl ethyl ketone
- Methyl iso-butyl ketone
- Furfural

8 Carboxylic acids (See **Acids, Carboxylic**)
- Acetic acid

9 **Esters**
- Methyl acetate
- Ethyl acetate
- Iso-propyl acetate
- Normal-butyl acetate

10 Chloro-organic compounds (See **Chlorine**)
- Ethyl chloride
- Chloroform
- Carbon tetrachloride
- Ethylene dichloride
- Trichloroethylene
- Propylene dichloride
- 1, 1, 2-Trichloroethane
- Tetrachloroethylene
- Monochlorobenzene
- Acetylene tetrachloride
- Ortho-dichlorobenzene
- Trichlorobenzene
- Epichlorohydrin

11 Bromo-organic compounds (See **Bromine**)
- Methyl bromide
- Ethyl bromide
- Bromoform
- Ethylene dibromide
- Ethylene chlorobromide
- Ortho-dibromobenzene

12 Nitrogen organic compounds (See **Nitrogen**)
- Pyridine
- Aniline
- Monoethanolamine
  - (2-hydroxyethylamine)
- Diethanolamine
  - (di-2-hydroxyethylamine)
- Triethanolamine
  - (tri-2-hydroxyethylamine)
- Acetamide
- Tetralkyl ammonium compounds

13 Sulfur organic compounds (See **Sulfur**)
- Carbon disulfide
- Thiophene

14 Liquified gases
- **Ammonia**
- **Sulfur dioxide**
- **Hydrogen sulfide**
- **Hydrogen chloride**
- **Hydrogen bromide**
- **Cyanogen**
- **Nitrogen** tetroxide

15 Inorganic liquids
- **Sulfur** monochloride
- **Phosphorus** trichloride
- **Phosphorus** tribromide
- **Phosphorus** oxychloride
- **Arsenious** chloride
- **Hydrogen cyanide**

The data available on the subject of solvents is large in amount, but far from complete The applications are many and growing rapidly Illustrative selections must necessarily be very limited

1 **Sulfur, iodine,** yellow **phosphorus** (red phosphorous insoluble) are dissolved by **carbon** disulfide, and, upon evaporation of the solvent at room temperature, these solids remain as a residue

SOLUBILITY OF VARIOUS SUBSTANCES IN CARBON DISULFIDE

Substance	Temperature °C	Grams Substance per 100 Grams Carbon Disulfide
Sulfur	0	22 0
	20	41 8
	40	100 0
Iodine	0	7 9
	20	14 6
	40	25 2
Phosphorus	0	81 3
	10	89 8

2 Sulfur is dissolved by carbon disulfide, **carbon tetrachloride, chloroform, benzene, toluene, aniline, phenol,** and many other solvents

SOLUBILITY OF SULFUR IN VARIOUS SOLVENTS

Solvent	Temperature °C.	Grams Sulfur per 100 Grams Solvent
Aniline	130	85 3
Benzene	15	1 5
Carbon disulfide	20	41 8
Carbon tetrachloride	25	0 86
Chloroform	19	0 92
Ethylene dichloride	25	0 84
Phenol	174	16 4
Toluene	23	1 48
Trichloroethylene	25	1 63

3 Laszczynski (1894) reported the solubility of about 15 inorganic salts in 7 organic solvents The following data is illustrative

Salt	Solvent	Grams Salt per 100 Grams Solvent at Room Temperature
Mercuric chloride ($HgCl_2$)	Ether	6 4
	Ethyl acetate	30 0
	Acetone	126
Stannous chloride ($SnCl_2\ 2H_2O$)	Ether	11 4
	Ethyl acetate (77° C)	73 3
Potassium thiocyanate (KCNS)	Pyridine	6 1
	Acetone	20 7
Silver iodide (AgI)	Pyridine (115° C)	8 6

4 In some cases, the solvent, upon evaporation, forms a residue containing solvent of crystallization, e g , **calcium** chloride tetramethyl alcohol ($CaCl_2\ 4CH_3OH$) below 55° C , calcium chloride triethyl alcohol ($CaCl_2 \cdot 3C_2H_5OH$) above 55° C

5 The application of solvents is not confined to the solution of solids, but includes also gases and liquids Nor is it strictly limited to cases where true solutions result, but includes pseudo-solutions, that is, suspensions and emulsions

Common solvents used in pharmacy are water (liquors, aquae, solutions), **ethyl alcohol** plus water (spirits, tinctures, extracts, essences), **sucrose** plus water (syrups), **glycerol** with or without water (glycerites) In the extraction of oils and fats from materials such as seeds, and in dry cleaning of fabrics, such solvents as **carbon** disulfide, carbon tetrachloride, trichloroethylene, **benzene,** ligroin are used In paints, varnishes and lacquers, **turpentine** is commonly used, also tetrahydronaphthalene, and benzene Several of the ethers are used in the preparation of **cellulose** nitrate and cellulose acetate lacquers and dopes In the explosives industry, acetone is used, and in certain cases ethyl alcohol-ether mixture

In general, substances of similar chemical constitution dissolve each other, e g , hydrocarbons dissolve hydrocarbons By the use of two or more mutually miscible solvents the field of application is greatly extended

7 Chloro-organic compounds are among the more chemically inert solvents

8 In the petroleum industry, solvents serve to extract certain portions of the raw material in the process of refining Liquid sulfur dioxide may be used for differential solution Liquid propane is also used

9 Solvent recovery is usually accomplished by evaporation and condensation, but adsorption by such materials as silica-gel is also utilized (R K S)

SOMITE One of the longitudinal series of segments into which the bodies of many animals are divided These segments are clearly shown in a simple form in the **earthworms.** In man they are made evident by the structure of the spinal column and the series of spinal nerves, but they are overshadowed externally by the high development of the appendages The term is synonymous with metamere

The segmental masses of mesoderm in the vertebrate embryo are also called somites They are the primordia of the axial skeleton, voluntary muscles of the body and appendages, and the inner layer of the skin (A W L)

SONOMETER. Musical Sounds.

SONSTADT SOLUTION Thoulet Solution.

SORGHUM. *Andropogon Sorghum* Gramineae Sorghums are annual grasses of tropical origin They have an extensive system of wiry roots and solid stems from three to fifteen feet tall The leaves are smaller than those of corn, and capable of rolling up tightly during periods of drought, and quickly unrolling and starting to function when favorable moisture conditions return Because of this habit sorghums are often grown in regions subject to frequent drought The **inflorescence** is a **panicle** usually of very compact habit Ordinarily the **spikelets** are paired, one of the pair being sessile or stemless, the other having a short stem or pedicel The former is fertile, the latter staminate (See **Stamen**) The grains are enclosed in the glumes and vary considerably in shape in different varieties There are two main groups of sorghums, the sweet or saccharine sorghums, the juicy pith of which is a source of syrup, and the grain sorghums, which yield grain, stock food and ensilage Kaffir is one of the latter group In Asia grain sorghums are employed in a countless variety of ways, as for fuel, brooms, mats, fences, windbreaks, roof thatch, and in making a fermented drink (R M W)

SORUS. Ferns.

SOUND. Physically, sound is a longitudinal elastic wave motion propagated by alternate compressions and rarefactions of the medium, usually air If air is compressed by the sudden movement of some object, as a piece of cardboard, its elasticity causes it to expand and compress the air ahead of it This generates a wave, in which each molecule of the medium oscillates forward and backward An excellent analogy is the propagation of a bump or a jerk from the engine at one end of a freight train to the caboose at the other

There are thermodynamic aspects of the propagation of sound, which in the earlier study of the theory were overlooked The heating and cooling effects of compression and expansion are not negligible, in deriving the following expression for the speed of propagation of sound, it is assumed that they are **adiabatic processes.** The formula commonly used for gases is

$$v = \sqrt{\frac{\gamma p}{\rho}}$$

In this equation p is the pressure of the gas in absolute units (bars) and ρ is its density, γ is the ratio of the specific heat at constant pressure to the specific heat at constant volume Thus, for air at normal temperature and pressure $p = 1{,}013{,}250$ dynes per square centimeter (1 atmosphere), $\rho = 1\ 293 \times 10^{-3}$ grams per cubic centimeter, and $\gamma = 1\ 408$ This gives $v = 33{,}220$ centimeters per second, which is quite near the measured value For room temperatures the speed is greater (about 34,400 centimeters per second), since the density ρ is less

Modern research in **acoustics** has been greatly aided by the instantaneous photography of sound waves, or rather, of their refraction patterns, cast like shadows upon a photographic plate, by the light from an electric spark In this way the progress of the wave and its reflection, refraction, and diffraction are permanently preserved for study and measurement **Sound recording** is also much utilized in the analysis of **musical sounds**

The mechanism of the ear and of hearing is but imperfectly understood In some way the sound vibrations reaching the inner ear stimulate the auditory nerves, but the extreme sensitiveness and delicacy of discrimination possessed by the ear are hard to explain. It has been shown that our ability to locate the direction from which a sound comes is due to the slight difference in time at which the waves reach the two ears. (L D W)

SOUNDING. A knowledge of the depth of water under the keel of a vessel is frequently of great importance to a navigator or pilot The process of obtaining this depth of water is known as taking soundings The term is also applied directly to the determined depth All charts of coast lines give the soundings in great detail out to a depth of one hundred fathoms. In

addition to the depth of water the character of the bottom is also given When a vessel is continually taking soundings and using the contour and character of the bottom for the purpose of directing the pilotage, she is said to be "on soundings"

The simplest, and perhaps most effective, method of taking soundings is to use the old fashioned lead and line The lead is simply a piece of lead hollowed out at the bottom and "armed" by placing tallow in this hollow for bringing up a sample of the bottom The line is graduated in measured lengths, due allowance being made for the distance of the person who is "flying the blue pigeon" from the surface of the water The great difficulty with this method is that the speed of the vessel must be checked in order that the line may be perpendicular to the surface of the water when the lead reaches the bottom.

To avoid the necessity of stopping the ship various types of sounding machines are used In these machines the lead is attached to a line or wire and allowed to trail out behind the vessel until it reaches the bottom The depth of the water is determined, not by the length of line paid out, but by a device attached to the lead which measures the maximum pressure of the water This maximum pressure of the water is proportional to the depth of water and will be attained when the lead reaches the bottom

Within recent years the so-called sonic depth recorder has been developed for taking soundings This instrument operates on the principle that sound travels with a finite velocity in water and the length of time required for a signal to go from the keel to the bottom of the ocean then be reflected back to the ship is proportional to the depth of water under the ship A device is placed against the skin of the ship near the keel which sends out a sharp signal A receiver detects the reflected signal from the ocean floor on its return to the ship's bottom The time between the sending of the signal and the reception of the reflection is converted into the desired sounding In the so-called Fathometer the entire instrument is operated from the pilot house and is so designed that all that is necessary is to turn a switch and the depth of water appears on a dial, all of the operations being fully automatic (W K G)

SOUND RECORDING. The recording and subsequent reproduction of **sound,** somewhat parallelling the development of photography, ranks among the unique achievements of modern times The fact that its largest application so far has been to entertainment in no way detracts from its noteworthy character or its potential usefulness The first phonograph was constructed in 1855 by Leon Scott This was largely improved by Edison about 1877 and in the years following In the Edison apparatus a needle, attached to a diaphragm vibrating with the sound waves, makes indentations in soft tin foil or wax When the needle is again drawn over these indentations, it is caused to vibrate as before, and communicates its motion to the diaphragm, so that the original sound is reproduced In a much used modification of this device, the needle vibrates sidewise, producing a wavy groove instead of indentations. The nearest modern counterpart of the original Edison phonograph is the "dictaphone" used in lieu of shorthand in some business offices

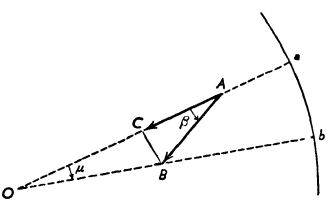
Recent years have brought the perfection of photographic sound recording, now universally used with talking pictures The sounds to be reproduced are made to modulate a beam of light, a narrow trace of which is impressed at the edge of the picture film This is done by varying either the width or the intensity of the light beam, the former by means of a slit with vibrating jaws, the latter by the use of a Kerr electro-optical cell (See **Electric and Magnetic Double Refraction**) In reproducing the sounds so recorded, a beam of light, shining through this modulated strip and thus varying as the film moves past, enters a photoelectric cell The cell is in circuit with amplifiers which actuate the loud speakers back of the screen Therefore, as the light beam is modulated by the moving film record, the loud speakers give forth the corresponding sounds Both mechanical and photographic sound reproduction have achieved remarkable distinctness and fidelity to the original enunciation and tone quality (L D W.)

SOW-BUG. **Wood-louse.**

SOYBEAN. *Glycine max* **Bean.**

SPACE-TIME. **Relativity.**

SPACE VELOCITY. The space velocity of a star is its actual velocity in space The term "fixed star' is one which has been handed down to us from the era when philosophers believed that the stars were fixed on a sphere, rotating about the earth, which they referred to as the celestial sphere At the present time we believe that practically all of the stars are actually in motion in space with velocities comparable in magnitude to the velocities with which the **planets** are moving about the sun in their orbits In measuring any velocity it is necessary to have a definite reference point and the space velocity of a star is its velocity referred to the sun.



In the figure we have the space velocity of a star represented by the **vector** (directed straight line proportional to the velocity in direction and magnitude) *AB* The angle β which this vector makes with the direction of the star from the sun at any particular instant gives the direction of the space velocity at that instant

As observed from the solar system this space velocity may be resolved into two components *AC* the **radial velocity,** and μ the **proper motion.** The radial velocity is determined directly in terms of linear velocity (i e , in miles or kilometers per second) but the proper motion may only be determined in angular units, usually expressed in seconds of arc per year In order that the space velocity may be known the proper motion must be converted into a linear velocity, commonly known as the transverse velocity of the star This may be accomplished only if the distance of the star is known. Expressing the distance in terms of the stellar parallax, P'', and calling the transverse velocity T (the line CB in the figure), the following relations may be derived·

$$T = 4.74\ \mu/P''\ \text{km/sec or}\ T = 2.94\ \mu/P''\ \text{mi/sec.}$$

With both the transverse velocity, T, and the radial velocity, R, both known in the same units the problem of determining the space velocity S in the same units is merely that of solving the plane right triangle ACB This solution yields:

$$S^2 = T^2 + R^2 \qquad \text{cosine}\ \beta = R/S \qquad \text{sine}\ \beta = T/S$$

(W K G)

SPADIX. **Flower.**

SPANISH FLY. A pharmaceutical preparation consisting of the dried and powdered bodies of a European species of blister beetle These **beetles,** constituting the family Meloidae, contain a poisonous substance known as cantharidin from the family name Cantharidae formerly applied to the group. Cantharidin is a powerful

irritant, dangerous when taken internally It blisters the surface of the skin and is used as a counter-irritant. (A W L)

SPANISH MOSS. **Tillandsia usneoides.** Bromeliaceae Spanish Moss is in fact not a moss at all, but a flowering plant related to the Pineapple The plant is a perennial herbaceous plant growing as an **epiphyte** on any solid support available It is found throughout tropical and subtropical America from Brazil to the southern United States

Spanish Moss is rootless, and has a long slender branching stem which reaches a length of two to six feet, and narrow tapering leaves The entire plant surface is covered with grayish scales capable of absorbing water The flowers are small and yellow, the fruit, a dry **capsule.** The plant propagates itself readily by means of small fragments which are blown about by the wind Again the plant may be carried by birds, who seek the plant as nest-building materials

The entire plant is frequently used as a packing material or for stuffing furniture From the stem is obtained a coarse stiff black fibrous material, very like horsehair in appearance, this also is used in upholstery There are several other species in the genus. Other common names applied to this plant are Southern Moss, old man's beard, vegetable horsehair, and long moss (R M W)

SPAR. In marine parlance a spar is a round timber used to extend a sail Used with this meaning it could be a mast, a boom or a yard

A structural member used similarly to extend a surface to obtain an air reaction is found in the wing of an **airplane** There, the spar is a principal structural member running the length of the **wing.** Usually there are two, parallel to one another, but wings have been built having only one spar In such a design the spar is required to take torsion as well as compression and bending The spars support the ribs upon which the wing covering is stretched The reaction of the air upon the latter is transmitted to the spars which in turn are attached to the fuselage The air reaction may be carried by the spars entirely by bending as in the cause of a truly cantilever wing, or it may be carried by spars which are braced outboard of the fuselage by wires or struts (F T M)

SPARAGMITE. A general and somewhat local term for late **Proterozoic** poorly graded **clastic,** sedimentary formations including such distinctive types as **arkose** and **graywacke,** intermixed or interbedded with conglomerates and intraformational **breccias** Some of the pebbles in the conglomerates are **dreikanter,** and the total textural and structural features of the sedimentary suite suggest arid to semi-arid, **torrential,** and **intermontane** conditions of deposition (R M F)

SPARK. An electric spark is a sudden breakdown of the insulating strength of the dielectric separating two electrodes, due to the formation of ions by an intense electric field, accompanied by a rush of electricity across the "spark gap," and a flash of light indicating very high temperature Unlike the arc, glow, and brush discharges, the spark is of very short duration It may be oscillatory or intermittent, several discharges taking place in quick succession In gases, the spark takes place only at appreciable pressures, such as normal atmospheric pressure

If the voltage across a spark gap is progressively raised, a spark passes when it has become sufficiently high. The lowest voltage at which the spark will pass is the "sparking potential", but there is usually a time interval, called the "spark lag," between the attainment of this voltage and the passage of the spark Also the voltage may be increased for a moment considerably above this value without producing a spark These characteristics depend upon the condition of the gas, especially upon the ions and the vapors present in it. After one spark has passed, others follow at lower sparking potential, because of the ions already formed, and this is also true if the "pilot spark" takes place across another neighboring spark gap Paschen found that for a given pressure the sparking potential is a nearly linear function of the length of the gap, and for a given gap it is a nearly linear function of the pressure For spherical terminals, the relation is so definite that the "sphere gap" is often used as a rough measure of high voltages Thus with spherical electrodes 5 cm in diameter, a 2-cm spark in air at normal pressure corresponds to a potential difference of 56,300 volts, a 5-cm gap to 102,250 volts With 10-cm spheres, the corresponding voltages are 59,460 and 123,850.

When metallic terminals are used, the light from the spark exhibits the spark **spectrum** of the vaporized metal The spark is also the source of a type of ultra violet radiation known as **Entladungsstrahlen,** which accounts for the effect of the pilot spark, referred to above (L D W)

SPARK PLUG. Ignition System.

SPARROW. Aves, Passeriformes. A common form of small seed-eating bird (**Aves**) of the family Fringillidae The many species are for the greater part rather quietly colored in browns and grays with streaked and spotted plumage, but some bear conspicuous black or white marks and the browns of some species are very bright Some of the sparrows have beautiful songs, although none rival such outstanding singers as the brown thrasher and the mockingbird

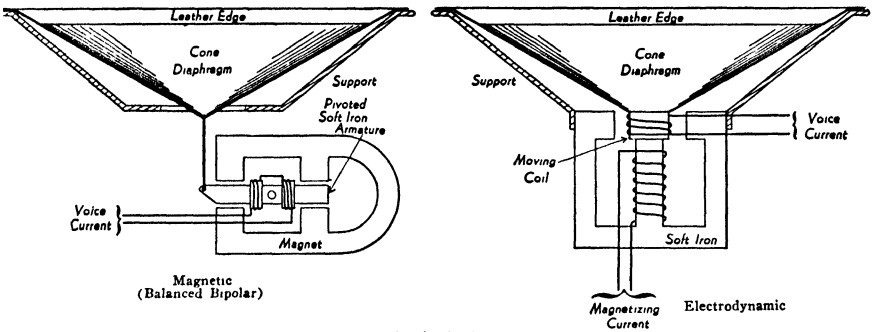
The field sparrow (*Spizella pusilla*), chipping sparrow (*S passerina*), white-throated (*Zonotrichia albicollis*) and white-crowned (*Z leucophrys*) sparrows, song sparrow (*Melospiza melodia*), and in the west the lark sparrow (*Chondestes grammacus*), are among the well-known North American species (A W L)

SPASTIC COLON. Constipation.

SPATHE. Flower.

SPATIAL DEGREE. Degree.

SPEAKER. The loud speaker, which has come to replace earphones in broadcast radio reception, and which has made possible the public address systems now so extensively used, is a device for converting an **alternating current** modulated by voice waves into a powerful **diaphragm** vibration which sets in motion a column of sound **waves** of sufficient intensity to be heard at some distance from the speaker Speakers employed to radiate sound from radio broadcast receivers are non-directional, having a diaphragm ordinarily of a conical form Those used for public address systems are somewhat directional, and employ a horn for acoustic radiation The two principal parts of a loud speaker are the driving motor and the sound radiator Two forms of motors are shown in the illustration In the magnetic type, which is an improvement upon the original magnetic speakers, the soft iron **armature** is pivoted and balanced between the pole shoes of a permanent **magnet.** The alternating current carrying the voice waves is passed through two coils mounted on this armature, so polarizing it that the magnetic attractions reproduce the electrical impulses as a vibration transmitted to the diaphragm, the diaphragm in this case consisting of a paper cone which is caused to move with piston motion The cone is flexibly joined to the frame by a leather junction strip Most recent radio receivers are equipped with electro-dynamic speakers, in which the magnetic field is produced by an electro-magnet. The alternating current is led to a light moving coil which is free to vibrate in this electro-magnetic field, and which is attached to the diaphragm. The



Forms of radio loudspeakers

moving coil, of course, has motion imparted to it by the magnetic reactions of the varying alternating current passing through it with the electro-magnetic field Where a volume of sound above that which would be desirable in a closed room is wanted, it becomes necessary to design the sound radiator upon more scientific acoustic principles, making use of air compression and rarefication chambers between the diaphragms and the horn, and to employ a horn which tapers properly from the throat to the mouth A common form employed is known as the exponential horn, since its cross-sectional area varies exponentially with its length Such horns are built with lengths up to six feet, being straight if there is sufficient room, or curled where space is limited. (F T M)

SPEARMINT, OIL OF. Volatile oils.

SPECIES. The smallest taxonomic category, excluding the various subdivisions recognized in very detailed study A species is made up of a group of individuals, but beyond this limitation the definition of the term has varied from the denial of its existence as a natural entity to various attempts at rigid characterization

As a rule the individuals of a species resemble each other within established limits of variation, but in some species the sexes are conspicuously different, in some the component individuals differ with the seasons, and in some there are various forms of individuals adapted for different tasks The principle of fertility as a test of the relationship has been adopted by some biologists, but here again species differ In some extremely variable species individuals may be found which are incapable of mating, and in some cases different species produce fertile hybrids when crossed The two criteria, reproductive association and structural resemblance, seem to provide a workable definition when taken together According to this concept a species may be defined as a natural group of individuals which are either similar in form or associated in a reproductive sequence Like all other definitions it will be found difficult to apply to certain specific cases, but it is more generally applicable than most (A W L)

SPECIFIC. Any **drug** or treatment that has a special or individual action in the cure of some disorder or disease, such as **quinine** in **malaria** or **salvarsan** in **syphilis.** (R S M)

SPECIFIC GRAVITY. Density and Specific Gravity.

SPECIFIC GRAVITY BOTTLE. Pycnometer.

SPECIFIC HEAT. The specific heat of a substance is the quantity of heat required to impart a unit increase in temperature to a unit mass of that substance; commonly expressed in **calories** per centigrade degree per gram (Some writers regard the specific heat as the abstract ratio of the quantity just defined to the corresponding value for water) The "thermal capacity" of a body of any mass is the quantity of heat required to raise its temperature one degree (calories per gram), so that the specific heat of a substance may be defined as its thermal capacity per unit mass Of all known substances, that having the greatest specific heat is hydrogen, for which, at constant volume, it is 2 418 calories per gram per degree, next is water, with specific heat unity (at 15° C) For gold it is only about 0 031 calories per gram per degree

These wide variations are qualitatively explained by the fact that, since the atoms and molecules of gold are much more massive than those of hydrogen and hence there are much fewer of them in a gram, and since the temperature is determined by the kinetic energy per molecule, the total energy required for a gram of gold molecules is correspondingly less than for a gram of hydrogen molecules Dulong and Petit (1819) concluded, indeed, that the specific heats of elements are inversely proportional to their atomic weights (See **Dulong and Petit's Law of Specific Heats**)

It is necessary to discriminate between the true or temperature specific heat and the apparent or total specific heat which we encounter when the thermal energy imparted is allowed to do more than agitate the molecules or atoms of the substance Expansion with rise of temperature may require energy because of work done against external pressure or against cohesion This is notably true with gases, the specific heats of which are, on the average, some 40% greater when they are allowed to expand at constant pressure than when kept at constant volume as the temperature is raised

SPECIFIC HEATS OF SOME COMMON SUBSTANCES

Substance	Specific Heat	Substance	Specific Heat
Air (c v)	0 171	Iron	0 107
Alcohol (0° C)	548	Lead	031
Aluminum	214	Mercury	033
Copper	090	Nitrogen (c v)	176
Glycerine	576	Oxygen (c v)	156
Helium (c v)	075	Silver	056
Hydrogen (c v)	2 418	Water	1 000
Ice	493	Zinc	090

(L.D W.)

SPECIFIC SPEED. The specific speed of a **hydraulic turbine** is the number of revolutions per minute at which it would develop one horsepower under one foot head, all dimensions of the turbine being reduced proportionally to enable it to meet these conditions.

The specific speed is the most important single dimension of a turbine It very fully indicates the characteristics of the runner. By making a comparison of specific speeds, the characteristics of turbine runners can be judged without considering their actual speed, head, or power And yet the specific speed is not completely satisfactory because it is not non-dimensional but is based on the respective dimensional systems, i e , English or metric

In general, runners of low specific speeds are suitable for high heads and those of high specific speed are suitable for low heads The combination of **head** and specific speed is such as to keep the generator speeds within reasonable range for all values of head This is fortunate since the possible range of head in present-day hydro-electric developments is from 5 to 5000 feet. The range of specific speeds is served by the various types of turbines about as follows.

N_s	TYPE
10–20	Pelton
20–120	Francis
120–150	Nagler, Kaplan

For an average generator, the cost decreases as the speed increases, at least within certain limits, hence as high a specific speed as can be safely used should be chosen (F T M)

SPECTACLES. Vision.

SPECTROGRAPH. Spectroscope.

SPECTRA. Spectrum.

SPECTRAL CLASS Examination of stars with the unaided eye will indicate that they are not all of the same apparent color This fact has been noticed from earliest times, and we find the names of many of the stars carrying an indication of their color e g , **Antares** was undoubtedly so named because of its reddish color similar to that of the planet Mars With the application of the **spectroscope** to astronomical research, several attempts were made to classify the stars according to their spectra Secchi and Vogel each proposed spectral classification sequences based upon visual observations The system which is now universally employed was developed by Dr E C Pickering, Director of the Harvard College Observatory from 1877 to 1919 The first results of his classification were published by the observatory with funds made available by Henry Draper, and the classification system is known either as the "Harvard system" or as the "Henry Draper system "

The Harvard system of classification is based upon the relative intensity of certain selected **absorption** lines in the stellar spectra The various types are designated by letters, and the principal characteristics of the different classes are:

Class B—Helium stars—Absorption lines of helium and hydrogen characteristic features

Class A—Hydrogen stars—Intensity of helium lines weaker and hydrogen lines the most prominent feature

Class F—Calcium stars—The *H* and *K* lines of calcium are much stronger than the hydrogen lines, although the latter are still prominent A few metallic lines are present

Class G—Solar stars—Calcium lines the most prominent feature, with the hydrogen lines distinctly fainter Many metallic lines

Class K—Metallic lines—Calcium lines still strong but spectrum predominated by multitude of lines due to metals. The violet end of the continuous background distinctly weaker

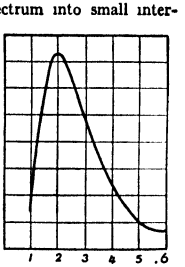
Class M—Molecular compound lines—Calcium and many metallic lines still prominent, but characteristic feature is the presence of bands due to molecular compounds The violet end of the continuous background extremely weak

Accompanying the above changes in the absorption lines there is a progressive change in the position of maximum intensity of the continuous background, the colors of the stars changing from blue for the B-type through yellow for the G-type to red for the M-type. This is an indication of a temperature sequence for the stars, those of the B-type being hottest and those of the M-type coolest Ninety-nine per cent of all stars thus far examined may be fitted into this sequence of six letters Stars with spectra intermediate between the various types are designated by a decimal system e g , a G5 star is half way between a G- and a K-type star To provide for the few stars which cannot be fitted into the main sequence there are a number of small classes For example, certain blue stars, some of which show bright lines, are known as O-type, while red stars, other than M-type, are grouped under N, R, and S

At present, over 275,000 stars have been classified at Harvard on the above system The spectra for classification purposes are obtained by **objective prism** photographs and have been examined and classified chiefly by Miss Annie J Cannon The results are published in the so-called Henry Draper Catalogue and its extensions The Mount Wilson Observatory, using its powerful light-gathering equipment, is engaged on a long program of classification of faint stars, and critical examination of fine differences within the different spectral classes, largely with a view to improvements in methods for determinations of **spectroscopic parallax.** At the Hamburg Observatory in Bergedorf a program of determination of the spectral classes of 150,000 stars in the Kapteyn **selected areas** is in progress The part that the spectral classification plays in theories of stellar evolution will be found discussed in the article on the **stars** and the correlation between spectral type and brightness, temperature and other physical characteristics of the stars will be found under **giant and dwarf stars**

Within the past decade spectral classification series have been developed for designating different types of **nebulae**, both bright line and **extra-galactic** (W K G)

SPECTRAL ENERGY DISTRIBUTION. When radiation exhibiting a continuous spectrum, as that from a hot stove or the light from an incandescent lamp, is quantitatively analyzed, it is found that quite different amounts of power are represented by the radiation within equal ranges of wave length or of frequency having different limits The proportion in any such range depends upon the character of the source Thus, in the radiation from a candle, the ratio of the energy output between 6500 and 6600 angstroms (red) to that between 4500 and 4600 angstroms (blue-violet) is greater than the corresponding ratio for the radiation from an arc lamp If we divide the spectrum into small intervals of wave length, say 10 angstroms, and plot the power output for each range as ordinate with the mean wave length of the interval as abscissa, the result is a curve showing the distribution of power through the spectrum When the radiation is due to high temperature, as in the above examples, there is always a wave-length interval having maximum power, that is, the curve has a "peak," from which the ordinates fall off in both directions Wien pointed out that the higher the temperature of the source, the farther toward the short-wave-length end of the spectrum does this peak lie (See **Wien's Laws, Planck's Equation, and Radiation Pyrometer.**)



Spectral energy distribution for black body at 1170° C (1443° Abs), with peak at 2000 A (2 micron)

An instrument utilizing a prism for dispersing the radiation, together with a thermocouple or similar device for measuring its flux density in different ranges, may be used to analyze infrared thermal radiation, and is called a "spectroradiometer" The **spectrophotometer** performs a similar service for visible light, except that the results in this case are usually tabulated in terms of the visibility rather than the actual power of the emission (L D W)

SPECTRAL SERIES. Atomic Spectra; Molecular Spectra; X-ray Spectra.

SPECTROHELIOGRAPH. As the construction of the term indicates, the spectroheliograph pictures the sun in its **spectrum.** Essentially the instrument consists of a high dispersion spectrograph with a second slit placed directly in front of the photographic plate so that the radiation from only one spectral line is received on the plate If the instrument is so placed that the first slit is in the principal focus of a telescope directed toward the sun, a narrow strip of the sun's image will be admitted by the first slit and an image of that narrow section of the sun will be formed on the photographic plate in the particular radiation for wh ch the second slit is adjusted The instrument is so constructed that the first slit may be moved across the image and at the same time the second slit moves across the photographic plate at the same rate Hence, it is possible to obtain a photograph of the sun in the monochromatic radiation of any particular element, say calcium

From the **flash spectrum** we can determine the heights to which various elements rise in the solar atmosphere, and thus by means of the spectroheliograph it is possible to obtain photographs of the sun at various levels above the **photosphere** (W K G)

SPECTROMETER. Spectroscope.

SPECTROPHOTOMETER An instrument for analyzing the **spectral energy distributions** of sources of light It is thus a spectroradiometer for visible radiation Various types are in use A representative form includes a **monochromatic illuminator,** from the slit of which proceeds an isolated, narrow frequency range of the light under examination This may be compared, by means of a **wedge photometer** device or otherwise, with the light of the same frequency range from a source whose spectral energy distribution is known In interpreting the results, it is important to take into account the visibility factor (See **Photometry**), and thus to distinguish between the relative absolute (energy) and apparent (visual) intensities for different wave lengths There are spectrophotometers which exhibit directly an approximate curve of apparent intensity distribution A simple type consists of a spectrometer with a neutral absorbing wedge placed with the thick base over the upper end of the slit and the thin edge over the lower The spectrum then appears as a strip whose upper margin, penetrating visibly to various distances into the region of greater absorption, corresponds to the distribution curve (L D W)

SPECTRORADIOMETER. Spectral Energy Distribution; Radiation Pyrometer.

SPECTROSCOPE. Many types of instrument for producing and viewing spectra are included under this term Variations in form are due, not only to differences in principle, but also to the type of radiation to be examined, which ranges all the way from **infrared** to **x-rays**

The earlier spectroscopes, developed by Fraunhofer, Ångstrom, and others in the early part of the last century, adapted **Newton's** discovery of the **dispersion** of light by a **prism.** The essential features (Figure 1) are a slit, S, a **collimating** lens C for rendering the light from the slit parallel before entering the prism, one or

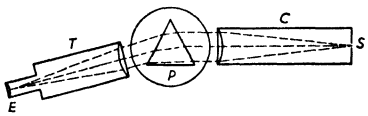


Figure 1 Diagram of simple prism spectroscope *C*, collimator with slit *S*, *P*, prism, *T*, telescope for viewing spectrum at eyepiece *E*

more dispersing prisms, P, and a **telescope** T (or a **camera**) for forming images of the slit in the various wave lengths and thus providing a method for viewing or photographing the **spectrum.** The light passes through these in the order named, being deviated by the prism through various angles according to the wave length When a spectroscope is provided with a graduated circle for measuring deviations, it is called a "spectrometer" The "direct vision" or non-deviation spectroscope, employing an **Amici prism,** is a compact instrument for qualitative purposes The photographic spectroscope, known as a "spectrograph," is now almost universally used in spectral research

Many modern spectroscopes employ the **diffraction grating** instead of the prism In the concave grating spectroscope, developed by Rowland, the collimating lens and telescope or camera objective are unnecessary be-

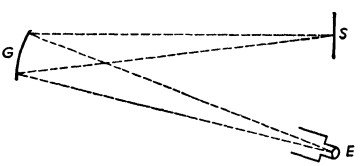


Figure 2 Concave grating spectroscope *S*, slit, *G*, grating, *E*, eyepiece (or plate holder) (Diagrammatic)

cause of the focusing effect of the grating itself (Figure 2) Other types of instruments developed for particular purposes will be found described under **X-ray Spectrometer** and **Objective Prism**

SPECTROSCOPIC BINARIES. Within the past fifty years we have become acquainted with a class of **binary stars** which are not **double stars** in the ordinary sense of the term, because of the fact that the components are too close together for them to be observed separately even in **telescopes** of the highest **resolving power** In such binaries the period is usually short and the orbital velocities high. Unless the orbit plane happens to be perpendicular to the line of sight, the orbital velocities will have components in the line of sight and the observed **radial velocity** of the system will vary periodically Since radial velocity is measured with the **spectroscope,** employing the **Doppler-Fizeau principle,** the binaries so observed are known as spectroscopic binaries. In some spectroscopic binaries the spectra of both stars are visible and the lines are alternately double and single Such stars are known as double line binaries. In. others the spectrum of only one component is seen and the lines in this spectrum move periodically from violet toward the red and back again.

The determination of the **orbit** of a spectroscopic binary is made from a long series of observations of the radial velocity of the system The observations are first plotted against time and from the resulting curve the period may be obtained. With this period determined observations are then reduced to a single epoch and the best possible curve drawn through the points, ob-

taining what is known as the velocity curve of the system If the orbit is circular the velocity curve will be a sine curve, if elliptical, the shape of the curve will depend upon the eccentricity of the ellipse and the orientation of the major axis with reference to the line of sight From the shape of the velocity curve the orbit of the system in space may be determined In the solution of the spectroscopic orbit it is impossible to determine individually the semimajor axis, a, and the inclination of the orbit plane, i However, the product of the semimajor axis by the sine of the inclination (i e, $a \sin i$) may be determined directly in linear units (i e, in either miles or kilometers) If either a or i can be obtained from other types of observations, as in the case of **eclipsing binaries**, a complete solution for the orbit can be made (W K G)

SPECTROSCOPIC PARALLAX The term spectroscopic parallax of a star is applied to a determination of the distance of a star in which the **stellar parallax** is determined from observations of spectral peculiarities of the star together with determinations of the apparent brightness of the object

The apparent brightness of a star depends upon two fundamental factors the intrinsic brightness of the star and its distance from the observer Expressed on the **stellar magnitude** scale, we find the apparent magnitude, mg, the **absolute magnitude**, M, and the stellar parallax, π'', to be connected by the analytical expressions $M = mg + 5 + 5 \log_{10} \pi''$ The apparent magnitude of a star may be determined by a variety of methods of **stellar photometry**, and if a method is available for the determination of the absolute magnitude the value of the stellar parallax may be determined

The relative intensities of certain **spectral lines** are different in **giant and dwarf stars** of the same spectral type The relative intensities of selected pairs of lines may be compared in stars of the same spectral type and known absolute magnitudes and a "calibration curve" obtained The relative intensities of the same pairs may then be found in stars of unknown absolute magnitudes and the calibration curves used to determine the absolute magnitude Thus, the parallax may be determined from a study of spectra The accuracy of the determinations of spectroscopic parallax compares very favorably with parallaxes obtained from the relative trigonometric methods. (W K G)

SPECTRUM. This term, in general, refers to the array of wave lengths or frequencies resulting from the **dispersion** of light or other **radiation**, as by a **prism** or a **diffraction grating**, and revealed by the **spectroscope.** The emission spectrum of a substance is that of the radiation which it emits when "excited," while the result of passing white light through the substance is its **absorption spectrum.** Incandescent solids, liquids, or gases under high pressure give a continuous spectrum, while gases under a relatively low pressure give either an **atomic spectrum** made up of lines, or a **molecular spectrum** of bands, or both The spectrum of the same substance may differ according to the method of excitation Thus we may have the flame spectrum, the arc spectrum, or the spark spectrum of, say, iron That is, iron salts may be vaporized in a flame, or an arc or a spark may be passed between iron electrodes **X-ray spectra**, while in many essential respects similar to those of light, belong in a distinct class, because of the differences in technique required by the much shorter wave lengths employed (L D.W)

SPECULAR IRON. **Hematite.**

SPEED CHANGERS AND REDUCERS. The rotative speed of **shafts** transmitting mechanical power often needs to be changed or varied so as to accommodate the best speeds of driven machinery to a set driver speed. Slowly rotating machinery, driven by electric **motors**, offers a frequent example of the need for speed reducers **Gear trains** and **belts** coupling countershafts can be arranged to reduce rotative speed Combinations of **chains** and sprockets can also be used for this service By speed reducer, however, is usually meant a device which consists of **gears** compactly arranged in a case, completely enclosed, and containing a lubricant. From this case protrude two shafts, one the high, the other the low speed, and it is provided with means for securely fastening to a foundation Speed reducers are employed instead of belts and chains when the ratio of reduction is very high, or when the location is dusty, gritty, or damp, and a fully enclosed reduction mechanism is required Furthermore, in crowded locations, especially in factories, belts or chains may consume too much floor space or offer personal hazard, which is eliminated by the use of speed reducers The construction of speed reducers, based on gearing, involves the use of a train of gears sufficient to accomplish the required reduction ratio These gears are either spur gears, herringbone gears, or worm gears, and are frequently arranged in planetary form The worm and herringbone types, especially, are very quiet in operation, although they are more expensive than the simpler spur gear reducers The efficiency of gear type speed reducers is quite high, and when they are correctly serviced with lubricant the friction losses are negligible There are limitations in the maximum power that can be transmitted in the commercial lines of speed reducers, but most speed reducer applications are for coupling to motors of 15 horsepower or less Large reduction ratios may be obtained, even as high as several hundred to one

Speed changers offer more complication than speed reducers, since they are, in effect, speed reducers having several possible reduction ratios which may be chosen at will by the operator Sometimes these are continuously variable from one extreme of reduction ratio to the other, but more frequently they are variable in a certain number of steps Among examples of speed changers are the transmission gear of the automobile, in which are provided three or four forward speeds through the use of gears sliding on a countershaft, the change speed gear boxes of engine lathes (See **Turning**), and certain classes of **friction gearing** Some manufacturers offer speed-changing devices being totally enclosed in a case for general usage, and providing a continuously variable reduction ratio within the range of the changer These usually operate on a belt and variable diameter pulley scheme, and are available in low horsepower capacities only (F T M)

SPEED REGULATION. **Steam engines, steam turbines, internal combustion engines** under automatic governing, also certain types of **electric motors**, vary slightly in speed between no-load and full load In the case of electric motors, this variation of speed is accounted for by the electrical characteristics In the case of the prime movers, the variation in speed is due to the characteristics of the governors The speed regulation is the speed variation between no-load and full load expressed as a percentage of the full load The basic actuation of governors is caused by a change of centrifugal force during change of speed Usually the centrifugal force is opposed mechanically by springs The modulus of the springs has a direct bearing upon the speed regulation created by the governor. (F T M)

SPEED RING. **Hydraulic Turbine.**

SPENOLITH. A term proposed by Burckhardt in 1906 for wedge-shaped **igneous** intrusions (R M F)

SPERM. **Gamete.**

SPERMATHECA. **Receptaculum seminis.**

SPERMATOPHORE. A packet of spermatozoa In some of the invertebrates, including **annelid** worms,

arthropods, and **mollusks**, instead of swimming freely in a seminal fluid the reproductive cells of the male are transferred to the female in these small bundles The formation of the packets is a function of the male genital ducts, which secrete a retaining envelope about the masses of sperm cells. (A W L)

SPERMATOPHYTA. Seed Plants This is the largest division of the plant kingdom, comprising over 130,000 species Members of this division, including nearly all plants of economic value, are of the utmost importance to man, for from them come practically all his foodstuffs and that of his domestic animals, his clothing, and, to a great degree, his shelter

Seed plants are much more complex than are those in the other divisions Their common distinguishing feature, of course, is the **seed.** A seed is composed of an **embryo** plant which has developed from a mature egg, usually after the latter is fertilized, together with a certain amount of reserve food substance which may surround the embryo or be stored within its tissues, and one or more seed coats which completely surround the embryo plant and the food reserves

In seed plants there occurs a definite alternation of generations The **gametophyte** generation, however, is very much reduced, and entirely dependent on the **sporophyte** throughout its brief existence The familiar seed plants are the sporophyte generation

Seed plants are divided into two groups, the **gymnosperms** and the **angiosperms**, of which the gymnosperms are the more primitive In them the seed is formed on the surface of an ovuliferous scale Pines, spruces, cedars, larches, and cycads are all gymnosperms The angiosperms are more advanced, and are generally called flowering plants Two groups of angiosperms are recognized, the **dicotyledons** and the **monocotyledons** Plants in these two groups are separated by the number of seed leaves or cotyledons present on the embryo Roses, grapes, lilies, maples, and orchids are all angiosperms (See also **Paleobotany**) (R M W)

SPERMATOZOA. The male sex **cells**, which are formed in the testicles and are the main element of the semen or seminal fluid With coitus they are ejaculated into the vagina, where under favorable conditions a single spermatozoon unites with an **ovum** In a single ejaculation several million of the spermatozoa are contained in the semen The spermatozoon is a small cell about 1/500 of an inch in length and in shape resembles a tadpole in that it has a head, a long body, and a long tail which, by its movement, allows free motion (R S M)

SPERMATOZOID. Gamete.

SPERMATOZOON. The male **gamete**

SPERM DUCT. Any of the ducts of the testes **Reproductive system** (A W L)

SPERMOPHILE. Mammalia, Rodentia A small slender animal with short legs, small external ears, a short hairy tail, and large cheek pouches Also called ground squirrel and gopher The name spermophile is derived from the genus *Spermophilus*, in which these animals were formerly grouped

Most of the several species of spermophiles are confined to limited areas in the arid lands of the west. The striped species, commonly called the gopher, ranges from central Ohio to the Rockies and from Canada to Texas This species is brown with alternating clay-yellow stripes and rows of spots on the back and sides. It is destructive to crops and damages lawns (A W L.)

SPERM SAC. Seminal vesicle.

SPERM VESICLE. A dilation of the terminal portion of the vasa deferentia of the arrow worms Unlike the seminal vesicles of most animals, which are nearer to the testes, these reservoirs open directly to the exterior. (A W L)

SPESSARTITE. Garnet.

SPHAGNUM. Bryophytes.

SPHALERITE — ZINC BLENDE — BLENDE. Sphalerite is **zinc** sulfide, ZnS, crystallizing in the **isometric** system frequently as **tetrahedrons**, sometimes as cubes or **dodecahedrons**, but usually massive with easy **cleavage**, which is dodecahedral It is a brittle mineral with a conchoidal fracture, hardness, 3 5–5, specific gravity, 3 9–4 1, luster, adamantine to resinous, commonly the latter It is usually some shade of yellow brown or brownish black, less often red, green, whitish, or colorless, streak, yellowish or brownish, sometimes white, transparent to translucent Certain varieties are phosphorescent or fluorescent Sphalerite is the commonest of the zinc-bearing minerals, and is found associated with **galena**, **chalcopyrite**, **tetrahedrite**, **barite**, **fluorite**, etc, as a result of contact **metamorphism**, and as replacements, and **vein** deposits There are very many foreign localities, including Saxony, Bohemia, Switzerland, Cornwall, in England, Spain, Sweden, Japan, and elsewhere In the United States sphalerite is found in Arkansas, Iowa, Wisconsin, Illinois, Colorado, New Jersey, Pennsylvania, Ohio, and especially in the so-called Tri-State area which includes parts of Kansas, Missouri, and Oklahoma, the largest zinc-producing district in the world at the present time The word sphalerite is derived from the Greek, meaning treacherous, and its older name, blende, meaning blind or deceiving, refers to the fact that it was often mistaken for lead ore (E S C S)

SPHENE. Titanite.

SPHENISCIFORMES. The penguins On order of birds (**Aves**) characterized by the paddle-like wings, webbed feet, and upright posture when out of the water They are remarkable swimmers, using both wings and feet under the water Penguins are confined chiefly to the more southern parts of the southern hemisphere, including the Antarctic regions, but one species is found on the Galapagos Islands (A W L)

SPHENOID. A bone located in the anterior part of the base of the skull It forms part of the floor of the brain cavity and is of complex shape, articulating with most of the other bones of the skull (A W L)

SPHENOPHYLLALES. Paleobotany.

SPHERE. A spherical surface is a **surface** all points of which are at a fixed distance, its radius, from a fixed point, its center It is often referred to as a sphere, although this term frequently means the solid bounded by the spherical surface

The equation in **rectangular coordinates** of a sphere with center at (h,k,l) and radius r is

$$(x-h)^2+(y-k)^2+(z-l)^2=r^2.$$

Any equation of the form

$$x^2+y^2+z^2+Ax+By+Cz+D=0$$

represents a sphere

For a sphere of radius R, the area of the surface is $4\pi R^2$ and its volume is $\frac{4}{3}\pi R^3$. (L L S)

SPHERE PHOTOMETER. Integrating Photometer.

SPHERICAL ABERRATION. If the surfaces of a **lens** or the reflecting surface of a mirror are spherical, the rays refracted through or reflected from the outer portions will be brought to a focus in a different plane

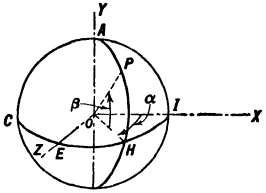
than those from the center, thus producing a blurring of the resultant image known as spherical aberration This effect is more pronounced in short focus lenses or mirrors than in long focus instruments, for the curvature of the surfaces of the short focus instruments is greater

The decrease of spherical aberration with increase in focal length was discovered very early in the history of optical instruments, and during the seventeenth century we find telescope builders increasing the focal lengths of their instruments to tremendous proportions Telescopes with focal lengths between one and two hundred feet were not uncommon during this period, and the problem of supporting the long thin tubes so that they could be used for astronomical purposes and remain straight was one calling for great ingenuity Descartes in 1637 published the theory of spherical aberration and showed that theoretically it could be corrected by grinding the surfaces of lenses and mirrors in curves other than spheres The difficulties of grinding the required lens curves were apparently greater than those of operating the long focus telescopes About the middle of the eighteenth century John Dolland published the fact that spherical aberration could be corrected by the same method employed for the treatment of **chromatic aberration**, i e , by using two lenses, one convergent and the other divergent All modern telescopic lenses of good quality now employ the double object glass with the figures of the lenses and the separation between the components depending upon the ideas of the makers. For wide-angle, short-focus lenses, such as are used in modern hand **cameras** and in astrographic cameras, the simple pair of lenses does not provide sufficient correction for all of the aberrations, and three or more lenses are used in combination Perhaps the most common is the so-called doublet, in which two pairs of lenses are used with a considerable separation between the pairs

Spherical aberration may be corrected in the case of a mirror by grinding the concave surface in the form of a **paraboloid** of revolution instead of in the form of a sphere This provides almost complete correction for rays entering the mirror parallel to the axis of revolution of the paraboloid, i e , along the principal axis of the mirror, but for rays entering at a moderately large angle spherical and various other aberrations make their appearance in the resultant image Hence, while the reflecting type of telescope can be more easily corrected for the aberrations along the axis, nevertheless it cannot be used to obtain photographs of large areas with good definition throughout (W K G)

SPHERICAL ANGLE. A spherical angle is formed by two intersecting arcs on the surface of a **sphere**, it is measured by the plane angle formed by the **tangents** to the arcs (L L S)

SPHERICAL COORDINATES. The spherical coordinates of a point in space are three numbers which determine the position of the point and which are particularly adapted to problems involving **spheres** In case the point is assumed to be located on the surface of a sphere of known or unknown radius two angular coordinates are sufficient for locating the position of the point on the surface of the sphere



The accompanying figure represents a reference frame for both spherical and also three-dimensional rectangular coordinates In setting up the spherical system an origin, O is first selected, and assumed to be the center of the sphere of reference A line, AB, is then passed through the origin and must intersect the sphere in diametrically opposite points This line is known as the fundamental line for the spherical system A plane is then passed through the origin perpendicular to the fundamental line, and this plane becomes known as the fundamental plane Since the fundamental plane passes through the center of the sphere it must intersect the sphere in a great circle, $CEHI$ Since the fundamental plane is perpendicular to the fundamental line, AB, the points A and B must be poles of the great circle on the sphere For reference purposes some fundamental direction, say OI in the figure, must be selected in the fundamental plane

To determine the position of the point, P, on the sphere a plane, $AOBHP$, is passed through the fundamental line, intersecting the surface of the sphere in the great circle, $APHB$ One angular coordinate, α in the figure, is measured in the fundamental plane from the fundamental direction to the line of intersection of the plane passed through the point with the fundamental plane The other angular coordinate, β in the figure, is measured in the plane, $AOBHP$, through the point from the fundamental plane to the radius of the sphere through the point P Both angular coordinates may be measured by the arcs of the great circles cut out on the sphere by the planes involved e g , α may be measured by the arc, IH, of the fundamental plane, and β by the arc, HP, of the plane through the point and the fundamental line

To define the position of P in three-dimensional space referred to the point O as origin the radius of the sphere, ρ, is also necessary The transfer from spherical to **rectangular coordinates** may readily be made by passing the XY, XZ, and XY planes through the sphere as shown in the figure Then we have at once.

$$x = \rho \cos\beta \cos\alpha,\ y = \rho \sin\beta,\ z = \rho \cos\beta \sin\alpha,$$

$$\rho^2 = x^2 + y^2 + z^2,\ \tan\alpha = \frac{z}{x},\ \tan^2\beta = \frac{y^2}{x^2 + z^2}$$

(W K G)

SPHERICAL HARMONICS A spherical harmonic is frequently defined as any homogeneous **polynomial** V_n in the variables x, y, z of the n^{th} degree which satisfies **Laplace's equation**

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

If this equation is transformed to **spherical coordinates** r, θ, ϕ, the solution is called a solid spherical harmonic, U_n If this function be divided by r^n, we obtain a function of θ and ϕ only, which is called a surface spherical harmonic When the spherical harmonic is independent of ϕ, it is called a surface zonal harmonic and satisfies Legendre's equation, and is therefore a **Legendre function** (L L S)

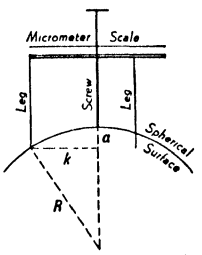
SPHEROCLAST. **Phenoclast.**

SPHEROIDAL STATE. **Ebullition.**

SPHEROMETER. An instrument for measuring the curvature of solid spherical surfaces, either convex or concave, such as those of lenses, a measurement in which high precision is not easily attained The most familiar mechanical device for this purpose is a form of **micrometer** It resembles a small three-legged stool, the sharp steel points of whose legs form an equilateral triangle The micrometer screw, also with a sharp point, is mounted at the center of this supporting trivet, and is adjusted to read zero when all four points are in one plane, as determined by standing the instrument on a flat plate of glass and screwing the micrometer point down to it The distance from each of the legs

to the central axis must be accurately known If it is called k, and if the elevation (or depression) of the micrometer point to fit a given spherical surface is a, then the radius of curvature of the surface is readily calculated as

$$R = \frac{k^2 + a^2}{2a}$$



Diagrammatic section of spherometer

The chief sources of error are in determining just when contact takes place between micrometer point and surface, and in measuring k. (L D W)

SPHERULITES. In lavas there are frequently to be found radial or concentric aggregates of **mineral** crystals from microscopic size to an inch or two in diameter, although rarely their dimensions may be much greater. These radial aggregates are believed to be the result of rapid growth of small **crystals** at favorable points in the quickly cooling lava (E S C S)

SPHINCTER A ring of muscle fibers surrounding a hollow organ or the opening of a duct By their contraction sphincters constrict or close the passages with which they are associated Muscles of this kind are found in the iris of the **eye** around the margin of the pupil, in the wall of the **anus**, at the union of the urethra with the urinary **bladder**, at the **pylorus** between the stomach and the duodenum, and in other similar relations (A W L)

SPHYGMOMANOMETER. An apparatus for measuring the **blood** pressure The apparatus consists of a rubber bag cuff which is wrapped around the upper arm This is inflated by a hand bulb The cuff is connected by rubber tubing to a measuring device which is either a sealed column of mercury or a spring scale Sufficient pressure is pumped into the rubber cuff to compress the brachial artery in the upper arm A stethoscope is applied over the artery below the cuff and air is gradually allowed to escape from the cuff until the pulse can be heard The reading on the scale or column of mercury at this point indicates the systolic pressure or the highest pressure in the arteries during contraction of the **heart** The deflation of the cuff is continued, and that point on the scale when the last sound of the disappearing pulse is heard is the diastolic pressure or lowest pressure in the artery during diastole or relaxation of the heart muscle between beats The normal systolic reading of an adult varies from 110 to 130 or 140 millimeters of mercury Normal diastolic readings vary from 60 to 80 millimeters of mercury. (R S M)

SPICA. Spica (α Virginis) is a brilliant first **magnitude** star Spica is particularly interesting in that it is believed to be the star that provided Hipparchus with the data which enabled him to discover the **precession** of the equinoxes The temple at Thebes was oriented with reference to Spica in about 3200 B C Later, temples which were oriented to this same star indicated the motion of the star due to precession and provided the necessary data (W K G)

SPICULE. A small hard body formed within the tissues of animals Spicules are formed in all sponges (**Porifera**) by cells called scleroblasts in the mesogloea They vary in form from simple rods to complex structures radiating from a common center on three to six axes Some are straight with expanded ends In the **coelenterates** spicules appear only in some of the **alcyonarians**, where they are formed in the mesogloea by cells that migrate from the ectoderm The term has also been applied to the radiating hard structures of the one-celled **radiolarians** (A W L)

SPIDER. Arachnida, Araneina **Arthropods** of almost exclusively terrestrial habits, known commonly for their ability to spin silken webs They differ from other arthropods in one or more of the following characters The body is divided into **cephalothorax** and abdomen, and the latter is unsegmented The head bears a group of simple eyes Four pairs of legs are present The jaws are perforated by the ducts of poison glands The ventral surface of the abdomen bears the openings of the **lung books**, respiratory organs of peculiar form, and a group of **spinnerets** through which the ducts of the silk glands open

Spiders are widely known and unaccountably repulsive In fact, they are among the most interesting of all animals, and with a single known exception, the black widow spider, are harmless Even though they secrete poison most of them are too small to bite a human being unless on a very thin fold of tissue, and most seem to have no inclination to bite Even the large hairy species commonly called banana spiders or tarantulas are mild-mannered creatures.

To what extent the bad reputation of the black widow (*Latrodectus mactans*) is deserved seems difficult to establish Apparently its bite is severely poisonous and occasionally fatal, and apparently it is vicious in habits. There is contradictory evidence, however, so the case is not wholly settled

Spiders vary greatly in habits Some spin funnel-like webs in which they hide to await their prey, others form irregular webs, and still others make the orb webs so beautifully demonstrated in our gardens on dewy mornings Other forms spin no web but capture their prey by pouncing on it from concealment or by open chase Among these forms are the crab spiders, named from their short broad form, which lie in wait on plants and are sometimes almost perfectly hidden in flowers by their concealing coloration The wolf spiders are stout hairy species, often black in color They hunt like the predators for which they are named

The spiders that capture prey without the use of webs have other uses for silk, such as the formation of cocoons or egg-sacs in which the eggs are deposited, and the construction of a smooth lining for their hiding places The most remarkable example of the latter use is the nest of the trapdoor spiders of warm regions These nests consist of a silk-lined burrow with a beveled margin at the surface of the ground A lid hinged with tough silk fits perfectly into this beveled depression and can be held shut by the spider, which provides in its lining two depressions to be gripped by the claws.

The mating habits of spiders are also remarkable The male, in many species much smaller than the female, goes through a courting procedure as complex as that of the birds, and is often killed by his consort Reproductive adaptations are also peculiar in the males, in that the **palpi** are modified to convey the seminal fluid to the genital passages of the female When sexually mature the male spins a web in which the contents of the reproductive organs are discharged, to be taken up into the cavities in the palpi When the individual is successful in securing a mate he thrusts the palpi one at a time into her genital aperture. (A.W.L.)

SPIKE. **Flower.**

SPIKELET. **Flower.**

SPILITE. A term used to define a **basaltic** rock whose **feldspars** are chiefly **albite** or **soda-rich oligoclase.** (R M F)

SPILLWAY. One of the important adjuncts of a **dam** of the overflow type is a spillway, which is simply an opening through or over which excess water may flow

when the reservoir is full The spillway may be a certain overflow section of the dam, or it may be cut in rock along the normal reservoir line at one side of the dam. It is necessary for the crest to be sufficiently long that maximum expected flood may be passed through it without the depth of water on the spillway crest exceeding a predetermined depth A plain spillway fixes the maximum depth of water in the reservoir The discharge over a spillway is something like that over a weir, and the rate of flow is proportional to the length of crest and the 3/2 power of the **head** over the crest It is possible to raise the water level several feet above the spillway, and yet preserve the safety features, by equipping it with crest gates, which normally will be lowered onto the crest of the spillway, obstructing it and raising the water level, but which may be raised out of the way and leave the stream unobstructed during the flood seasons (See **Gates**) (F T M)

SPINAL ANESTHESIA. Anesthesia.

SPINAL CORD. The large axial structure of the central **nervous system** of **vertebrates,** extending from the brain back through the body. It lies in the dorsal body wall and is surrounded by the neural arches of the spinal column It consists of nerve tracts or aggregations of fibers for communication of impulses to and from other parts of the nervous system, and of nuclei, which are aggregates of cell bodies of **neurons**

In man the spinal cord is a cylindrical mass of nervous tissue about eighteen inches long within the vertebral canal of the spine Thirty-one pairs of nerves are attached to the **spinal cord** The spinal cord diminishes in size from above downward, and is suspended within the spinal canal by certain ligaments and membranes which protect and nourish it The spinal canal contains spinal fluid which is in free communication with the fluid surrounding the brain and filling its ventricles The spinal fluid serves as a nutritive medium for nerve cells and acts as a fluid cushion for the spinal cord Removal of spinal fluid by means of a spinal tap is commonly used for diagnostic information and therapeutic procedures The fluid is cultured for bacterial growth, examined chemically, the cells counted, and its pressure within the canal measured, as well as other specific tests Drugs and serum are injected into the spinal fluid in certain diseases (A W L, R S M)

SPINE. The vertebral column or backbone composed of thirty-three vertebrae which, grouped according to regions, are as follows seven cervical, twelve thoracic, five lumbar, five sacral, and four coccygeal vertebrae (R S M)

SPINEL. The mineral spinel is one of a group of minerals which crystallize in the **isometric** system with an **octahedral** habit, and whose chemical compositions are analogous These minerals are combinations of bivalent and trivalent oxides of **magnesium, zinc, iron, manganese, aluminum,** and **chromium,** the general formula being represented as $R''O\ R_2'''O_3$ The bivalent oxides may be MgO, ZnO, FeO, and MnO, and the trivalent oxides Al_2O_3, Fe_2O_3, Mn_2O_3, and Cr_2O_3 The more important members of the spinel group are **spinel,** $MgAl_2O_4$, **gahnite,** zinc spinel, $ZnAl_2O_4$, **franklinite** $(Fe\ Mn\ Zn)$, $(Fe\ Mn)_3O_4$, and **chromite,** $(Fe\ Mg)Cr_2O_4$ True spinel has long been found in the gem-bearing gravels of the Island of Ceylon and in the limestones of Burma and Siam Spinel usually occurs in isometric crystals, octahedrons, often twinned It has an imperfect octahedral **cleavage;** conchoidal fracture, is brittle, hardness, 8; specific gravity, 3 5–4 1, luster, vitreous to dull, transparent to opaque, streak white, may be colorless, rarely through various shades of red, blue, green yellow, brown, or black. These colors are doubtless due to small amounts of impurities The clear red spinels are called spinel-rubies or balas-rubies and were often confused with genuine rubies in times past Rubicelle is a yellow spinel A violet-colored manganese-bearing spinel is called almandine Spinel is found as a **metamorphic** mineral, also as a primary mineral in **basic rocks,** because in such **magmas** the absence of alkalies prevents the formation of feldspars, and any aluminum oxide present will form corundum or combine with magnesia to form spinel This fact accounts for the finding of both ruby and spinel together Besides the localities mentioned above, in Burma and Siam, the Ceylon yields beautiful specimens Spinel is found in Italy and Sweden and on the Island of Madagascar Also in the United States in Orange County, New York, and in Sussex County, New Jersey, are many well-known spinel localities Spinel is found also in Macon County, North Carolina, and in Canada in Quebec and Ontario The name spinel is derived from the Greek, meaning a spark, in reference to the fire-red color of the sort much used for gems Balas ruby is derived from Balascia, the ancient name for Badakhshan, a country of central Asia situated in the upper valley of the Kokcha River, one of the principal tributaries of the Oxus (E S C S)

SPINNERET. A spinning organ of the **spiders** The spinnerets are located on the ventral surface of the abdomen, near or at its tip, and vary from one to three pairs They are conical to cylindrical in form Each has a membranous terminal portion called the spinning field, through which run many minute spinning tubes from the silk glands The nature of the spinning tubes varies, different tubes producing different kinds of silk

In the act of spinning the liquid silk is forced through the spinning tubes, to harden on exposure to the air as silk The spinnerets bear spines, some of them apparently tactile, and are moved by muscles, so that the spider is able to form and place its threads with precision (A W L)

SPINNING. Turning.

SPINTHARISCOPE. A simple apparatus, designed by Sir William Crookes, for observing the scintillations produced by alpha rays (See **Radioactive Emissions**) It consists of a short metal tube with a screen of phosphorescent zinc sulfide closing one end, and a strong magnifying lens at the other, focused upon the screen Projecting out in front of the screen, inside the tube, is a narrow metal point, the tip of which bears a trace of radium The alpha particles emitted by the radium fall upon the screen and produce scintillations which, under suitable conditions, are plainly visible through the lens, looking like minute sparks To see them clearly, one must have been in a dark room for some minutes, also care should be taken not to expose the screen to a strong light beforehand, or its phosphorescence may obscure the scintillations (L D W)

SPINULOSA Asteroidea.

SPINY ANTEATER. Echidna.

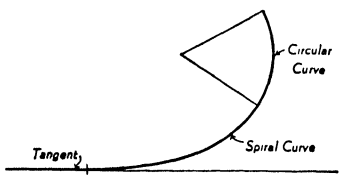
SPIRACLE. 1 A small opening on the surface of the insect body, leading into an air tube of the **respiratory system** Insect spiracles are simple openings in some species, but usually they are guarded by some structure which prevents the entrance of foreign particles This guard varies from a fringe of hairs to an elaborate sieve-like plate Some insects depend on a closing apparatus of the associated **trachea** for the exclusion of particles

In the primitive condition spiracles apparently were paired and **metameric,** one opening on each side of each segment This arrangement is only slightly modified in some species, which are said to be peripneustic In other cases the number of openings is greatly restricted, only one or two pairs providing the sole entrance to the respiratory apparatus. Insects with a single pair at the anterior end of the body are called propneustic, those

with a pair at the posterior end metapneustic, and those with a pair at each end amphipneustic The spiracles may also be associated with tubes, either extending the tracheae beyond the general surface of the body or forming external conduits for air, by which the insect may reach the air from within the water or decaying matter in which it lives

2 The greatly reduced external opening representing the first of the series of **gill slits** in elasmobranch fishes (A W L)

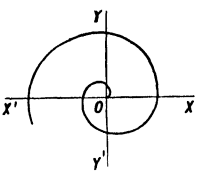
SPIRAL CURVE. In railway or highway alignments a spiral curve, sometimes called an easement or transition curve, is one which provides a gradual change of curvature when passing from a tangent (straight line)



Spiral curve

to a circular curve The cubic parabola and cubic spiral are curves well suited for this purpose The former is used when spirals are to be laid out by offsets from the tangent (See **Tangent Offset**), since the offset to any point on the curve varies as the cube of the distance along the tangent from the point where the curve begins When the curve is to be laid out by **deflection** angles the cubic spiral is used In this curve the offset from the tangent is proportional to the cube of the distance along the curve measured from the point of tangency Spiral curves are particularly well adapted for the use of **superelevation** since they furnish a means for gradually increasing this quantity from zero to the amount required on the circular portion of the curve Railroads use a combination of spiral and circular curves to connect the tangents on their main lines The value of the spiral is being recognized in modern highway design for high-speed traffic (C W C)

SPIRAL OF ARCHIMEDES The spiral of Archimedes is a mathematical curve of spiral form, as shown in the accompanying figure. Its equation in polar coordinates is $r = a\theta$ (L L S)



Spiral of Archimedes

SPIRALS In mathematics, the term spiral is applied to a number of curves The important spiral curves are the **spiral of Archimedes**, the **logarithmic spiral** (or equiangular spiral), the **hyperbolic spiral**, the **parabolic spiral**, and the **lituus.**

In astronomy, the use of the term spiral is as follows For many years the extra-galactic **nebulae** were known as spiral nebulae, but recent researches have proved conclusively that they are a totally different class of objects from the galactic nebulae Their **spectra**, instead of being characterized by the bright lines commonly found in the galactic nebulae, are of the absorption type such as would be produced by a large number of stars of various **spectral classes.** Long exposure photographs of the extra-galactic nebulae, taken with instruments of long focal length, have definitely proved the hypothesis that these objects are in reality large groups of very distant stars

In at least five of the extra-galactic nebulae **Cepheids** have been discovered, and the application of the **period-luminosity relation for Cepheids gives distances of between 100,000 and 1,000,000 light years** from the sun By various statistical methods, largely developed by Hubble at the Mount Wilson Observatory, the distances of a number of other extra-galactic objects have been obtained Distances of the order of magnitude of one billion (1,000,000,000) light years have been obtained, which seems to be about the limiting distance at which these objects can be distinguished with the 100-inch telescope Researches on the distances of the extra-galactic nebulae will be one of the first problems for the new 200-inch telescope

The extra-galactic nebulae are classified by Hubble as (1) Spirals (with subdivisions of normal spirals and barred spirals), (2) Elliptical, and (3) Irregular A more detailed subdivision of each main type has been suggested, but is too complex to be considered here Of the extra-galactic nebulae which are bright enough to have been classified thus far, about 77% belong to the first type, 20% to the second type, and 3% to the third

The normal spirals are characterized by two main whorls, each of which may have several branches, which come out from opposite sides of a large central condensation and wind about this condensation in the same plane and in the same direction The central condensation is distinctly ellipsoidal in form, being much more extensive perpendicular to the plane of the whorls than are the whorls themselves The spirals are found in all types of orientation, some with the plane of the spiral perpendicular to the line of light, and in others with the whorls seen edge on In the latter cases a dark band is observed passing across the nucleus as though there was a dark extension in the plane of the whorls which would otherwise be unobserved The great spiral in Andromeda has an angular diameter of two degrees, corresponding to a linear diameter of 28,000 light years The barred spirals differ from the normal spirals in that the arms begin at the ends of a long bar which extends outward from the central condensation or nucleus

The elliptic extra-galactic nebulae show no structural forms even when examined with the most powerful instruments They are ellipsoidal in form, ranging from spheres to thin lens-shaped volumes The elliptic nebulae which apparently have the largest size, are the companions to the Andromeda spiral The major axes of these objects are 2000 and 1000 light years, respectively

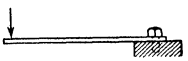
The irregular extra-galactic nebulae are relatively rare objects As the name implies, they have no definite form, and appear like clouds in space The largest one known is found in the constellation of Sagittarius, with extreme dimensions of 1000 and 2000 light years

A spectrographic study of some of the brighter spirals indicates that these objects are in rotation about their minor axes From the rotational speeds and sizes of these objects Hubble estimates their total masses to be of the order of magnitude of 600,000,000 to 1,000,000,000 times the mass of the sun

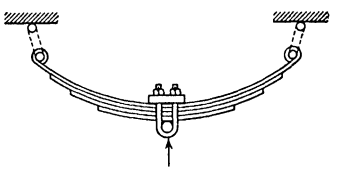
The absorption lines in the spectra of the extra-galactic nebulae show strong displacement to the red, with the amount of displacement increasing with the distance of the object from the sun If this "red shift" is interpreted as a **radial velocity** effect it implies that all of the extra-galactic nebulae are receding from the sun, with the more distant ones receding the more rapidly The implication from these results is that the entire universe of nebulae is expanding, and several attempts have been made to explain this theoretically However, Hubble and other observational workers are by no means convinced that the red shift of the lines in extra-galactic nebular spectra is due to a radial velocity effect, although they are unable as yet to find any other satisfactory explanation Until the question as to whether these observations prove the expansion of the universe is answered, it does not seem desirable to enter upon a discussion of so controversial a problem.

Statistical studies of extra-galactic nebulae indicate that there are between 50 and 100 million of these objects within the limiting distance of observation with the 100-inch telescope Studies of the distribution of these objects throughout this immense volume of space (approximately 1,000,000,000 light years in extent) indicate clustering of the objects in certain regions The surveys are still in progress and results are uncertain, but it seems probable that there are galaxies of galaxies in space The suggestion has been made that our own **galactic system** may be such a group (W K G)

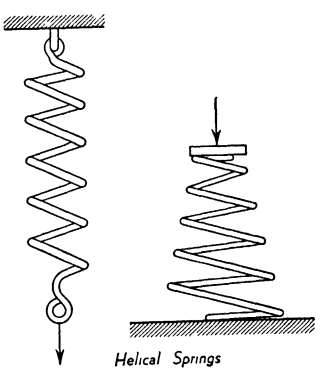
SPRING. A spring is an elastic body which will deflect or elongate under the action of an externally applied force and return to its original shape after removal of the force The spring is constructed of metals having relatively high elastic limits Common materials from which springs are made are steel, brass, phosphor bronze



True spring action is always that which stresses the spring below the elastic limit. In this operating range,

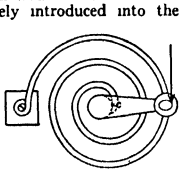


Leaf Springs



Helical Springs

the spring is subject to Hooke's Law The strain is proportional to the stress The spring is most frequently used either to store energy which would otherwise cause a shock, or which is deliberately introduced into the spring to provide a source of energy Examples of these cases are found in shock-absorbing springs for vehicles and clock springs.



Spiral spring.

The main classes of springs are leaf springs, spiral coiled springs, helical coiled springs In leaf springs and spiral coiled springs bending stress governs the characteristics of the deflected spring, while shearing stress governs in the case of helical coiled springs

A spring modulus is the additional force necessary to deflect it an additional unit distance If a certain spring has a modulus of 40 pounds per inch, a 40-pound weight will compress it 1 inch, an 80-pound weight 2 inches, and so on It is apparent that the energy stored in a spring is $\frac{1}{2}$(spring modulus $\times$ deflection^2). (F T M)

SPIRAL VALVE. A thin ridge projecting from the lining of the intestine of elasmobranch fishes to the center of the cavity and following a spiral course through the length of the tube The structure provides greatly increased surface for the digestion and absorption of food It is so arranged that the food must follow a spiral course, but beyond this regulating effect is not a valve in the usual sense It merely slows the passage of food (A W L)

SPIRE. The portion of a conical **snail** shell above the large whorl into which the aperture leads (A W L)

SPIRIFER Invertebrate paleontology.

SPIRILLUM. Bacteria.

SPIROGYRA. Algae.

SPITTLE BUG. Frog hopper.

SPLEEN. An organ of vertebrates derived from **mesenchyme** and lying in the **mesentery** It is closely associated with the **circulatory system** The organ consists of masses of tissue of granular appearance, known as lymphoid tissue, located around fine terminal branches of veins and arteries According to one interpretation these vessels are connected through the spleen pulp by modified capillaries called splenic sinuses The pulp is supported by a reticular tissue foundation and contains blood cells of all kinds in addition to the characteristic mesenchymal cells The function of the organ is the formation of **blood** cells, the destruction of old **red corpuscles**, the removal of other debris from the blood stream, and as a reservoir for blood

The human spleen is situated in the left upper part of the abdomen, behind the stomach, just below the diaphragm This gland, in the normal individual, measures about five by three by two inches in size In certain diseases it increases greatly in size, and it may even fill a large portion of the left side of the abdomen Such diseases are **malaria, tuberculosis, syphilis, leukemia, pernicious anemia, Hodgkins' disease, Banti's disease, tumors,** and **cysts** of the spleen

The spleen is classified as a ductless gland This organ is not an organ necessary for life It may be removed surgically and often is, as a result of injuries or in certain splenic disorders Rarely it has been found to be completely absent The ancients are said to have removed the spleen from runners, believing that this increased their speed Functions of the spleen are varied and not well understood It is one of the organs concerned with blood cell formation, and in destruction and removal of injured or worn-out cells It also plays an important role in **immunity**, destroying bacteria and toxic substances and producing antibodies (A W L, R S M)

SPLIT-TAIL. Pisces, Teleostei A small silvery **minnow**, *Pogonichthys macrolepidotus*, of central California (A W L)

SPODUMENE. The mineral spodumene is a **lithium aluminum silicate** corresponding to the formula $LiAl(SiO_3)_2$ and occurs in **monoclinic** prismatic crystals, occasionally of very large size It also occurs massive Spodumene has a perfect prismatic **cleavage** often very noticeable, uneven to splintery fracture, brittle, hardness 6 5–7, specific gravity 3 13–3 20, luster, vitreous to pearly, color, grayish to greenish white, green, yellow and purple Its streak is white, it is transparent to translucent Spodumene is characteristically a mineral of the **pegmatites**, and it is found in Sweden, Ireland, Madagascar and Brazil In the United States it is found especially in the pegmatites

of Oxford County, Maine, in the towns of Goshen, Huntington and Chesterfield in western Massachusetts; at Branchville, Connecticut, in North Carolina, in South Dakota in huge crystals and in San Diego and Riverside Counties in California The name spodumene is derived from the Greek meaning ash colored, particularly appropriate for the slightly weathered varieties Hiddenite, the beautiful emerald green or yellow green spodumene that is used as a gem, was named for W E Hidden Kunzite, named in honor of the late George F Kunz, is a transparent lilac to rose-colored spodumene from Madagascar and California, also used as a gem stone Spodumene alters rather readily to a mass of **albite** and **muscovite** The commercial use of spodumene is chiefly as a source of lithium compounds (E S C S)

SPONDYLITIS Inflammation of the vertebrae of the spine, especially from tubercular disease (R S M)

SPONGE. An animal of the phylum **Porifera** In the vernacular the word refers to the sponge of commerce, which is the skeleton of a sponge from which the animal matter has been removed by maceration and washing The material of which these sponges are composed is spongin Calcareous (**calcium**) and siliceous (**silicon**) sponges are, of course, too harsh for similar use

Commercial sponges are derived from various species and come in many grades, from the fine soft lambs' wool sponges to the coarse grades used for washing cars They come from fisheries in the Mediterranean and in the West Indies and nearby waters The industry has reached a value of about $3,000,000 annually but the manufacture of substitutes from rubber and cellulose is destined to reduce its importance Cellulose sponges, in particular, have the good qualities of natural sponges with greater uniformity (A W L)

SPONGIN. A horny material found in the skeletons of sponges In some species it unites **spicules** of other materials and in some it forms fibers in which the spicules are imbedded The sponges of commerce have a skeleton formed wholly of a fibrous mass of spongin (A W L)

SPONGIOBLAST A form of **cell** in the mesogloea of **sponges** by which the fibrous structures of the body are formed (A W L)

SPOONBILL 1 Pisces, Chondrostei The **paddlefish** of the Mississippi River system 2 Aves, Ciconiiformes Large long-legged wading birds related to the herons and flamingoes The beak is very long and broad, with the terminal portion still further broadened to give it a spoonlike form 3 Aves, Anseriformes The **shoveller** ducks (A W L)

SPORANGIUM **Flower.**

SPORE A spore is a special type of reproductive **cell** which develops directly into a new plant like that on which the spore was borne Spores are not sexual (R M W)

SPOROBLAST. A stage in the life cycle of some of the one-celled animals of the class **Sporozoa** After **fertilization**, the **nucleus** of the **zygote** subdivides Each of the daughter nuclei, together with a surrounding mass of **cytoplasm**, becomes a sporoblast which secretes an enveloping membrane and becomes a spore (A W L)

SPOROCYST. A stage in the life cycle of some one-celled animals, characterized by the presence of a heavy protecting wall enclosing a number of separate cells, the **spores** (A W L)

SPORONT The stage in the **reproductive** cycle of one-celled parasites of the class **Sporozoa** which subdivides to produce the active **sporozoites** The sporozoites begin a new life cycle (A W L)

SPOROPHORE. **Fungi.**

SPOROPHYLL. A sporophyll is a **spore-bearing leaf** It may be greatly modified in structure and appearance (R M W)

SPOROPHYTE. In plants in which there is a distinct **alternation of generations**, the generation which bears the spores is called the sporophytic generation A spore-bearing plant is a sporophyte Its cells all contain the diploid or double number of **chromosomes** (R M W)

SPOROSAC. A **sessile** medusoid (**medusa**) that remains attached to the parent colony Since the medusoids produce reproductive cells, these individuals, without need for locomotion, retain no other conspicuous function (A W L)

SPOROTRICHOSIS. A chronic infection caused by the genus *Sporothrichum* It is characterized by tumor-like nodules, abscess formation and ulcers of the skin Most of the cases in the United States have been reported in the Middle West where the parasite has been found on vegetable matter

Treatment by **iodine** compounds is usually successful in arresting the disease (R S M)

SPOROZOA. One-celled animals of parasitic habits which are usually incapable of locomotion The immature stages of some species form pesudopodia but neither **cilia** nor **flagella** are ever present A class of the phylum **Protozoa**

The sporozoans absorb nutriment from the body of the host, a type of nutrition rarely possible save in parasites In connection with their parasitic habits also they undergo intricate cycles of **reproduction**, often associated with life in alternating hosts of different species They attack animals of almost every phylum, sometimes with fatal results or with more or less serious disturbances of normal functions In man these relations are illustrated by the **malarial** parasites whose complex life cycle is completed in Anopheles **mosquitoes** and the human blood stream Malaria, the result of their presence in the human body, varies from the periodic chills and fever of the milder forms to an extremely virulent disease

The classification of the sporozoans is work for an expert, depending upon highly technical distinctions In brief summary the class is divided as follows

Subclass Telosporidia.
- Order Coccidia Intracellular parasites in digestive **epithelium** Some are transmitted by blood-sucking animals Parasitic in invertebrates and vertebrates
- Order Haemosporidia Parasitic in the blood of vertebrates and in the alimentary tract of blood-sucking invertebrates The malarial parasites belong here
- Order Gregarinida Parasitic in various stages in the cells and in the cavity of the invertebrate intestine

Subclass Cnidosporidia
- Order Myxosporidia Mostly parasitic in fishes, a few in amphibians and reptiles
- Order Actinomyxidia In the body cavity or the lining of the alimentary tract of aquatic **annelids**
- Order Microsporidia Mostly intracellular parasites in **arthropods** and fishes
- Order Helicosporidia A single known species, parasitic in insects

Subclass Acnidosporidia
- Order Sarcosporidia Parasitic chiefly in the muscles of mammals, some in birds and reptiles
- Order Haplosporidia. Found in invertebrates and lower vertebrates. (A W L)

SPOROZOITE. A stage in the reproductive cycle of the one-celled parasites of the class **Sporozoa**. The sporozoites are the active individuals formed by the subdivision of the zygote or sporont. (A.W.L.)

SPORULATION. The process of **spore** production, a type of reproduction more common in plants than in animals, but highly developed in some of the one-celled forms. In this process the parent cell subdivides to form a number of smaller active cells which begin a new life cycle. (A.W.L.)

SPOT-TAIL. Pisces, Teleostei. A small **minnow**, *Hybopsis hudsonius*, widely distributed and abundant in the fresh waters of the eastern half of the United States. Also called the **shiner**. It usually has a black spot at the base of the tail. A species with a similar mark in a closely related genus, *Cyprinella stigmatura*, is called the spotted tail. The latter is found only in the southeast. (A.W.L.)

SPRAIN. An injury in which a sudden wrenching or twisting produces tearing of the ligaments or tendons of a part of the body, especially around a joint. The symptoms of a sprain are pain, swelling and limitation of motion of the part. (R.S.M.)

SPRAT. Pisces, Teleostei. A small marine food fish (Pisces), *Clupea sprattus*, related to the herring. It occurs on the Atlantic coast of Europe. (A.W.L.)

SPRINGBOK. Mammalia, Artiodactyla. A small South African **antelope**, *Antidorcas marsupialis*, of striking appearance. One of the **gazelles**. The animal is cinnamon and white with a dark brown streak on the sides. (A.W.L.)

SPRING PEEPER. Amphibia, Anura. A tree **frog**, *Hyla crucifer*, about an inch in length, with an elongate X on its back. The color varies greatly, including shades of brown, yellow, green and gray. The species is found through most of the eastern half of North America. It is named from the early appearance of the animals in the spring, when their not unmusical tones are one of the first indications that hibernating animals are active again. (A.W.L.)

SPRING TAIL. **Collembola.**

SPRUCE. **Conifers.**

SPRUE. A deficiency disease of tropical countries, marked by chronic wasting of the body, sore and raw tongue and mouth, intestinal fermentation and diarrhea with light colored and frothy stools. The principal **vitamin** involved is vitamin B. Those affected with the disease prefer and crave **carbohydrates** and **fats**, avoiding foods of **protein** nature.

After the disease is well established, a yeast **fungus** is found with ease in the intestinal tract. This parasite is called *monilia psilosis*, but is believed to be a secondary invader growing in the intestinal tract in this disease because a favorable medium is provided by the fermentation in the intestine.

Treatment is similar to that of the other vitamin B deficiency diseases, that is, liver injections, and a high protein diet made up largely of potent sources of vitamin B.

This disease was first recognized in 1766 by William Hillary in Barbadoes. (R.S.M.)

SPUR-FOWL. Aves, Galliformes. Long-tailed Indian and Ceylonese **partridges** which resemble pheasants. (A.W.L.)

SPUR GEAR. The spur gear is a **cylinder** bearing **teeth** externally (sometimes internally), suitably shaped to engage with other similar teeth on a mating **gear**. Figure 1 shows the simplest form of spur gears, two straight spur gears connecting parallel shafts. The special province of the spur gear is the transmission of power, with minimum loss, between shafts which are parallel. The velocity ratio between two shafts connected by spur gears is in inverse ratio to the number of teeth

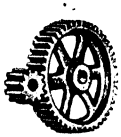


Figure 1.

Figure 2.

Figure 3.

on the respective gears. As shown in Figure 2, the teeth are not always on the external surface of the gear. If the large internal gear were imagined to be cut, laid out, and unwrapped in a straight line, it would be a rack. The spur gear may be made with straight teeth, as shown in the figures just mentioned, or helical teeth (Figure 3).

The helical gear has a wide face which, in conjunction with the shape of the teeth, provides more than one tooth in action at a time. The continuity of tooth action depends on the width of the face as well as the helix angle. This aids in transfer of load from one tooth to another, evenly, without shock. Consequently, this gear may be operated at high speed, with the elimination of considerable noise and vibration present in straight tooth gears. The double helical gear, sometimes called the herringbone gear, overcomes the serious defect of plain helical gears, namely, the axial thrust caused by the diagonal pressure between the teeth. (F.T.M.)

SPURGE FAMILY. Euphorbiaceae. Members of this large family are found in many tropical and temperate regions. The greater number are trees or shrubs, with a few herbaceous species, especially in cooler regions. Many of the tropical species are interesting xerophytes, plants capable of enduring the driest climates. Often these have a habit very similar to that of species of *Cactus*, with which they may easily be confused, especially if not in flower. However, nearly all members of the spurge family contain a milky juice which exudes from them when the surface is cut or broken. This milky juice, or latex, will readily distinguish them from cacti, which lack latex. Leaves, when present, are usually alternate and have **stipules**. In many species, such as the frequently cultivated *Euphorbia splendens*, or "Crown of Thorns," the leaves soon drop off, leaving a spine-covered stem. In one genus, *Phyllanthus*, leaves are frequently reduced to minute scales, and the stem flattened and green; in these the small pinkish flowers are borne around the edge of the flattened stem. In some species of *Euphorbia* the leaves near the top of the stem become brilliantly colored, as in *Euphorbia pulcherrima*, the poinsettia, where they are bright red. Such leaves, surrounding the inconspicuous flower masses, are often mistaken for parts of the flower.

The **inflorescence**, in members of this family, is often very complex. In many species the individual flowers are crowded together in such a way as collectively to resemble a single large flower. The flowers are unisexual. The plants are either **monoecious** or **dioecious**. In many cases the flowers entirely lack both **calyx** and **corolla**, in others a calyx is present, but no corolla, while in some both calyx and corolla are present. They are regular flowers with the **perianth** commonly five-parted. The number of stamens varies from one to many; in many cases they are variously

united; in some, as in the castor bean, they are branched The ovary is usually three-celled, with one or two ovules in each cell The **fruit** is a capsule, which when mature often opens with considerable force, throwing the seeds out, often to considerable distances The **seeds** have an abundant endosperm and a caruncle

Among the members of this family are some plants of great economic importance Many others are poisonous plants

Hevea brasiliensis, the Para **rubber** plant, is perhaps the most valuable member Species of *Ricinus* supply castor oil Species of *Manihot*, a South American genus, yield cassava or manioc, a starchy foodstuff, prepared from the large roots *Manihot esculenta*, for instance, has long been cultivated in Brazil It is a large, somewhat bushy herb with long-petioled leaves, the smooth blades of which are deeply cleft into three to seven lobes The roots, which have the appearance of sweet potatoes, are eaten in much the same way as sweet potatoes Grated, they yield a starchy product used like bread From the roots tapioca may be prepared The poisonous principle which is present in many species of *Manihot* is removed by squeezing or destroyed by heating From other species of this genus may be obtained, by tapping, a milky juice which is a source of rubber

Hura crepitans, the sand box tree, is another member of the family of some slight commercial value The plant is a fairly large tree the stem of which is covered with short, sharp spines, and bears long-petioled, toothed leaves The fruit is composed of numerous hard carpels which, when mature, explode violently, throwing the seeds out forcibly These fruits, about three inches in diameter, were formerly gathered and wired to prevent bursting When dry they were used as containers for the fine sand which was then used to blot ink,—hence the common name of the tree The wood of the tree is used locally, but rarely exported The milky juice of the tree is very poisonous This juice, mixed with meal or similar substances, and thrown into the waters of a stream or lake, stupefies the fish present therein, so that they may be readily captured The poison does not render the fish unfit for human consumption

Several species of *Croton* yield important purgative drugs *Croton eluteria* gives Cascarilla bark, used as a tonic

Jatropha curcas, a small shrub or tree, bears egg-shaped green fruits which contain a high percentage of an odorless oil called "curcas" oil, used in making paints, as a lubricant, and in soap-making From the leaves of this tree, natives of the Philippine Islands prepare a fish poison used in much the same way as that obtained from *Hura*

Aleurites species, natives of the East Indian region, are important sources of oil (R M W)

SPUTTERING. A result of the disintegration of the metal **cathode** in a **vacuum tube** due to bombardment by positive ions **Atoms** of the metal are ejected in various directions, leaving the cathode surface in an abraded and roughened condition The ejected atoms alight upon and cling firmly to the tube walls and other adjacent surfaces, forming a blackish or lustrous metallic film This effect is often utilized to form very fine-grained coatings of metal upon surfaces of glass, quartz, etc, purposely exposed to the sputtering. Films of different metals can be obtained by using cathodes made of these metals Glass plates may be thus silvered, or suspension fibers of spun quartz rendered conducting for use in electrometers, etc. (L D.W)

SQUAMATES. Fossil Reptiles.

SQUASH. *Cucurbita maxima* (*pepo*) and (*moschata*) **Gourd Family.**

SQUASH BORER. Insecta, Lepidoptera. The **larva** of a **moth**, *Melittia satyriniformis*, which bores in the root and stem of squash vines, often killing the plant The moth is a beautiful species with olive fore wings, transparent hind wings, and legs tufted with orange and black

The larva thrusts waste material out of holes in the stem When detected by this means it can be cut out of the plant and killed In large fields where hand control is impossible, deep plowing when the vines are dead kills many of the insects Other methods depend on an accurate knowledge of the time of deposition of the eggs Spraying is effective during that period (A W L.)

SQUASH BUG. Insecta, Hemiptera. A true **bug**, *Anasa tristis*, about five eighths of an inch long, gray-brown above and mottled with yellow below, showing red in flight from areas beneath the wings It sucks the juices of pumpkins, squash, and related vines and spreads a bacterial wilt

The adults hibernate beneath debris on the ground and may be trapped under pieces of board and destroyed Colonies of young are said to be destroyed by dusting with calcium cyanide (See **Calcium**) (50% or 25% cyanide), and the masses of eggs are large enough to be seen and destroyed by hand They are often deposited on the underside of leaves, however, where they are difficult to see (A W L)

SQUID. Mollusca, Cephalopoda Marine animals with usually elongate bodies bearing a pair of lateral fins The head is provided with large eyes and ten tentacles, two much longer than the rest and expanded at their tips

The squids vary in size from the little butterfly squid of the Maine coast, scarcely more than an inch long, to the giant squids of the deep seas with bodies, exclusive of the tentacles, twenty feet long The common squids of the genus *Loligo* are also called calamaries

Squids are eaten by the Chinese, who regard them as a delicacy In North America they are important as bait in the marine fisheries of the northern Atlantic coast (A W L)

SQUIRREL. Mammalia, Rodentia An arboreal or terrestrial **rodent** with a long bushy tail These animals, together with the chipmunks, ground squirrels, woodchucks, and flying squirrels, make up the family Sciuridae Representatives of the true squirrels are found on all continents but Australia

Flying squirrels belong to a subfamily distinguished from the true squirrels and related forms by the presence of folds of skin stretching from the front to the hind legs along the sides of the body These folds, held extended by the legs, support the animal in the air during long gliding leaps

Still another small division of the family contains the pigmy squirrels of Africa, Borneo and the Philippines These few species are about as large as mice.

North America has ten species of true squirrels, some widely distributed and extremely variable, and two species of flying squirrels (*Glaucomys*) The little red squirrel, *Sciurus hudsonicus*, is the most widely known, with the gray (*S. carolinensis*) and fox (*S niger*) squirrels very close The two last are valued as small game, their flesh is excellent (A.W L)

SQUIRREL CAGE. Motors.

SQUIRTING CUCUMBER. *Ecballium elaterium* **Gourd Family.**

STABILITY. Equilibrium of Forces; Least Energy Principle.

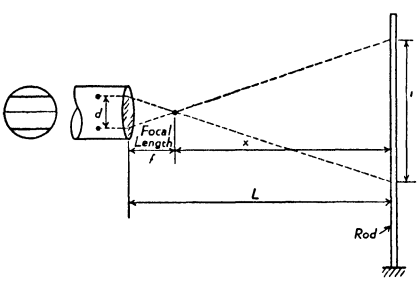
STABILIZER. Airplane.

STABLE FLY. Insecta, Diptera A true fly, *Stomoxys calcitrans*, similar in appearance to the house fly but with a mouth fitted for piercing and sucking. It is common in barns, breeding in manure and other organic refuse, but it sometimes enters houses The impression that house flies bite is due to the occasional attacks of this similar species (A W L)

STACK. In geology a rock pillar or monument which occurs relatively close to marine cliffs which have usually been developed in hard horizontally bedded but jointed sedimentary rocks In some cases a stack is the remaining pillar of an arch Both sea arches and stacks are well developed on the coast lines of the Gaspé Peninsula and the North East Highlands of Scotland. (R M F)

STADIA. This term refers to a method of obtaining distances and elevations of points on the earth's surface with respect to some known point by means of a **transit** equipped for stadia readings and an ordinary **level rod** Stadia measurements are most useful when applied to measurement of inaccessible lines or some limited area such as a farm It is not applied to precise control work such as the triangulation surveys of the Coast and Geodetic survey Since contour data for all surrounding points may be taken from one instrument station, the stadia method is particularly adaptable to topographical surveying

The stadia transit is equipped with two parallel horizontal wires which appear in the field These are in addition to the ordinary centering hairline The principle of distance measurement by stadia is explained in connection with the diagram The telescope of the instrument is sighted on the rod which is held erect at the point whose distance from the instrument is to be measured The rays of light coming from the points on the rod which appear in line with the wires are shown dotted They cross at the optical center, creating two similar triangles The equation of similarity of bases and altitudes of these triangles is



$$\frac{x}{f} = \frac{i}{d},$$

which reduces to

$$x = i\frac{f}{d}.$$

The above shows that to measure distance L one needs to read the intercept on the rod of the stadia wires, multiply it by a factor which is a characteristic of the instrument, and add the focal length

If the ground elevation at the rod is different than that at the transit certain corrections must be applied to the above method The corrections involve trigonometric functions derived from the angle of elevation read on the vertical circle of the transit This angle is also employed to find the elevation of the distant point above the instrument station. (F.T M.)

STAGE. Steam Turbine.

STAGE EFFICIENCY. By stage efficiency is meant the fraction of **adiabatic** heat drop in a **steam turbine** stage that is transferred to the rotor as mechanical energy The remainder goes to reheating the steam at the lower pressure The failure of any stage to convert all the heat drop into mechanical energy is due to

1 Friction of steam on nozzles, blades, and casing
2 Throttling flow of steam through clearance spaces
3 Shock loss

A well designed turbine may have a stage efficiency as high as 85%. (F T M)

STALACTITE. A stalactite is a deposit of **calcium carbonate** which hangs icicle-like from the roof or wall of a **limestone** cavern, and is formed by the dripping of mineralized **solutions** Corresponding columnar structures built upward from the floors of caves beneath the stalactites in a similar manner, are called stalagmites Stalactite is derived from the Greek meaning to fall in drops, stalagmite, from the Greek meaning that which drops (R M F)

STALAGMITE. Stalactite.

STALL. Airfoil and Lift.

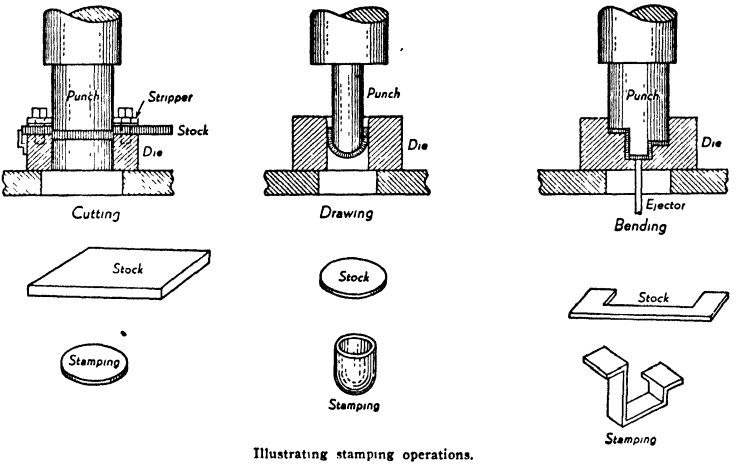
STAMEN. Flower.

STAMPING. The cheapest method of producing many parts, as employed in the construction of various articles and machines, is generally by stamping When a part may be formed from sheet stock, as, for example, sheet metal, cardboard, etc, and is required in large quantities, it will be found that modern manufacturing produces these parts most economically by stamping them out on a press with punch and die In elementary terms, stamping is the cutting and/or forming of a part from sheet stock with the use of a suitably shaped punch and die located in a press which is usually power operated, although some small presses are operated by hand or foot power

Manufacturing by stamping is generally not practical unless a fairly large quantity of the part is to be produced, since before the first piece can be produced, dies of varying complexity and cost must be manufactured by the die maker more or less by hand Hence for a half dozen pieces or so, a part would be more economically produced by forging or cutting from solid stock, whereas several hundred would be more cheaply produced by stamping. One important advantage of the stamping process is, that while it is a quantity production method, the entire set-up does not have to be specially tooled to the part being produced, since the punch press is a standard piece of equipment A press may be adapted to stamping many different parts merely by changing the punches and dies These are likely to be relatively small and compact, are set up in the press without a great deal of difficulty, and are readily and easily stored when not in use

The die is generally mounted on the stationary table of the press, and the punch in the moving head or plunger It is characteristic of the art of stamping that a single reciprocation of the plunger performs the entire service for which that plunger and die (often called set of dies) were designed This is in contrast with the hammer forging, milling, turning, and other operations in which the part is sized by repeated operations on it, and accounts for the speed of the stamping process

There are a great variety of operations possible in stamping. An attempt to classify them would logically look towards the action of the press on the stock From this viewpoint, press work might be divided into operations which cut; draw; emboss, or bend the stock. These different types of stamping operations will



Illustrating stamping operations.

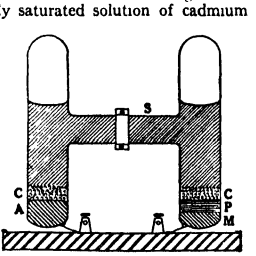
be briefly described Cutting dies are those which by virtue of a shearing action of the punch on the die perform such operations as cutting blanks from flat stock, or piercing various openings, such as round holes, slots, etc This type of die, which is diagrammed in the accompanying figure, usually has a relatively simple form As pictured, a circular blank is being stamped from sheet metal stock by a circular punch which descends into a die, also circular, and of the same diameter, plus a slight clearance The punch descends first through a similar hole in the stripper plate, the function of which is to prevent the stock being withdrawn by the punch as the latter leaves the die When this arrangement is mounted in the punch press and provided with guides and stops to limit the movement of the stock, it becomes a machine for the stamping of circular blanks in quantity The blank thus formed might be subjected to other stamping operations in other presses For example, it might be used in a cupping die, also illustrated, in which the operation is one of deforming and drawing the metal under circumstances in which a certain amount of change in the thickness of the stock is necessary If considerable deformation is needed, it may have to be accomplished in a series of dies in order to prevent wrinkling, since there are certain limits to the drawing process that can be accomplished in a single die The bending process would be illustrated by a die which took a previously cut blank and bent it to an angular shape Some presses may be set up for combination dies, that is, the operation of cutting the blank, of bending, piercing, cupping, etc, being so performed as to produce a finished piece in one pass through the press Such presses frequently have double concentric plungers whose stroke is slightly out of phase Another class of stamping is that wherein the dies cause a plastic flow of the stock This is illustrated by the embossing and coining dies used to produce raised designs, medals, and the like.

The material of which dies are made is usually steel, as this can be hardened to stand the wear of constant use, and is readily worked by the die makers Another method is to use a cast iron die made from a pattern which was worked in wood The pattern naturally would have the shape of the stamping,—at least on the working face Wood has been used for dies for soft metals such as aluminum, especially where a limited number of parts were produced, and the expense of the steel die was not warranted. (F.T.M.)

STANDARD CELL. Precise measurements of **electromotive force**, as with a **potentiometer**, require a constant, known source of voltage The only practicable means of supplying this is by some special type of **electrolytic cell** Of these, two have been highly developed and much used

The older is the Clark standard cell, which, as improved by Carhart, has a mercury **cathode** and an amalgamated zinc **anode** The cathode is submerged in a **mercurous** sulfate paste, and the **electrolyte** is a solution of zinc sulfate saturated at 0° C The whole is sealed in a suitable glass tube This cell has an electromotive force of 1 440 volts at 15° C, with a decrease of 0 00056 volt per degree rise in temperature

In 1891 Weston substituted cadmium amalgam for zinc, and a continuously saturated solution of cadmium sulfate for the zinc sulfate electrolyte, the whole in an *H*-shaped tube The Weston normal cell has a somewhat lower voltage than the Clark (1 0183 volts at 20° C), but its temperature coefficient is practically negligible The official adoption of the voltage above given for the Weston normal cell by the standards laboratories of Great Britain, the United States, and Germany (1911) gave in effect an alternative definition of the **volt**, i e, 0 98203 of the electromotive force of the Weston normal cadmium cell at 20° C An unsaturated type of Weston cell is much used commercially in the United States (See also **Reactions Involving Oxidation-Reduction.**) (L D W)



Standard Weston normal cadmium cell.

STANDARD INTEGRALS. Integration, Technique of.

STANDARD NOTATION FOR NUMBERS IN DECIMAL FORM. The use of positive and negative **exponents** finds useful practical application in the so-called standard (or scientific) notation for numbers in decimal form. In much scientific work and elsewhere.

very large and very small numbers need to be expressed in convenient form. For this purpose, a number between 1 and 10 is multiplied by the appropriate power (positive or negative) of 10. Thus, 93,000,000 would be written 9.3×10^7, and 0.000,000,065 would be written 6.5×10^{-8}. (L.L.S.)

STANDARD TIME. With the defining of mean solar time and the manufacture of clocks which could be regulated to keep this sort of time with some little precision, each different locality set its clocks to correspond with its own local mean time. With the development of railway systems the confusion introduced by having so many different sorts of time along the lines became intolerable and a series of "railway times" was introduced. As interstate and international communication developed, following the invention of the telegraph and the cable, it became apparent that some international agreement must be arrived at regarding the sort of time that should be used in different places.

The remedy for all of the confusion is due to Sandford Fleming who, in 1878, advanced a plan for dividing the entire earth into a system of 24 time zones using as standard **meridians** the successive meridians spaced at 15°, or one hour, from Greenwich. While this ideal scheme has never been adopted by all nations, nevertheless, the plan is in quite general use at present. The standard time system is in general use in Canada and the United States with the continent divided into five different standard zones known as Atlantic, Eastern, Central, Mountain, and Pacific times corresponding to the local time for the 60th, 75th, 90th, 105th, and 120th meridians west of Greenwich. These standard times are slow on Greenwich time by 4, 5, 6, 7, or 8 hours respectively; e.g., 7 A.M. central standard time corresponds to 1 P.M. (13 hours) Greenwich Civil time. While the agreement between European nations is not as complete as on the North American continent, we find most of them either use Greenwich, Mid-European, or Eastern European time. In Europe the admirable plan has been adopted in many countries of keeping time consecutively throughout the twenty-four hours, thus avoiding the confusion which is introduced by having 6 o'clock occur twice during each twenty-four hours as is customary in the United States.

The lines of demarcation between successive time zones are theoretically meridians of terrestrial **longitude**. In practice the dividing lines between the different time zones is arranged for national, state, municipal, or commercial convenience with the result that the division lines do not exactly follow meridians. Tables are published in a variety of places which give the particular standard times in use in the principal nations and cities of the world.

In 1916 the practice of adopting summer, or daylight saving, time became quite common. This means that during certain months a particular locality adopts the time corresponding to the standard time of the next zone to the east. Hence, 7 o'clock daylight saving time in New York is in reality 7 o'clock Atlantic time instead of 6 o'clock Eastern Standard Time, which is the standard time for that city. (W.K.G.)

STANN(IC), (OUS). Tin.

STANNITE. The mineral stannite is a **sulfo-stannate** of **copper** and **iron**, sometimes with some **zinc**, corresponding to the formula $Cu_2S \cdot FeS \cdot SnS_2$. It is **tetragonal**; brittle with uneven fracture; hardness, 3.5; specific gravity, 4.3–4.5; metallic luster; color, gray to black, sometimes tarnished by **chalcopyrite**; **streak**, black; opaque. It occurs associated with **cassiterite**, chalcopyrite, **tetrahedrite** and **pyrite**, probably the result of deposition by hot alkaline solution. This mineral occurs in Bohemia: Cornwall, England; Tasmania, Bolivia and in the United States in South Dakota. It derives its name from the Latin word for tin, *stannum*. (E.S.C.S.)

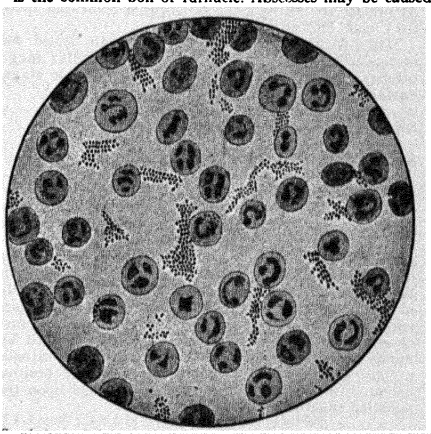
STANNUM. Tin.

STAPHYLOCOCCUS. A member of a group of microorganisms that are commonly the cause of **pyogenic** infections, or infections that are accompanied by the formation of **pus.** The most important microorganism of this group is the *Staphylococcus aureus* and is the one most often found invading the body. The other common strain is the *S. albus.*

The *Staphylococcus* is a spherical coccus occurring singly, in pairs or in irregular grapelike clusters.

Different strains of this organism vary greatly in virulence in their effect on living organisms. *Staphylococci* are constantly in the air, water, or on the surface of the body. Some strains however are harmless to the human body although in appearance and cultural characteristics they cannot be differentiated from pathogenic forms.

The most common infection caused by this organism is the common boil or furnucle. Abscesses may be caused



Staphylococci from an abscess of the parotid gland (Jakob). The staphylococci are seen as clumps of dots between pus cells. (From Todd and Sanford, *Clinical Diagnosis by Laboratory Methods*, W. B. Saunders Co.)

by *Staphylococci* in any organ of the body. The most frequent cause of pus infection in bone (**osteomylitis**) is due to this organism. If the virulence of the strain of the organism is great or if the body resistance is low septicemia may develop with a mortality of 60 to 90%. Meningitis, empyema, kidney, and urinary infection and peritonitis may be caused by this organism.

Several different poisons or toxins are given off by the organism. In chronic *Staphylococcus* infection vaccine therapy has been successful. Treatment of an acute infection by antitoxin has not proved to be of very great help. (R.S.M.)

STAR CATALOGUES. Any listing of stars, usually arranged in order of increasing **right ascension**, is known as a star catalogue. Originally, star catalogues were intended merely for the purpose of providing accurate positions of the stars for use by navigators, but many modern catalogues are designed to provide particular characteristics of the stars.

The oldest existing star catalogue is contained in the **Almagest** of Ptolemy issued about 137 A.D. This is undoubtedly a reissue of the catalogue of Hipparchus

of which there is no copy known to exist. The Almagest catalogue was the only one of any real value until the fifteenth century when an Arabian catalogue made its appearance. Tycho Brahe's catalogue of 1580 marks the dawn of the modern era of star catalogues and since that time many others have appeared. Probably the most comprehensive catalogue issued is the **Bonner Durchmusterung**, which first appeared about 1850, together with the various extensions which have since been published. During the last half of the 19th century the Astronomische Gesellschaft sponsored a catalogue of accurate positions of the majority of the stars contained in the Bonner Durchmusterung.

With application of photography to astronomy several projects have been launched for obtaining comprehensive star catalogues. By far the most ambitious of all of the photographic catalogues is the so-called Astrographic Catalogue which was started as a cooperative effort of eighteen observatories in 1887. When completed the catalogue will contain positions of between three and four million stars measured on about 44,000 plates. As well as the positions of the stars, there will be also issued prints from the plates forming the atlas frequently referred to as the Carte du Ciel. At present the astrographic catalogue is somewhat more than half finished.

Many particular types of catalogues are issued for particular purposes, such as catalogues of **stellar magnitudes, spectral class, proper motions, double stars, variable stars**, etc. (W.K.G.)

STARCH. Carbohydrates.

STAR COUNTS. Milky Way.

STARFISH. Asteroidea.

STARK EFFECT. The effect of a strong transverse electric field upon the **spectrum** lines of a gas subjected to its influence. In many respects it resembles the more complicated types of **Zeeman effect**, but is subject to different laws, and may change radically in character and in multiplicity of component lines with increasing field intensity. The phenomenon, first observed by Stark in 1913, is conveniently studied by means of a **canal-ray** tube having behind the cathode a third electrode which may be given a high positive potential, in order to impose the desired field upon the radiating canal-ray particles. (L.D.W.)

STARLING. Aves, Passeriformes. A bird (**Aves**) of any of several species native to Europe, Asia, and northern Africa. The African glossy starlings belong to a family containing also the Asiatic grackles or hill mynas, while the true starlings are placed in a closely related family.

The one species which concerns us in North America is the common European starling, *Sturnus vulgaris*, which was introduced into New York in 1890 and has since spread a third of the way across the continent. The males are black with green and blue iridescence and light tips on many of the smaller feathers, and the females are brownish gray. The beak is rather large. In Europe the starlings are valued as destroyers of insects and for their song. They are able mimics. The same good qualities are worthy of consideration in America but the birds are also destructive of native species and in the fall they become a nuisance by gathering in great flocks to roost in countless thousands in the trees of residential districts. The net verdict is against them, and they are commonly regarded as another of our imported pests. (A.W.L.)

Starling. *Sternus vulgaris.*

STARS. There is certainly no class of physical objects that has attracted more popular and scientific attention throughout the ages than have the stars. A small portion of the huge mass of mythology associated with these apparent points of light will be found discussed in the articles on the individual **constellations** and under the names of a few of the particularly interesting stars. The methods for the determination of the various physical characteristics will be found under such titles as **stellar parallax, stellar magnitude, spectral class, binary stars, variable stars, giant** and **dwarf stars**, etc. Since the sun is a typical dwarf G-type star, much detailed information regarding this class of objects will be found in the various articles on this object.

The accompanying table gives some of the physical characteristics of a few typical stars. The definitions of the various column headings will be found discussed elsewhere. We shall limit ourselves in this article to an attempt to discuss the elements of the modern theory for the internal constitution of the stars and a possible evolutionary process. Examination of the table will indicate that while there is a ratio of 10^{11} in density, a ratio of 10^{6} in luminosity, and of 10^{4} in diameter, nevertheless the most massive star is not more than 500 times as massive as the least massive of them all.

As early as 1870 Lane and Ritter had discussed from a purely theoretical point of view the behavior of a mass of gas isolated in space and contracting under the influence of the mutual gravitational attraction of the particles. They showed that the temperature of such a mass would rise to values comparable with those estimated for the stars, and that the internal pressure would rise to such a value that the star would radiate with a continuous spectrum. Helmholtz had also studied critically the possibility of accounting for the radiation from the sun on the basis of a theory that this object is contracting and the conversion of potential into kinetic energy is producing the radiant energy.

During the early part of the present century it was generally believed that in some entirely unexplained manner the stars were "created as hot stars" and evolved by losing heat through radiation, passing through the successive spectral classes B-A-F-G-K-M. Space does not permit of a discussion of the various arguments for and against this evolutionary sequence, but it should be said that the "hot creation" idea was abhorrent to many astronomers and philosophers.

The discovery of the low mean density of the giant M-type stars indicated that certain stars were attenuated enough to be behaving as a "perfect" gas. The rapid advance of atomic physics during the first quarter of the present century indicated that a mass of stripped **atoms, electrons, protons**, and **photons**, such as would be developed under the extreme conditions of temperature and pressure developed in the interior of a large contracting mass of gas, might obey the gas laws even at such mean densities as were indicated for the main sequence stars.

One fundamental difficulty with any of the contraction hypotheses for the development of the stars had been the length of time that a star must take in going from stage to stage. For example, geologists have shown that the earth's crust has been in much the same general condition as at present for approximately 10^{9} years. Hence the sun must have been a G-type main sequence star for at least that length of time, which is greater than that permitted on the basis of the original contraction hypotheses for a star to go completely through all stages of development.

The way out of the dilemma was found by Eddington by considering **radiation** pressure as a possible agent for slowing down the contraction process. Working entirely in the realm of theoretical physics he con-

sidered the behavior of various masses of gas isolated in space and contracting He showed that, irrespective of the initial mass, the temperature and pressure in the interior would rise to tremendously high values and that radiation pressure would be developed which would tend to retard the contraction process However, for masses less than 10^{33} the effect of the radiation pressure would be much less than the gravitational contraction and the mass would heat up and cool down far too rapidly to satisfy the required time scale For masses greater than 10^{35} the temperatures developed would produce such tremendous radiation pressure that the mass would explode. Between 10^{33} and 10^{35} grams the mass would remain practically in equilibrium with radiation pressure tending to expand the gravitation tending to contract the mass In accordance with the relation between mass and radiation as developed by Einstein a radiating mass is continually losing mass and eventually the equilibrium would be upset and the gas would then contract and cool down The mass of the sun is about 2×10^{33} grams and examination of the table will indicate that the stars fall between 10^{33} and 10^{35} grams

PHYSICAL CHARACTERISTICS OF TYPICAL STARS

Star	Spectral Class	Temperature in °K.	Density in Terms of Water	Referred to Sun As Unity		
				Luminosity	Mass	Diameter
Giants						
Antares	M_0	3,100	0 0000003	3500	30	480
Aldeberan	K_5	3,300	0 00002	90	4	60
Arcturus	K_0	4,100	0 0003	100	8	30
Capella	G_0	5,500	0 002	150	4 2	12
Main Sequence						
β Centauri	B_1	21,000	0 02	3100	25	11
Vega	A_0	11,200	0 1	50	3	2 4
Sirius A	A_0	11,200	0 4	26	2 4	1 8
Altair	A_5	8,600	0 6	9 2	2	1 4
Procyon	F_5	6,500	1 2	5 4	1 1	1 9
α Centauri A	G_0	6,000	1 1	1 12	1 1	1 0
The Sun	G_0	6,000	1 4	1	1	1 0
70 Ophiuchi A	K_0	5,100	0 9	0 42	0 9	1 0
61 Cygni A	K_7	3,800	1 3	0 21	0 5	0 7
Krueger 60 A	M_2	3,300	9	0 002	0 3	0 3
White Dwarfs						
Sirius B	F	5,700	27,000	0 003	0 96	0 034
O_2 Eridani B	A_0	11,000	64,000	0 003	0 44	0 019

On the basis of the modern theories it is believed that the general evolutionary process of a star is as indicated above A mass of cool attenuated material contracts under gravitational contraction and the temperature rises The mass first becomes visible as a giant M-type star and as contraction continues the temperature rises until the B-type stage is reached The temperatures in the interior are of the order of magnitude of millions of degrees and pressures of millions of atmospheres Radiation pressure is acting against gravitational contraction and holding the mass in approximate equilibrium From this stage on the contraction is relatively slow and the continuous outpouring of energy, coupled with the loss of mass by radiation, permits a cooling of the star and it slowly passes down along the main sequence to the M-type, after which it is lost to view.

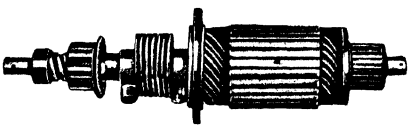
Such is the general theory which forms the point of departure from which astrophysicists are working It can by no manner of means be considered as complete There are many types of objects such as, for example, the white dwarfs which are not included at all The problems regarding the source of the tremendous amount of radiation that is pouring out from the star, while it is in practically static condition so far as contraction is concerned, is not satisfactorily answered There are other objections which we have no space to enlarge upon here (W K G)

STAR STREAMING. Moving Cluster.

STARTER. The cycle of the **internal combustion engine** is such that the engine must be initially revolved from an external source of power The mechanism supplying this initial effort is known as the starter Certain small semi-portable or stationary engines, also tractor engines, truck engines, etc, are frequently started by manual cranking, but a mechanical starter is standard equipment on automobile engines **Diesel engines** are rarely hand cranked, although they are started by more varied types of starters than are employed with the gasoline engine **Aeronautical engines** were, until recently, universally started by swinging the propeller by hand However, many are now equipped with starters, the commercial plane because of the size of the engine and the inconvenient location of the propeller viewed from the standpoint of manual starting, the small plane for convenience of the private owner, or in emulation of the standard practice on automobiles

Starters for automobile engines are electric motors of a series wound type, deriving their supply of electricity from a storage battery (See **Accumulator**) The relation of motor output to battery capacity is such that the use of the motor must be restricted to short intervals of time, between which the battery is recharged Normally, the starting motor is disengaged from the **engine** During the starting cycle it is con-

nected by a reduction gear which multiplies the **torque** produced by the motor. A small pinion on the motor engages with a large annular gear, usually placed on the circumference of the flywheel of the engine. The speed reduction is between 10:1 and 15:1. The method of engaging the pinion with the gear for starting used most frequently is the Bendix drive. This is shown in the accompanying figure. The motor shaft is extended



Starter rotor.

to form support for an externally threaded sleeve and two collars. One collar is fixed to the shaft and to one end of a coil spring. The other end of the spring is attached to the remaining collar, as is also the threaded sleeve. When the shaft revolves, the sleeve and collar revolves as well, being driven by the spring. The pinion has an internal thread corresponding to that on the sleeve, and is unbalanced by having a weight cast on one side of the circumference. When the starter is connected to the battery, the armature immediately starts to revolve, but not so the pinion, due to its inertia, and the effect of the unbalanced weight. Consequently, it moves endwise along the thread. The starting motor is so placed that this movement engages the pinion with its gear. When the end of the thread is reached, the pinion jams against a stop, and must then, perforce, turn with the armature. The shock of connecting a moving with a stationary body is eased by the spring connection between the pinion and the armature shaft.

Small Diesel engines are started by electric starters, but this is not usual in the sizes in which these engines are usually built. Because of the high compression pressure, a heavy torque must be exerted to revolve the Diesel engine during starting. The method most commonly employed is to use compressed air from storage tanks which are recharged after a start. Some manufacturers supply the compressed air to one cylinder, only, of the engine, and have the exhaust valves propped open on the other cylinders so as to reduce the torque required. Others supply compressed air to all cylinders at the time of the normal power impulse by means of a rotary distributor valve.

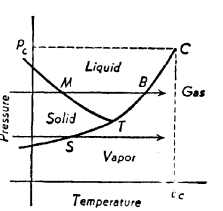
Electric starters have been used on aeronautical engines, and it is probable that as starters continue to be applied in that field, that the electrical starter will be the more important type. Its use was at one time restricted because of the aversion of manufacturers to including a wet storage battery in an airplane, and to the lack of suitable aircraft types of storage batteries. With the development of the latter, and the increasing desire for storage battery current to operate lights, radio, etc., there is a noticeable trend to the use of electric starters, and coil and battery ignition in place of magnetos. A compressed air type of starter has been available for aeronautical engines for some time, and compares very favorably with the battery type as regards fire hazard and dead weight. The air is carried in a small tank at a high pressure, this tank being charged by a small compressor driven from the engine shaft. (F.T.M.)

STARVATION. A state of existence without food or with inadequate food. When animals are completely deprived of food their only source of energy for the essential processes of **metabolism** is the material already present in the body. The **carbohydrate** stored as glycogen is quickly used up, leaving only the stored fat, the circulating protein (See **Amino Acids**), and the protein of the tissues. Studies of the progress of starvation in mammals have shown that the fat is almost completely used up and that the greatest loss of tissue proteins is from the muscles, due to their great bulk. In percentages, however, the **liver**, **spleen**, and **gonads** lose more of their bulk than other parts of the body, and the **heart** and central **nervous system** are maintained at the expense of the other parts with very little loss of substance. Extensive observations of the details of metabolism and bodily changes during starvation allowed to continue to the death of the animal have been recorded.

A remarkable result of starvation in some of the lower invertebrates is a progressive shrinkage of the body as a whole, in contrast with the emaciation which results in vertebrates. Observations on the flatworm, *Planaria*, have shown that ultimately it even retraces its development to assume an embryonic form. (A.W.L.)

STATES OF MATTER. The term refers to the solid, liquid, and gaseous forms in which matter presents itself. If we started with any pure element at the lowest attainable temperature and, keeping it at some fixed pressure, as that of the atmosphere, raised the temperature gradually to the highest point known to the laboratory, the substance would be observed to pass through certain stages and to undergo changes from one stage to another at more or less definite transition points. If the pressure were different, similar changes would take place, but in general at somewhat altered transition temperatures. The same statements may be made concerning a pure compound, except that there are some compounds which are so unstable as to decompose before attaining all the states. (For example, if one attempts to melt nitrogen iodide, the result is an explosion, the products of which are nitrogen gas and iodine vapor.)

The stages referred to are the solid, the liquid, and the vapor states; which, for any pure substance, are determined by the two variables, temperature and pressure, with the density as a third, related variable. If the temperature and pressure are under complete control, it is possible to pass from any one to any other of the three states, either directly by a single transition, or by passing through the third state with two transitions. This will be clear from the accompanying phase diagram, which represents the temperature-pressure equilibrium curves for a substance converging at the **three-phase equilibrium** or "triple" point *T*. (It is understood that each phase of the substance is to be strictly pure; for example, no air is to be mixed with the vapor.) Thus, if a mass of pure ice were kept completely enclosed by itself at a fixed pressure below 4.6 millimeters (its "triple point"), and its temperature raised, it would turn directly into vapor at the **sublimation** point *S*; but if the pressure exceeded 4.6 millimeters, the ice would first become liquid at the **melting point** *M*, and the water would then vaporize at the **boiling point** *B*, corresponding to the existing pressure. The volume of the enclosure would, of course, have to be varied to keep the pressure constant during these changes.



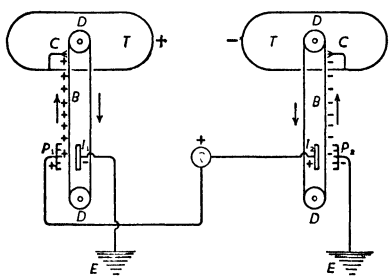
Temperature - pressure curves for substance like water. *C* represents the critical state, *T* the three-phase equilibrium point.

When the temperature has exceeded the critical temperature t_c (See **Critical State**), neither the solid nor the liquid phase is longer possible, even with greatly increased pressure. The liquid-vapor curve must be considered as terminating at *C*, since it pertains specifically to two phases in equilibrium, while beyond the point *C* the substance does not exhibit two phases.

The one apparently homogeneous phase now remaining is said to be a true "gas" (L D W)

STATIC LENGTH. Relativity.

STATIC MACHINES. A variety of devices have been employed to furnish charges of electricity of considerable quantity at high voltage Probably the simplest static machine is the **electrophorus**, operating on the principle of electric induction, but its capacity and voltage are quite limited Some of the older machines generated charges by friction, but modern machines are of the induction type Among the latter, the well known Toepler-Holtz and Wimshurst machines have rotating glass or mica plates bearing metal "carriers" on which the charges are induced as on the metal plate of the electrophorus Recently some very powerful induction machines, embodying all the principles of the older types, have been developed by Van de Graaff and others and have come into use in nuclear research One of the simplest of these is illustrated in the diagram.



Diagrammatic sketch of a modern electrostatic generator

Two endless belts, B, of silk or paper revolve on insulated drums D, the upper of which are mounted inside two hollow, rounded metal tanks T forming the terminals of the machine R represents the positive terminal of an ordinary static machine or of a high-voltage rectifier-transformer, which keeps the system from the inductor plate to the "comb" of charging points P_1, positively charged at about 10,000 volts The negative inductor plate I_1 and the charging comb P_2, opposite P_1 and I_2, respectively, are grounded at one end, their other ends being maintained negative by induction As the belts revolve, the sharp teeth of the combs P, under the influence of the inductors I, discharge upon the belts, which carry the charge inside the hollow terminals T Here the belts discharge themselves against the contact brushes C, the charges at once appearing on the outside of the respective terminals, in accordance with Faraday's law of electric distribution (See **Electrostatics**) Very large charges may thus accumulate on the terminals T, T, at potentials of many hundreds of kilovolts The energy represented by these charges is supplied by the work required to drive the charged belts B toward the similarly charged terminals Modifications of this design are in actual use in some research laboratories (L D W.)

STATIC METAMORPHISM. A term proposed by Judd in 1889 and synonymous with the German, *Belastungmetemorphismus* That form of regional metamorphism which may be considered as due to "load," and which is primarily induced by vertical or gravity pressure, as opposed to regional metamorphism which is caused by **orogenic pressures** (R M.F.)

STATICS. Statics is that branch of mechanics which deals with particles or bodies in **equilibrium** under the action of **forces** or of **torques.** It treats of the composition and resolution of forces, the equilibrium of bodies under balanced forces, and such properties of areas and bodies as center of gravity and moment of inertia

A set of forces may be exerted along lines which all lie in the same plane, in which case they are said to be coplanar Again, the lines of action may all intersect at one point, so that the forces are "concurrent" A torque, or moment, is that which tends to produce rotation about some axis The measure of the torque of a given force about an axis not parallel to its line of action is the product of the force, the perpendicular distance from its line of action to the axis, and the sine of the angle between the axis and the direction of the force Two forces of equal magnitude, acting along parallel lines in opposite directions, constitute a couple, the torque of which, about any axis perpendicular to its plane, is the product of either force by the perpendicular distance between their lines of action Such a pair of forces has no resultant and no equilibrant, since it can neither be replaced nor balanced by a single force It is possible to have a system of more than two forces, not necessarily parallel or even coplanar, but which is equivalent to a couple in that it has a torque without having a resultant. Only another couple, or its equivalent, can balance such a system One of the basic propositions of statics is that any system of forces is, in general, equivalent to a single force acting along a definite line and a couple whose torque axis is in a definite direction, and that for equilibrium, this force and this couple must both become zero These ideas are most conveniently expressed by means of the notation of vector analysis

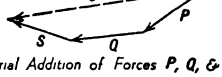
A force whose line of action lies at θ degrees to one of two mutually perpendicular axes, may be resolved into components of $F \cos \theta$ and $F \sin \theta$, parallel to the axes When several forces are concurrent, and coplanar as well, the components of their resultant are found as the sum of the components of the separate forces, due account being given to algebraic sign The resultant of two coplanar forces P and Q having an included angle θ, is expressed by the equation

$$R = \sqrt{P^2 + Q^2 + 2PQ \cos \theta}.$$

The angle between the resultant and the P force is

$$\text{arc tan } \frac{Q \sin \theta}{P + Q \cos \theta}$$

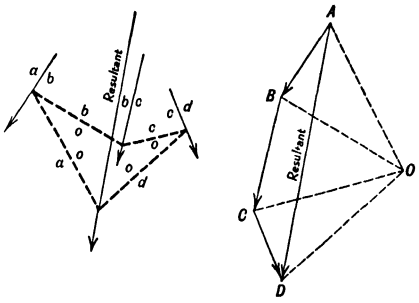
If there are more than two forces whose resultant is to be found, any two may be combined to find the resultant which may then be combined with a third, and so on until the last resultant found is that for the complete array of forces The same problem may be solved graphically by the vectorial addition of the forces In vectorial addition, lines whose lengths are equal to the magnitudes of the forces are drawn in the directions of the forces so that the force representing one line follows another, forming part of a polygon, the arrows of which, as shown in Figure 1, are in succession The resultant is the line drawn from the beginning of the first force to the end of the last. This resultant force, with direction of arrow reversed, is an equilibrant, or stabilizing force When forces are concurrent, the point of application of the resultant is known to be at the point of concurrence of the forces, but with non-concurrent forces, a force polygon, or an analysis by components, is not sufficient to es-



Vectorial Addition of Forces P, Q, & S

Figure 1.

tablish the point of application of the resultant force. To locate the point of action of the resultant of non-concurrent forces, a third condition of statics must be



Forces in space Force polygon

Figure 2 Funicular polygon

introduced It is that the moment of the resultant about any moment axis is equal to the sum of the moments of the forces about the same axis The **funicular polygon** may also be used to establish the line of action of non-concurrent forces Rays are drawn to the corners of the force polygon from some assumed pole, and the sides of the funicular polygon drawn parallel to these rays The corners of the funicular polygon lie on the forces themselves, and the closing lines intersect on the line of action of the resultant (See **Bow's Notation.**)

When forces are not coplanar, the solution involves simultaneous solution of six equations, as follows

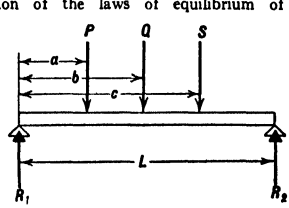
Let F_x, F_y, and F_z be components parallel to x, y, and z axes, respectively

R_x, R_y, R_z be similar components of the resultant.

$$\Sigma F_x = R_x,$$
$$\Sigma F_y = R_y,$$
$$\Sigma F_z = R_z,$$
$$\Sigma M_{Fx} = M_{Rx},$$
$$\Sigma M_{Fy} = M_{Ry},$$
$$\Sigma M_{Fz} = M_{Rz}$$ in which the M's

are the moments of the respective components about either axis perpendicular to them

Statical equilibrium is satisfied if the algebraic sum of the components of the forces in any direction is zero, and if the algebraic sum of the moments of the forces about any axis is zero. When a body is in equilibrium under forces, some of which are unknown, an analysis may be made by applying these conditions of equilibrium provided that for each independent equation that can be written not more than one force is unknown In the graphical analysis of static equilibrium, the conditions of equilibrium are that the force polygon and the funicular polygon close A common application of the laws of equilibrium of coplanar



Beam loaded with parallel forces

Figure 3

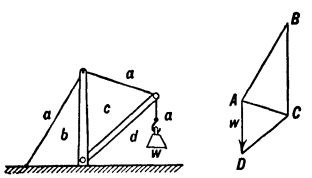
forces is the calculation of the reactions of a simply supported beam loaded with parallel forces which are perpendicular to the length of the beam. The reactions are determined by considering the whole system to be one in equilibrium, so that the moment equation may be applied by selecting the moment center on one of the unknown reactions Its moment becomes zero, and the moment equation has only one unknown reaction If a beam of span L (Figure 3) is loaded with forces P, Q, and S, at distances, a, b, and c (see illustration), the sum of the moments equals

$$Pa + Qb + Sc - R_2L$$

For equilibrium, this quantity must equal zero, hence

$$R_2 = \frac{Pa + Qb + Sc}{L}$$

Triangularly framed structures may be analyzed by algebraic resolution and composition of forces, or by the graphical method of funicular and force polygons Since the latter is simpler and entirely as useful, it is the one most frequently employed Consider a simple derrick, framed as shown in Figure 4, loaded with weight W This condition of static equilibrium may be analyzed for the forces acting in the structural members by drawing a force polygon for each joint, beginning with that which has only two forces unknown



Derrick Stress sheet

Figure 4

in magnitude, then proceeding to some other joint, where the same condition exists In the example given, it is plain that the joint at the load must be analyzed first The equilibrium polygon for this joint is CDA, and is drawn by laying off DA in the direction of W, and of the magnitude W, and locating point C as the intersection of lines DC and AC, drawn in the directions which those forces actually have in the derrick Using the magnitude of CA thus determined, the joint at the top of the mast may next be analyzed, locating the point B The magnitudes and character of the forces acting on triangularly framed structures are thus determined by the method of analysis of joints graphically by force polygons which close These force polygons begin at a point where all corners of the polygon are known except one, and proceed from there in succession to other joints, which will offer the same conditions Each joint has a separate force polygon, but it is usual to place these polygons in juxtaposition along the lines where they have lines in common, for convenience and simplification The resulting diagram, which is a composite force polygon, is known as a stress diagram or stress sheet See **Graphical Statics.**

Certain cases of **friction** lie properly in the realm of statics, since, though the friction may be that of moving bodies, the frictional surfaces themselves may not be in relative motion Friction gearing, wedges, friction clutches, and the general problem of the inclined plane which includes the screw jack are typical examples Friction is resistance offered by one body to the motion of another when the second body slides, or tends to slide, over the former A normal force between two surfaces, which have a coefficient of friction f, results in a force fN opposing motion, where N is the normal force This friction force is tangent

to the surfaces of contact in a direction which would oppose motion The resulting force, acting between a body and its supporting surface, takes the direction

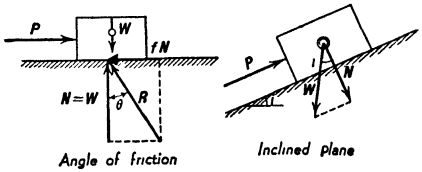


Figure 5

shown in Figure 5 The horizontal component of the reaction R is equal to P As P increases up to the point of sliding, the angle θ increases until its tangent equals the coefficient of friction of the surfaces in contact When P exceeds fN there will be relative motion between the body and the supporting surface Should a body having weight W rest on an inclined plane at angle i, the coefficient of friction between the surfaces being f, the force necessary to start the body up the plane must be greater than $W \sin i + fW \cos i$ where the P force is parallel to the plane If the P force is inclined to the plane, only its component parallel to the plane will be available for starting the load, and its perpendicular component may either tend to increase or decrease the friction resistance

The centers of gravity of areas and masses come under the head of statics, since they may be considered as made up of a number of elementary areas or masses, which could be treated as proportional to a set of parallel forces acting through their individual centers See **Centroid, Moment, Moment of Inertia, Friction, Equilibrium of Forces** (LDW, FTM)

STATIONARY WAVE. Interference

STATOBLAST Asexual reproductive bodies of freshwater **Bryozoa** They are disk shaped buds formed in the parent colonies with a protective test to enclose them When the colony dies in the winter the statoblasts remain alive and inactive, to produce new colonies in the spring (AWL)

STATOCYST A form of sense organ found at the margin of **hydrozoan** medusae It is a vesicular structure filled with a liquid containing small calcareous granules The ectodermal lining is sensory and is apparently stimulated by the impacts of the granules as the animal moves Varying stimuli in the eight statocysts around the margin of the animal bring about the proper movements to maintain its normal position in the water **Lithocyst** (AWL)

STAUROLITE. The mineral staurolite is a complex **silicate of iron** and **aluminum** corresponding to the formula $HFeAl_5Si_2O_{13}$, but somewhat varying and may carry **magnesium** or **manganese** It is orthorhombic, prismatic, twins common, often producing cruciform crystals It is a brittle mineral, fracture, sub-conchoidal, hardness, 7–7 5, specific gravity, 3 6–3 7, luster, sub-vitreous to resinous, color, dark brown, sometimes reddish to nearly black, grayish streak, translucent to opaque. Staurolite is a metamorphic mineral usually the result of regional rather than contact metamorphism, and is common in schists, phyllites and gneisses together with **garnet, kyanite, tourmaline,** etc Well known foreign localities are in Switzerland and Brittany, and in the United States this mineral is common in the schists of New England, and those of the southern Alleghenies Frequently the crystals are found loose in the soil after the disintegration of the country rock The name staurolite is derived from the Greek meaning a cross, in reference to the twin crystals, the more nearly perfect crosses being somewhat in demand as curios Quite frequently used as a baptismal stone, for according to early legend when the fairies heard of the crucifixion of Christ their falling tears when they reached the earth became crosses (RMF)

STAUROMEDUSAE. Scyphozoa.

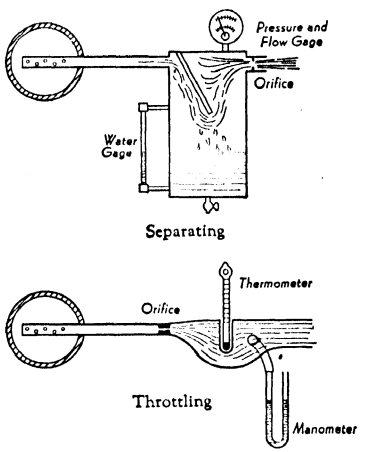
STAYBOLT. The surfaces of pressure vessels, such as **boiler** drums and **tanks**, which are not of a natural bulged shape, such as the cylinder or the sphere, must be stayed against bulging by special tension rods called staybolts An example of a stayed surface will be found in the horizontal return tubular boiler, which is simply a cylinder with flat ends having tubes extending from one end to the other, parallel to the axis of the cylinder The tubes act to stay the flat surfaces, but the portion of the surface above the water line is free of tubes, and must therefore be supported by stay bolts Stay bolts may be simple tie rods threaded on the ends to receive nuts which are screwed on the outside of the surface, or they may be hollow or flexible, the latter type having ball or socket joint at one or both ends of the staybolt (FTM)

STEAM. Steam is the vapor of water at or above its boiling temperature The universal occurrence of water, its cheapness, its solvent properties, its suitability as a medium for a vapor cycle, and general familiarity with it and its properties, all have contributed to make of steam the most important vapor used by man If a closed vessel is partially filled with water, and heat applied at a high temperature, the water will absorb the heat and rise in temperature until its molecular activity (which depends on its temperature) is so increased that the internal molecular attractions are no longer able to maintain it in the form of a liquid, and molecules leave the surface of the liquid and occupy the space above it in the rarefied condition of a **vapor.** Water has a definite vapor pressure at every temperature, when the vapor pressure becomes equal to the pressure above the liquid, the **boiling point** has been reached If the steam is produced in a closed vessel, it is invisible If it is released to the atmosphere, it partly condenses to form a cloud of mist (small drops of liquid water), which is visible The temperature at which the boiling takes place is dependent upon the pressure which is maintained in the boiler Steam which is in contact with the boiling water is known as saturated steam If it is led away from the boiler, and subjected to further heating, it can become superheated, that is, its temperature may be raised above the saturation temperature This elevation of temperature is known as superheat

The saturation temperature of steam increases under pressure, at first rapidly, then more slowly, with uniform increments of pressure, until a temperature of 706 1° F is reached, at a pressure of 3226 pounds per square inch The heat required to boil off a pound of water at the saturation temperature into dry saturated steam is greater at the lower pressures, and decreases as pressures increase, until it disappears at 3226 pounds per square inch This high pressure is the critical pressure at which steam and water are identical in physical properties Steam at a temperature above 706 1° F is certain to be superheated, no matter what the pressure The heat contained in saturated water increases with increase of pressure until it becomes equal to the full enthalpy at the critical pressure The rate of increase of heat of a liquid does not correspond with the rate of decrease of the heat of evaporation, and their sum, ie, the enthalpy of the dry steam, increases until it becomes maximum between 400 and 450 pounds per square inch, after which it decreases. At the critical pressure a pound of

saturated steam contains less heat than at any other pressure. See **Critical State.** (F.T.M.)

STEAM CALORIMETERS. Dry saturated **steam** is rarely produced by a **boiler.** If unequipped with a **superheater,** the boiler will generate steam which contains droplets of moisture suspended in the steam. The per cent of steam in a unit quantity of steam and water is known as the **quality.** Steam exhausted from an **engine** or **turbine** has a considerable amount of moisture, the quality often being as low as 85%. It is not possible to judge the quality by inspection of steam, or of pipes in which steam is flowing. A thermometer is of no avail, and yet, there often arises the need for knowing the quality of steam flowing in a pipe line. To meet this need, there have been devised so-called steam calorimeters—devices for experimentally determining the quality of steam. Such calorimeters are made in two forms, each of which has its own particular sphere of usefulness. These instruments, which differ in principle, range of quality measurable, and technique of operation, are known as the

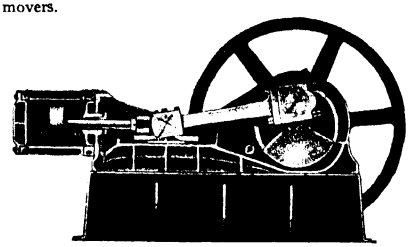


Steam calorimeters.

separating and throttling calorimeters. The separating calorimeter operates on a mechanical principle. It separates the water from the steam by centrifugal force, or difference of density of water and steam, and the principle is simply one of effecting the separation, and then separately measuring the water and dry steam. If A pounds of water are separated from B pounds of dry steam, the quality of the mixture is $\frac{B}{A+B}$. The calculations required in this calorimeter are thus seen to be simple, but the steam must be comparatively wet, because an extremely small amount of moisture can not be effectively separated from the stream of dry steam. The calorimeter is provided with a catch chamber in which the separated water collects. The amount collected is measured by a graduated gage glass connected to the calorimeter. The dry steam is measured by being passed through an **orifice.** A peculiar property of the orifice is that the weight of steam passed is proportional to the steam pressure. Using a fixed orifice, a scale of steam flow can be incorporated on the dial of an ordinary steam pressure gage.

The throttling calorimeter is not suitable for other than the measurement of steam of very high quality. Its action depends upon the fact that the throttling of high pressure steam through an orifice to a low pressure leaves the steam with the same heat content at the low pressure that it had at the high. Unless the high pressure steam exceeds 1800 pounds per square inch (a rare case), the heat it contains exceeds that of dry saturated steam at atmospheric pressure, so that it may be slightly wet, and yet have enough heat to produce superheated steam after being throttled. Now while the thermometer is of no avail in ascertaining the state of saturated steam, it does, in connection with pressure, definitely determine the state of superheated steam. That is, a temperature and a pressure together fix the state of steam and numerical data such as total heat, **entropy,** volume, etc., are readily obtained from compilations of steam data. Unless the steam is initially too wet to superheat the throttled product, the pressure and temperature readings of the low pressure steam in the calorimeter are sufficient to determine its heat. Taking this, also, as the heat of the high pressure steam, the quality is computed by the relationship: heat of wet steam = heat of liquid + quality × heat of evaporation. The quality and heat of evaporation are taken from steam tables at the pressure of the pipe line. The accompanying diagrams are intended to be illustrative of the principle, rather than of the actual arrangement of the calorimeter equipment. A very different apparatus, also known as a steam calorimeter, and used for measuring *specific heats* of substances, is described under calorimetry. (F.T.M.)

STEAM ENGINE. A steam engine is a positive displacement piston and cylinder machine which, when supplied with **steam** at a pressure above its exhaust pressure, uses that steam expansively for the production of power which it makes available as a rotating **torque** at a crankshaft or flywheel. The steam engine is, with few exceptions, double acting, and at present is most frequently built and used in sizes of less than 500 H.P. Larger power units are generally installed as turbines. The steam engine is characterized by moderate or low speeds (100–500 r.p.m.), the use of atmospheric exhaust (or of a very moderate vacuum), high starting torque, and ease of conversion to reversible operation if desired. The excellence of the **steam turbine** when a large amount of power is to be generated, especially where the exhaust is at a high vacuum, coupled with the high efficiency of the **Diesel engine** as a prime mover, has greatly restricted the field in which the steam engine is economically a superior prime mover. However, where a boiler must be supplied anyway, as for the generation of heating steam, the steam engine is usually superior to the Diesel engine as a source of power, and where exhaust pressures are high (often the case in industry, where the exhaust is process steam), the steam engine offers advantages which are not seriously challenged by the other types of prime movers.



Ames automatic engine.

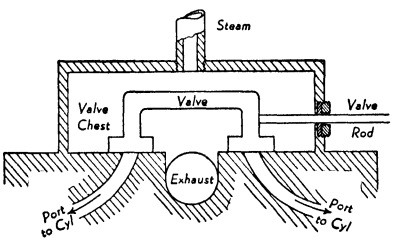
The principal parts of a steam engine are:

1. The frame or bedplate. In a multi-cylindered engine, this takes the form of a crankcase to which

the cylinders are attached, but in a single cylindered engine, the cylinder is often integral with the frame

2. Cylinder, with valve chest.
3. Piston, piston rod, cross-head, connecting rod This mechanical linkage receives a push from steam pressure at one end, and delivers it as a torque force on the crank
4. Crankshaft, bearings, and flywheel This part of the engine accomplishes the conversion of reciprocating to rotary motion, supports the shaft for power offtake, and steadies the speed
5. Valves and valve gear The device for admission and release of the steam to and from the cylinder, together with the means for actuating it from the crankshaft
6. Governor Stationary engines are automatically regulated for constant speed by means of a governor
7. Lubrication The piston and cylinder are lubricated by oil mixed with the steam The bearings are lubricated with grease cups, oil rings, wicks, etc The cross-head is often lubricated with a sight feed oil cup On certain engines the totally enclosed crankcase permits the use of a splash system of oiling

Unlike the gasoline engine, in which the valves have become standardized on the poppet type, the steam engine is built with many different valve types The



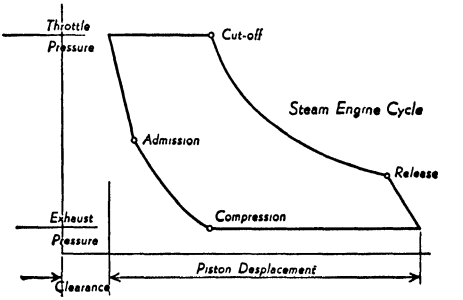
D–Slide Valve

original valve was known as the D-slide valve, because in cross-section it resembled the capital letter D Only one valve was needed to admit and release the steam at both ends of the cylinder This valve had definite disadvantages, to wit the unbalanced steam pressure on it was difficult to handle except in low pressure installations, its motion could be no faster than that of the piston, and consequently "wire drawing" of the steam existed during closure of the ports Governing, by changing the point of cut-off, was possible only at the expense also of changing the other events of the cycle The use of the D-slide valve necessitated dual flow engines, that is, steam entering and leaving by the same port The alternate heating and cooling of the ports caused a large thermal loss known as **initial condensation.** To overcome some or all of these disadvantages, a century of engine development has evolved the following improvements

a The piston valve—no unbalanced pressure.
b The Corliss—no wire drawing Partially balanced pressure, partially reduced condensation Cut-off independently controlled
c. The poppet valve—balanced pressure, partially reduced condensation, and cut-off independently controlled
d Multi-port balanced valves—reduction of wire drawing Balanced pressure.
e. **Uniflow** engine—elimination of initial condensation Adaptable to any of the improved valves

A steam engine converts from 5 to 15% of the heat supplied to it into work, depending on the state of the steam supplied, and on the exhaust pressure The heat unconverted is composed first, of heat remaining in the exhaust steam, second, initial condensation, third, incomplete expansion, fourth, wire drawing, fifth, friction, and sixth, radiation (negligible) The first of these is the largest, and is reducible only within certain limits Incomplete expansion results from the release of the steam at the end of the stroke at a pressure higher than the exhaust By using a longer stroke, this could be eliminated, but there is a point beyond which the increased cost of the engine more than offsets the gain derived by eliminating this loss

The cycle upon which the engine operates is briefly described as follows Slightly before the piston reaches the dead center position corresponding to minimum cylinder volume, the valve connects the cylinder with the steam line so that as the piston starts on its outward travel, the full steam pressure is acting on it.



Steam engine cycle

The beginning of this action is known as the event of admission When some 20 to 30% of the stroke has been completed, the valve closes the port on the event known as cut-off, and during the remainder of the stroke, the steam is expanded **adiabatically** to the accompaniment of decreasing pressure Near the end of its stroke, the valve again opens the port, this time connecting the cylinder with the exhaust line This event is known as release The cylinder remains connected with the exhaust during the return stroke of the piston, and the steam is expelled until approximately 2/3 of the return stroke has been completed The valve then closes the port, and the remaining steam is trapped in the cylinder and compressed The beginning of this process is known as the event of compression The four events just described govern the form of the steam engine cycle The engine using it will be able to develop a horsepower hour from 10 to 25 pounds of steam, depending upon the expansion permitted by the terminal conditions of the steam

The steam engine may be mechanically controlled to give variable output so that when it is connected to a load which varies, it maintains nearly constant speed There are two methods of accomplishing this result In one, called cut-off governing, the percent of the stroke during which the valve connects the cylinder with the boiler, is varied, and in this way different amounts of steam are admitted to the cylinder at one pressure The mechanism to effect this type of control is incorporated in the valve drive. The other method, called throttling governing, consists of interposing an artificial resistance to create a pressure drop between the boiler and the engine, so that although the same volume is admitted on each stroke (the cut-off being constant), the weight of steam admitted will vary because of the variation in density created by throttling The governor,

in this case, operates on a throttle valve located at the steam inlet. (F.T.M.)

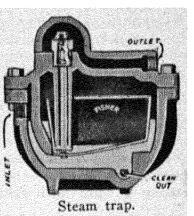
STEAM ENGINE INDICATOR. Thermodynamics.

STEAM RATE. The rate at which a **steam engine** or **turbine** consumes **steam** per unit power output is its steam rate. Originally, this quantity was called water rate, but since an engine operates on steam, the term steam rate seems more appropriate. It is usually given in units of pounds of steam per horsepower hour, or per kilowatt hour, in the case of a direct connected or turbo-generator unit. The steam rate varies with the load, being minimum at a load known as the most economical load. This is about 80% of the rated load in the turbine, and somewhat less in the engine. Steam rate is affected by initial pressure and degree of superheat; also, by exhaust pressure. The higher the initial pressure, or temperature, and the lower the final pressure, the smaller the steam rate will be. Thermal efficiency is inversely proportional to steam rate. Steam rate, multiplied by load, is steam consumption, and when this product is plotted against load, the result is a straight line up to the most economical load. This line is the well-known **Willans Line.** (F.T.M.)

STEAM RECEIVER. The steam receiver is a tank or vessel providing a volume for the storage of **steam**, so that sources which use the steam in a fluctuating manner may be supplied from the storage in the receiver without causing a large fluctuation of pressure in whatever supplies the steam to the receiver. For example, the use of steam by an engine is pulsating, and where the boiler drum which supplied that steam had insufficient volume of steam storage, a cyclical variation of pressure was created, which, in some cases, caused excessive vibration of steam pipes and boilers. This was remedied by setting up between the **boiler** and the engine a receiver of suitable volume to augment the vapor storage of the boiler. Cross-compounded **steam engines** require a steam receiver intermediate between the exhaust of the high pressure cylinder and the inlet of the low. The reason for this is that in this compounding arrangement, the low pressure cylinder does not take in steam simultaneously with the exhaust of the high pressure cylinder. A receiver of volume about equal to that of the high pressure cylinder must be provided to prevent fluctuations of pressure on the inlet to the low pressure cylinder. For much the same reason, receivers are used between the stages of multi-stage air compressors of the piston-cylinder type, though a cooling action is also incorporated in these receivers. (F.T.M.)

STEAM TRAP. A device which automatically operates to allow the discharge of water from a certain region, and prevent the escape of **steam** along with it, is known as a trap. The trap is used when condensate is to be drained from a vessel occupied by condensing steam, without the loss of steam. It traps the steam in the vessel and passes the water of condensation. Traps are used with steam heaters and cookers of all types, wherein a surface is interposed between the steam and that which is heated, to drain the condensation from steam lines, and for many similar services. A great deal of heat which is otherwise wasted by a partially opened drain valve will be saved by a trap if its discharge is connected to some point where the heat in the hot condensate can be used. The principal methods of operating a steam trap are expansion, float, tilting under the influence of accumulated condensate, and sinking bucket.

In an expansion trap, advantage is taken of the fact that condensate is usually a little cooler than the steam, and a metal expansion element is placed where it may be covered either with steam or condensate, depending on the amount of condensate in the trap. When it is covered with condensate it is cooler, and shrinks, opening a valve to pass the condensate from the trap. As the condensate is discharged, it uncovers the expansion element, and the hot steam causes it to expand and close the discharge valve. Such traps are frequently used on steam radiators. In a float type trap, the float is attached to the end of a pivoted lever, from the other end of which a link bar extends to open or close a discharge valve, depending on the position of the float. These two types tend to produce a continuous discharge through a valve which is cracked open just sufficiently to maintain a condition of equilibrium in the water level of the trap. The tilting and bucket type traps are intermittent in operation, which is much better from the standpoint of wear on the discharge valve. In the tilting trap, water collects in a pivoted chamber until the weight of it overcomes the counterbalance and the whole chamber tilts until a valve is opened and the discharge of water through it relieves the trap so that the counterbalance can return it to the closed position. A pivoted bucket trap is shown in the accompanying diagram. As the condensate is collected in the trap, it fills the bucket, which otherwise would tend to float on the surface of the water in the bucket chamber. When the bucket is filled it sinks, thereby opening a discharge valve. The pressure of the steam forces the water out through the discharge valve, and as soon as the bucket is empty, it again floats on the water in the chamber, closing the discharge valve. (F.T.M.)



Steam trap.

STEAM TURBINE. Prime movers utilizing **steam** are the reciprocating engine and the turbine. One is essentially a pressure machine, the other a flow machine. The reciprocating parts of engines limit their speed to a comparatively low value, but turbine energy is obtained from a number of small forces working at high velocity. Smaller dimensions and freedom from vibration give the turbine an advantage in first cost, space, and foundation requirements. Both engine and turbine are reliable prime movers.

Probably the most significant factor in the growing importance of the steam turbine is that it is the only prime mover available in the largest sizes desired. While many of the larger turbines are specially made to the purchaser's specifications, manufacturers have developed the practice of arranging the blading within a number of standard sizes of casings so that turbines of almost any capacity can be built at reasonable cost and fairly good efficiency. Selection of a turbo-generator may be for its (1) low first cost per kilowatt capacity, (2) low maintenance cost, (3) economy of foundation and building cubical content, (4) high efficiency when operated far into the low-pressure range, (5) uniform angular velocity with freedom from vibration, (6) oil-free character of the condensate.

The action in a steam turbine is the transfer of energy from the heat form first to kinetic energy of a high velocity steam jet, then to the energy in the rotating shaft. Its principal parts are:

1. Nozzles to change heat energy to work energy, and to direct the course of steam onto blades.
2. Blades, which change the kinetic energy of the jet of steam into shaft horsepower.
3. Rotating shaft, to which the blades are affixed.
4. A casing, which encloses the steam path and supports fixed parts.
5. Governor, bearings, lubrication, and other auxiliary devices.

When steam is expanded adiabetically through a stationary nozzle, it does not retain all the heat it originally had. The heat released during expansion does not disappear. According to the first law of thermodynamics, it must reappear as work energy in equivalent amounts (778 foot pounds for every B.T.U.). In the case of steam expanding through a stationary nozzle, the moving steam must gain this mechanical energy, with the result that its speed is considerably increased. An ordinary expansion involving a heat drop of approximately 100 B.T.U. of steam has the capacity to increase its speed to the amazingly large magnitude of 30 miles per minute. This may give some inkling as to the reason that so light a fluid medium as steam is capable of producing so much power in a machine of moderate dimensions. There are two principles of operation used in turbines, known as the impulse and reaction principles. The impulse principle involves stationary nozzles and moving blades which absorb the mechanical energy from the steam as it shoots past the blades. In the reaction turbine the nozzles are themselves attached to the shaft. In one case the motivating force is one of impulse of a stream against a blade; the other, one of a reaction force created by the acceleration of the steam in the moving nozzles. A hydraulic analogy of the reaction turbine is the common revolving lawn sprinkler. The machines using these two principles exhibit some dissimilarity. For example, in the impulse turbine, the blades are rather heavy, of steel, attached to wheels which are mounted on the shaft. The nozzles have definite nozzle form, and are fixed in the casing. Reaction turbine blades are lighter, of bronze, and are directly affixed to a drum, which takes the place of the shaft. The moving nozzles themselves are made of blades so shaped as to give nozzle action. Further comparison of the impulse and reaction principles may be had by reference to the accompanying figure, which illustrates diagrammatically the nozzle and blade arrangement of both types. In each case one stage is represented. The nozzle of the impulse turbine speeds up the steam and guides it onto the blades which move past. The pressure drop is entirely consummated in the nozzle. The velocity increases in the nozzle, and decreases on the blade. In the reaction stage, the row of fixed blades gives a nozzle effect which expands the steam and directs it onto a row of moving blades, also composed of nozzles. These, in turn, expand the steam, receiving thereby a reaction force from the acceleration of the expanding steam. The pressure drops in both fixed and moving nozzles. The fixed nozzles give the steam sufficient velocity to glide into the moving blades at their speed, or slightly faster. The expansion in the moving blades is sufficient to increase the relative velocity of the steam so that when it leaves them there will be no component of velocity in their direction.

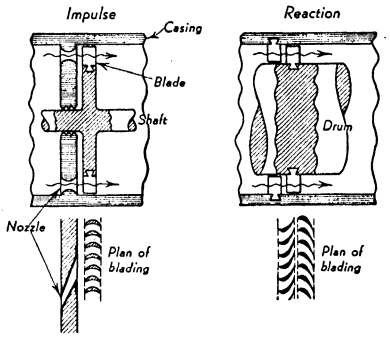


Figure 1(a) Figure 1(b)

One stage of steam turbines.

Very high rotative speeds are necessary if the entire adiabatic heat drop for the turbine is released in one set of nozzles. For example, an impulse turbine in ordinary, or even a conservative expansion, would create a steam speed which, if absorbed on one row of blades revolving in an 18-inch circle, would require a rotative speed at the shaft of better than 10,000 rpm. This gives a key to the desirability of staging a turbine through subdividing the heat drops, the energy being absorbed after each incremental heat liberation. Thus, in a five-stage impulse turbine, each stage may be called on to absorb only one-fifth of the total heat drop. The subdivision is even greater in the case of reaction turbines, where the B.T.U.'s liberated per stage rarely exceed 10. In consequence, the number of stages found in the reaction type turbine is greater than in the impulse. Except for areas of nozzles, size of blades, and blade angles, the stages resemble one another.

Large steam turbines fall into three classes.

1. Straight reaction.
2. Straight impulse.
3. Impulse reaction.

The straight reaction may have fifty or more stages, the straight impulse rarely more than twenty (half that number is more common). One or two impulse stages preceding a straight reaction section enable reduction of the number of reaction stages to about twenty.

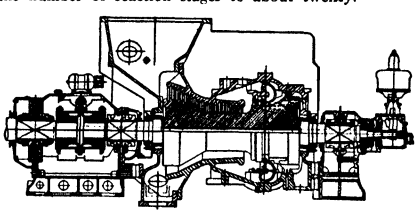


Figure 2. High-pressure section of 110,000-kw. Westinghouse turbine.

An impulse turbine is pressure staged, i.e., the pressure drop is subdivided among a number of stages, any one stage of which may be, in addition, velocity staged. By this is meant that, following one set of nozzles there may be two rows of moving blades which, together, effect the reduction of velocity and the absorption of energy created in those nozzles. The two rows of moving blades are separated by a row of fixed reversing blades, which receives the steam from the first row, and directs it at the proper angle for the second row. A velocity stage within a pressure stage is known as a Curtis stage. A simple pressure stage is a Rateau stage, and the reaction stage often is called Parson's staging. As steam expands through a multi-stage turbine it increases in volume after each stage, making it necessary either that the diameter of the circle in which the blades travel be increased, or that the height of the blades be increased to provide sufficient area for the increased volume of flow. Usually both of these expedients are adopted, so that the turbine exhibits, roughly, a somewhat conical shape, being smallest at the high pressure end, and largest at the exhaust.

Essential to the operation of a turbine are a number of auxiliary devices. These will be briefly mentioned. The impulse turbine rotor receives a moderate end thrust, due to the angle at which the steam strikes the blades. The reaction turbine has a large end thrust, because of the endwise component of the reaction force. While the end thrust of an impulse turbine can be accommodated by special thrust bearings, the large forces set up in a reaction turbine necessitate the use of a special device

known as a dummy piston. The dummy piston is a circular plate mounted concentric with the axis of the turbine, and having, on one side, high, and on the other, low steam pressure The pressures are so chosen that the direction of the resultant force on the plate is counter to the end thrust on the blades. A separate piston is used for each section of drum, so that although steam pressure and end thrusts may vary with different loads, the equalizing pressures also similarly vary A thrust bearing is provided to absorb the small amount of unbalance which may still exist

The moving parts of the turbine are few Principally, there are two bearings, one at each end of the turbine, which support the rotor These are rather heavily loaded so that plain babbitted bearings are usual Oil is pumped to these bearings and wasted from them to a sump, from which it is withdrawn, filtered, and cooled before being again supplied to the bearings An auxiliary pump maintains oil pressure during the starting and stopping cycle of the main unit Where the shaft of the turbine projects through the casing, means are provided for packing against leakage of the steam outward at the high pressure end, and infiltration of air at the low pressure end Packed stuffing boxes are used only on small turbines This service is performed on large turbines by sealing glands which are built into the turbine, and which seal the shaft with steam or water The outward leakage from the glands is minimized by labyrinths

Governing of steam turbines is accomplished by three methods, viz (1) throttling at inlet, (2) varying number of inlet nozzles in action, (3) varying duration of full pressure puffs (blasts), of which there are several per second In addition, some turbines are provided with hand operated by-pass valves which, by admitting high-pressure steam to low-pressure stages, enable the turbine to carry more overload though, of course, at reduced economy Of these methods, the first is widely used on small turbines In the large turbine field, the second is applied to the Curtis type, and the third to the Parsons type

The losses in a steam turbine, as is the case with the engine, are topped in magnitude by the heat in the exhaust Unfortunately, this is difficult to reduce because of the troubles attending the use of steam of **quality** lower than about 85% in the turbine Wet steam erodes turbine blades, due to the high velocity with which the particles of moisture strike them The other losses which occur in steam turbines are

A Thermodynamic losses
1 Leakage Past shaft gland packings, dummy pistons, diaphragms and blade tips
2 Blade and disk friction
3 Throttling at the control valves
4. Non-stream line flow at other than design conditions
5 Leaving loss, and pressure losses in exhaust nozzle

B Mechanical losses
1 Bearing and stuffing box friction
2 Windage action of idle blades.
3 Gland water-seal power
4 Oil pump and governor power

All of the thermodynamic losses of one stage are returned to the steam as it enters the next lower stage, so that one definite advantage of multi-staging is to make available to the next stage the thermal losses of the preceding one This is one factor in the superior performance of multi-stage turbines. To illustrate the point, consider the case of friction on the nozzles If the turbine casing is well insulated, the heat that is generated by friction of the steam against the nozzles simply elevates the nozzle temperature until it returns, by conduction to the steam, as much heat as is generated by friction. The greater part of the stage loss is returned to the steam at the low pressure, and in turbine design it is considered that all of the reheat occurs at the low pressure of the stage Figure 3 shows how in a stage an adiabatic heat drop, as in nozzles, followed by a reheat, in which the stage losses are added at the low pressure, results in a steadily increasing entropy in a multi-stage turbine This explains the typical expansion line of the steam turbine, which, as pressure is reduced, increases in entropy, whereas an ideal turbine would expand the steam at constant entropy The increase of entropy corresponds to a decrease of energy availability, and that turbine which has the minimum entropy increase shows the best performance See **Stage Efficiency.**

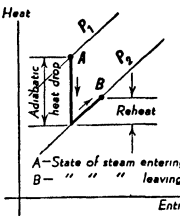


Figure 3 Steam conditions in one stage of a turbine

It is obvious from the foregoing analysis that all of the heat taken out of the steam during its passage from the throttle to the exhaust must have been put onto the rotating shaft as mechanical energy This is true because of the negligible radiation loss from the casing Friction and power required to drive the governor and oil pump take their toll of this energy, but they rarely amount to as much as 5% of the heat drop, so that practically all of the heat drop appears at the turbine shaft coupling as useful work (F T M)

STEARIC ACID AND STEARATES. Stearic acid ($H\ C_{18}H_{35}O_2$ or $C_{17}H_{35}\ COOH$ or $CH_3(CH_2)_{16}\ COOH$) is a white solid, melting point 69° C, boiling point 383° C, insoluble in water, slightly soluble in alcohol, soluble in ether Stearic acid may be obtained from glyceryl tristearate, present in many solid **fats,** such as tallow, and in smaller percentage in semi-solid fats (lard) and liquid vegetable oils (cottonseed oil, corn oil), by **hydrolysis** The crude stearic acid, after separation of the water solution of glycerol, is cooled to fractionally crystallize the stearic and **palmitic acids,** which are then separated by filtration (oleic acid in the liquid), and fractional **distillation** under diminished pressure With **sodium** hydroxide, stearic acid forms sodium stearate, a soap Most soaps are mixtures of sodium stearate, palmitate and oleate

The following are representative esters of stearic acid Methyl stearate ($C_{17}H_{35}COOCH_3$), melting point 38° C, boiling point 215° C at 15 mm pressure, Ethyl stearate ($C_{17}H_{35}COOC_2H_5$), melting point 35° C, boiling point 200° C at 10 mm pressure, Glyceryl tristearate (tristearin ($C_3H_5(COOC_{17}H_{35})_3$), melting point 70° C approx.

Stearic acid is used (1) in the preparation of metallic stearates, such as aluminum stearate for thickening lubricating oils, for water-proofing materials, and for varnish driers, (2) in the manufacture of "stearin" candles, and is added in small amounts to paraffin wax candles As the glyceryl ester, stearic acid is one of the constituents of many vegetable and animal oils and fats. (R.K.S.)

STEATITE. Talc.

STEEL. **Wrought iron** and pure **iron** are too soft and ductile for many of the purposes for which iron might be applied In an earlier age a harder, tougher product was desired mainly for weapons, but in this age the peaceful uses of such a material are almost infinite When iron is alloyed with carbon, there is produced a malleable, tough product which may be tempered, annealed, forged, cast, and altered as desired Various **alloys** with carbon go by the general name of

steel, although steel may contain other substances as well; for example, magnesium, silicon, phosphorus, chromium, molybdenum, and sulfur The qualities of steel vary with the amount of these alloying materials, especially with the carbon And yet steel is almost entirely iron, the percentages of these other materials being very low Carbon is present in steel to the extent of ¼ to 1½%, but this small quantity is sufficient to account for the difference between iron and steel Steels may be classified as plain carbon steels or alloy steels The plain carbon steels are divided into low, medium, and high carbon types, the low carbon type containing about ½% of carbon, and the high carbon steel up to 1½% of carbon Also steels are variously alloyed with **silicon, chromium, nickel, copper, phosphorus, molybdenum, vanadium, tungsten,** and other elements

The making of steel was known by the skilled artisans of the ancients, whose sword blades (steels of Damascus and Toledo) were known, admired, and respected wherever weapons were used After a period of decadence during the Middle Ages, the making of steel was again advanced, although the production was limited It was an expensive product until the earlier methods of the crucible and charcoal pot were superseded by the modern **Bessemer** and **open hearth** processes When steel making was revived after the art had been lost during medieval times, the method of manufacture employed was known as cementation Bars of wrought iron were packed in pots completely surrounded by charcoal The pots were covered to exclude air, and heated for some days at a temperature which would cause absorption of some of the carbon in the charcoal by the iron The carbon content was greatest at the surface, and decreased toward the core of the bar By repeated forgings and reheats, a fairly homogeneous product could be produced, but it was inferior to that produced by the crucible process, which is still used to some extent In this process a good grade of wrought iron or steel scrap is mixed with a recarburizer and heated to the point of fusion in crucibles from which air is excluded **Bessemer's** process provided the needed stimulus for cheapening steel, and found the world waiting and ready to make much more extensive use of steel than ever before In recent years the open hearth process has been used more widely than the Bessemer Sometimes steel is partially refined in the Bessemer converter, and then charged into an open hearth furnace for the final stages The product is known as duplex steel The alloy steels are largely made in the **electric furnace** because of the degree of control that may be exercised in that type. The product is known as electric steel (F T M)

STEFAN-BOLTZMANN LAW. An important law of **thermal radiation,** discovered empirically by J Stefan in 1879 and deduced theoretically five years later by L Boltzmann It states that the total emissive power of a **black body** is proportional to the fourth power of the absolute temperature of the black body

$$E = \sigma T^4$$

The constant of proportionality, σ, called the Stefan-Boltzmann constant, has been determined experimentally as $5\ 735 \times 10^{-5}$ erg/sec cm^2 deg^4, but the measurements are difficult and the precision is doubtful Boltzmann's deduction was based upon the thermodynamic theory of **radiation pressure.**

In accordance with this law and the principle of exchange of radiant energy, and since the emissivity and the absorptivity are equal, the net rate at which a black body of area a (square centimeters) loses energy by radiation when placed in an enclosure of temperature T_m is

$$\frac{dw}{dt} = a\sigma(T^4 - T_m^4) \text{ (ergs per second).}$$

Newton's Law of Cooling approximates the Stefan-Boltzmann law for small differences of temperature only (L D W)

STEGANOPODES, PELECANIFORMES Birds with long legs, webbed feet, and long beaks and necks The **pelicans** are typical of the group, which also contains the **cormorants** and some related marine forms (A W L)

STEGOCEPHALIA. Fossil Amphibia.

STEGODON. Fossil Mammals.

STEGOSAURUS. Fossil Reptiles.

STEGOTHERIUM. Miocene.

STEINBOK. Mammalia, Artiodactyla · A small African **antelope,** any member of several species. The group to which they belong includes several species named as steinboks (*Raphiceros*) and in addition the royal antelope (*Neotragus pygmaeus*), the grysbok (*Nototragus melanotus*), and the oribi. The name is also applied to the alpine **ibex.** (A W L)

STELE. The **vascular** tissue of the axis of a plant is called the stele or central cylinder The principal tissues composing it are the **xylem** and the **phloem.** The most primitive type is the protostele, which consists of a solid central mass of xylem surrounded by a cylinder of phloem There is no pith in a protostele Protosteles are found in the roots of all plants and in the stems of some of the ferns Many would set off the stele of the root as a separate type known as a radial stele, since the central mass of xylem is not a cylinder but has several arms projecting outward from its surface, with the phloem concentrated between these arms In stems, only those of certain Pteridophytes like *Lycopodium,* have radial steles

A siphonostele is composed of concentric cylinders of xylem and phloem enclosing a central pith If the xylem cylinder is next the pith and is surrounded by the phloem, the stele is an ectophloic siphonostele, if there are two cylinders of phloem, one inside and one outside the xylem, it is an amphiphloic siphonostele The most common type in **Gymnosperms** and **dicotyledon** stems is the ectophloic siphonostele The amphiphloic siphonostele is found in members of the gourd family and in some ferns Commonly there are many gaps in the siphonosteles, where vascular strands pass outward into a leaf These gaps are called leaf gaps, the strand, a leaf trace

A dictyostele is a siphonostele which is so broken up by numerous leaf gaps that it appears to be made up of a number of separate strands It is really a very much dissected siphonostele Dictyosteles are found in some **ferns** and in many **dicotyledons.** (R M W.)

STELLAR MAGNITUDE. In the first star catalogues issued by Hipparchus and Ptolemy the relative apparent brightness of the stars were designated by a system of five numbers referred to as the magnitude of the star Twenty of the brightest stars were referred to as first magnitude, while those at the limit of visibility were called sixth magnitude The stars with brightness intermediate between the two extremes were assigned to a magnitude number with the numbers increasing with faintness of the stars. With the application of the **telescope** to astronomy many faint stars were discovered and the need for additional magnitude numbers became evident Unfortunately for modern astronomers, the attempt was made to amplify the ancient magnitude sys-

tem not only to include the fainter stars, but also to indicate finer gradations of brightness by a decimal system The result is that astronomers are now using a system which was started about two thousand years ago and has all of the clumsiness and inconvenience for modern observers which is characteristic of so many of the ancient scientific instruments.

There is no definite evidence that Hipparchus or Ptolemy had any idea in mind at the time that they first used the magnitude system other than to provide a rough descriptive term for the stars In the early part of the 19th century Sir John Herschel found that the apparent brightness of a first magnitude star is about 100 times that of a sixth magnitude In 1850 Pogson proposed a fixed scale of stellar magnitudes based upon the original scale of Hipparchus and Ptolemy, but so adjusted that it would agree at the sixth magnitude with the system employed by Argelander in his famous **Bonner Durchmusterung.** Adopting the announcement of Herschel that the ratio of brightness of a first and sixth magnitude star is approximately 100, Pogson proposed that the ratio between successive magnitudes should be $\sqrt[5]{100}$ or approximately 2 512 This leads to an analytical expression for the magnitude scale as follows

Call B_1 the apparent brightness of a star of magnitude H and B_2 the apparent brightness of a star of magnitude J, then $B_1/B_2 = 2\ 512^{(J-H)}$ or, expressed in logarithmic form, $\log_{10} B_1 - \log_{10} B_2 = 0\ 4\ (J-H)$

Since the magnitude scale is a scale of relative brightness, it is necessary to establish a system of standards For this purpose a group of stars in the immediate vicinity of the north celestial pole has been selected The magnitudes of the stars in this "north polar sequence" have been very carefully determined and agreed upon by the International Astronomical Union All magnitudes determined at the present time should be referred, either directly or indirectly, to this standard sequence

The magnitude scale as originally established referred to the relative apparent visual brightnesses of the stars With the application of photography to astronomy difficulty with the magnitude scale immediately became evident If we have two stars of the same visual magnitude, one of them blue and the other red, the photographic image of the blue star will be much stronger than the photographic image of the red star The colors of the stars in the sky vary with the different spectral types, and the visual magnitude differences between a number of stars of different spectral types will differ considerably from the magnitude differences obtained by photographic means Furthermore, the photographic magnitudes, so-called, will be different, depending upon the type of plate used and the characteristics of different telescopes, and it becomes necessary to be very explicit in defining the particular range of wave-lengths of **spectral** energy that are to be used in any magnitude scale The difference between the photographic and visual magnitude of a star is known as the **color index** of the star, the term arising from the fact that the color is the determining factor in the magnitude scale difference

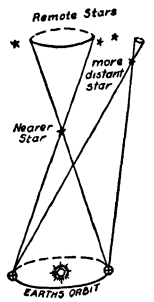
With the application of various other types of radiation measuring instruments, such as **bolometers** and **radiometers,** to the measurement of the apparent brightnesses, of the stars the necessity has arisen for various different magnitude scales such as bolometric magnitude, radiometric magnitude, etc The problem of the intercorrelation of the different systems is at present in a very confused state and much research is being carried on in this important field It is devoutly to be hoped for that in the future some system of expressing the apparent brightnesses of the stars may be devised that will replace the present complicated inverse logarithmic scale of magnitudes

For the purpose of expressing the intrinsic brightness of a star, independent of the distance of the star from the earth, a system of **absolute magnitudes** has been devised which will be discussed in more detail elsewhere (W K G)

STELLAR PARALLAX. The term stellar parallax is used by astronomers as a means for expressing the distance of a given star Technically defined, stellar parallax is the angle that would be subtended by the mean distance of the earth from the sun (one **astronomical unit**) at the distance of the star from the sun

From the earliest days of the Pythagoreans any theory of the structure of the **universe** which postulated that the earth might move about the sun was objected to on the ground that such motion should produce an apparent motion of the stars **Copernicus,** in proposing his heliocentric theory, met this objection by postulating that the distances of the stars were so incomparably greater than the distance of the earth from the sun that no instrumental methods would be capable of detecting the motion even if it did exist The attempts to test the Copernican doctrine by searching for this so-called stellar **parallax** gave a tremendous impetus to the design of accurate instruments, but even with the improvement in instrumental equipment the effect was not observed and the Copernican theory lost ground It was not until 1838 that **Bessel** was able to definitely prove that the effect is present

The type of effect to be looked for is illustrated in the figure The type of curve which the stars should apparently follow due to the earth's motion about the sun varies from an ellipse with eccentricity equal to that of the earth's orbit for stars at the pole of the ecliptic, to oscillations back and forth along a straight line for stars in the plane of the ecliptic



Parallaxes of the stars Owing to the earth's revolution the nearer stars describe parallax orbits annually with respect to the remote stars

The problem of determination of stellar parallax is theoretically very simple All that is necessary is to make a series of observations of the positions of a star on any system of **spherical coordinates** (e g, **right ascension** and **declination**) and from the observed changes in position throughout the year determine the stellar parallax This so-called absolute method was attempted many times but failed to reveal any definite value because of the fact that the instrumental corrections were larger than the effect sought for This is not surprising when we consider that the largest stellar parallax which has ever been found (for the star Proxima Centauri) has a value of 0″783, or equivalent to the angle subtended by a ten cent piece at a distance of approximately three miles

With the failure of the absolute method to yield any values for the parallaxes of the stars, Bessel and Struve decided upon an indirect or relative method for determining the desired quantity This method is based upon the assumption that certain stars are at such a great distance that their parallaxes are too small for detection, but that there are other stars closer to the sun which should show motion relative to the distant background Bessel selected the star 61 **Cygni** which was assumed to be relatively close to the earth from a large **proper motion** while Struve selected the star **Vega** which has an appreciable proper motion and is also so bright as to imply closeness to the earth Proceeding by different methods, in 1838 both Bessel and Struve were able to show that the stars which they had selected showed parallactic motion relative to the background of stars

Until the application of photography to astronomy the problem of determination of stellar parallaxes was very tedious and laborious and up to 1880 distances of less

than twenty-five stars had been determined With the application of photography the progress of parallax determination became very much more rapid, and at present many long programs of observations both in the northern and southern hemisphere are nearing completion.

The photographic method consists in first selecting stars which are suspected, either from proper motion, **spectral type,** or other characteristics, to be relatively close to the sun Plates are taken of these stars, great care being exercised in the guiding, and the brightness of the "parallax star" is reduced until its photographic image compares favorably with the images of the fainter "background stars" The plates are all taken at the same **hour angle,** either east or west, to eliminate so far as possible atmospheric effects, and the dates on which the plates are taken are separated as much as possible to make the effect of the earth's motion as large as possible Twenty or thirty plates, extending over several years, are taken and the position of the parallax star carefully measured with reference to half a dozen background stars A **least squares** solution will yield the motion of the star relative to the background This motion will consist both of the proper motion and the parallactic shift The former may be separated from the latter because proper motion is linear in character while the parallactic shift is periodic For stars within five million times the sun's distance from the earth (parallax 0″04) the mean of two or three determinations will be correct within twenty percent For twice this distance the results are only accurate enough for statistical purposes, while beyond this distance the trigonometric method is practically valueless Occasionally, due to an unfortunate choice of parallax star or of comparison stars, the value of the stellar parallax comes out to be a negative quantity Such a "negative parallax" simply means that the star under observation is more distant than those selected for comparison purposes For the more distant stars beyond the range of the trigonometric method certain other methods are available such as parallaxes of members of **moving clusters, mean parallaxes, dynamical parallaxes** of double stars, and **spectroscopic parallaxes.**

The "General Catalogue of Stellar Parallaxes," published by Dr Frank Schlesinger at the Yale University Observatory in 1935, lists 7534 parallaxes determined either by the relative trigonometric or spectroscopic methods, and 2482 parallaxes determined by the dynamical method (W K G)

STELLAR PHOTOMETRY. The problem of determining the **stellar magnitude,** or brightness, of a star is known as stellar **photometry.** Since the magnitude scale is a purely arbitrary one, all methods of stellar photometry consist fundamentally in the comparison of the brightness of one star with the brightness of a star of standard magnitude The simplest method is to make direct visual comparison between the two stars and estimate directly the difference in magnitude In the so-called "Argelander method" two stars of standard brightness are selected, one brighter and the other fainter than the star under consideration The difference in magnitude between these "comparison stars" should not be greater than one magnitude The observer then mentally divides the magnitude difference between the comparison stars into, say, ten, light steps and estimates the brightness of the unknown star in terms of these steps

It is a well known fact that the eye can more accurately determine when two objects are of equal brightness than it can determine the difference of brightness of two unequal objects A number of different devices, such, for example, as the **wedge photometer** and the **polarizing photometer,** are employed for equalizing the brightness either of an artificial star or a star of known magnitude with that of the star under consideration.

The above methods all employ the human eye as the instrument of measurement and the characteristics of different eyes vary not only between different observers, but also, to some extent, from day to day for an individual observer In the attempt to remove the human element from the determination of stellar magnitudes various stellar photometers have been devised which measure directly the intensity of the radiation from star images formed by telescopes Such photometers employ devices such as **photoelectric cells, selenium cells, thermopiles,** etc, by means of which the radiant energy is converted into a **galvanometer** deflection, with the deflection a complicated function of the amount of radiant energy The technique of using such instruments is difficult to master and the process of obtaining results is slow and tedious, but in the hands of skilled observers the results with these physical photometers are more accurate than those obtained by any other method These types of instruments are selective for particular wavelength bands of radiation, and great care must be taken in comparing results obtained with one instrument and telescope with the results obtained by others

The determination of stellar magnitudes either by direct visual comparison, by the use of visual photometers, or by the use of physical photometers is slow and fatiguing for the observers, with ten magnitudes per hour being a fair average rate of measurement With the photographic plate and modern astrographic **cameras,** images of several hundred stars may be obtained in one hour of observing with the telescope The size and blackness of a star image are complicated functions of the magnitude of the star A plate taken of a region of the sky for the determination of the magnitudes of the stars must be standardized in some manner There are many different methods of plate standardization in use, for example, photographing a standard sequence of stars, such as the polar sequence, on the same plate, or exposing the plate to a number of small areas with light of different intensity in each area The plates are measured in a **densitometer,** usually of the physical type of microdensitometer, and the photographic densities of the various star images and standardization images are obtained From the densities of the standardization images a calibration curve for the plate may be obtained and the magnitudes of the stars obtained In the photographic method, as in all methods of stellar photometry, color effects are very troublesome and the intercomparison of results obtained by different observers, using different photographic plates and cameras, is a difficult task

In all methods of stellar photometry a great many precautions must be taken to insure results of any value After all known corrections for observer, method, and telescope have been applied, there always remains the troublesome and uncertain error introduced by the effects of atmospheric absorption (W K G)

STELLITE. Alloys.

STEM. The stem of a plant is that part which bears the **leaves** and **flowers** and later **fruits.** Commonly it grows erect, lifting these various organs up above the ground It is readily distinguished from the root by being separated into joints or nodes and internodes, and by bearing leaves or by having on its surface scars left by the falling of leaves

Stems may be classified in several ways If one considers the duration of the stem, it becomes an annual lasting but one year, a biennial living two years, or a perennial stem which grows for several years If one considers the internal structure of the stem, he finds it to be herbaceous or woody An herbaceous stem is one which is largely made up of **parenchymatous** cells, without a great mass of woody tissue In temperate regions such stems last but a single year, at the end of which they die In annuals the entire plant dies, while in herbaceous perennials the top dies, but the basal portion including the root and the lower stem lives on. Woody plants are those in which the stem

is predominantly composed of **vascular** tissues Such plants are either trees or shrubs or vines Trees are commonly distinguished by the existence of a single stem or trunk which does not branch at its base, whereas in shrubs no single trunk exists, but several of equal size result from basal branchings Branching is either excurrent or deliquescent When excurrent, the trunk is distinctly recognizable throughout its length, the branches coming from it being much smaller, as in many **conifers** such as spruce or fir Usually such trees have a conical shape, due to the progressively smaller branches from bottom to top of the tree In deliquescent branching, the main trunk branches into several large branches which in turn divide, as in the elm Vines are distinguished by their long relatively slender stems which usually require external support. Another classification separates erect stems from those which are procumbent or trailing on the ground, from scandent stems which clamber over supports, and from twining stems which wind tightly around any supporting object

In many plants the stem is very much reduced in size, appearing as a small often flattened ball, as in the common Cyclamen or in certain Cactus plants Other plants are said to be stemless, the stem existing only as a small object at the top of the root, the leaves arising from it seeming to come directly from the top of the root. A familiar example is the dandelion The first year of growth in many biennials results in a similarly stemless plant, carrots, beets, and parsnips are common examples

As previously noted, one of the functions of the stem is to elevate the leaves into a position where they may function most efficiently and the flowers to a position where they may become more conspicuous and where the resulting fruits may be better scattered Not only does the stem perform this function, but it also permits a great increase in the number of leaves and flowers which may be borne The stem is the organ through which sap ascends from the root to the leaves and through which organic materials elaborated in the leaves pass to the place of storage The stem itself may be the place in which materials are stored

The stem develops from a **bud** In the **seeds**, the embryo has a terminal rudimentary bud, the plumule, from which the first stem develops The tip of this stem bears a terminal bud, from which further increase in the stem is developed In the axils of the leaves lateral buds are formed which develop into branches Elongation of the stem takes place only in the tip, extending downward therefrom a few inches, and is caused by the cellular changes like those that occur also in the elongating **root**. In some plants, as in Grasses, intercalary growth also occurs. This is growth in the region of the older nodes of the stem Increase in diameter of the stem results from the divisions of special cells called **cambium** cells

When the extreme variations of stem are considered, with their range from tiny plants less than half an inch in height to forest giants towering 300 feet and over, and from vines with slender wiry stem less than a sixteenth of an inch in diameter through succulent herbs to sturdy trunks 40 feet or more through, it is not surprising that stem structure should be very variable and often complex Yet they are all composed of the same types of cells and are all arranged on two fundamental patterns, one found in **dicotyledonous** plants, the other characterizing the **monocotyledons.**

In dicotyledons, the growing tip of the young stem has cells which are all alike, having a dense cytoplasm, and large nuclei, which, if the stem is growing, will be dividing frequently These cells comprise the promeristem, the region where active cell division occurs, but little change in cell form.

As these cells increase in number, some are carried ahead, while others remain unchanged in position. The latter gradually show very evident changes in size and shape, and in the nature of their walls The outermost layer, called the dermatogen, is made up of somewhat flattened cells which will become the epidermis, a protective covering against entrance of disease-producing organisms and against excessive loss of water Within the body of the stem tip certain strands of cells become distinct by their elongate shape and dense protoplasmic content These procambium strands are the beginnings of the vascular tissue presently to appear In cross-sections of the stem the procambium appears as a ring of separate masses of cells The remaining cells of the growing tip are parenchymatous cells, changed but little from the promeristem condition

As the procambial cells grow older, they gradually change in form Those cells which are nearest the center of the stem become xylem cells, those towards the circumference of the stem become phloem, with **cambium** cells separating the two types In some stems the differentiation of cells continues until the procambial strands have united to form a continuous cylinder which gives place to concentric rings of xylem and phloem cells separated by a band of cambium cells In other stems, the strands remain distinct, forming separate vascular bundles The fundamental tissue or parenchyma in the center of the stem becomes the pith, that surrounding the strands becomes the cortex, while the radiating masses of parenchyma cells between the separate strands make up the pith rays The outermost cells of the procambial strand may remain more or less parenchymatous, forming a tissue known as the pericycle, often very hard to distinguish from the cortex All these tissues, derived directly from the differentiation of the promeristem cells, form the primary body, composed of primary tissues

The epidermal cells are often somewhat elongated in the direction of the length of the stem The outer wall of an epidermal cell is frequently much thickened and cutinized, so that it becomes impervious to water Many **stomata** are found in the epidermis As the diameter of the stem increases, the epidermal cells gradually become stretched until they finally break apart and are lost

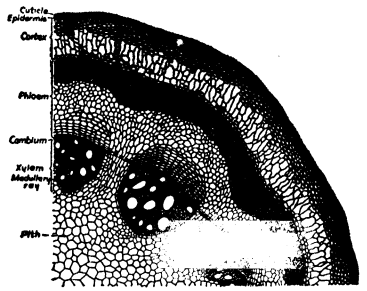
The cortex inside the epidermis is comprised of several kinds of cells Those nearest the surface are the collenchyma cells These are modified parenchyma cells, the walls of which are thickened in their angles Because of their thickened walls, collenchyma cells give support to the stem, while at the same time they allow growth to continue The parenchyma cells of the cortex are thin-walled, and either rounded in shape or, through mutual pressure, more or less angular Those near the surface of the stem often contain chloroplastids, and carry on photosynthesis They give rigidity to the stem because of their turgor pressure, and also serve as storage tissue In some stems there are also found in the cortex thick-walled sclerenchyma cells These may be either long slender fibers or short stone-cells The innermost cells of the cortex are often conspicuously filled with starch grains, which give to these cells collectively the name of starch sheath In a few plants the innermost cells of the cortex form a definite endodermis, the walls of each cell being much thickened

The tissues inside the cortex include the pericycle, the vascular bundles and the pith

The cells of the pericycle are very similar to those of the cortex, so much so that it is often very difficult to distinguish one from the other In the pericycle of stems, which usually is much thicker than that in roots, sclerenchyma cells may be found along with the parenchyma, just as in the cortex

The cells comprising the vascular system—xylem and phloem—are very much modified The procambial cells towards the center of the stem first elongate greatly, without appreciably increasing in diameter Soon changes appear in the wall, secondary deposits of cellulose being laid down against the primary wall The manner in

which the wall is thickened varies in different cells. In some the thick deposits are in rings: these are formed while the cell is still elongating and so are



Sector from cross section of stem of Dutchman's Pipe showing positions of phloem, xylem, and cambium layer.

gradually separated. Such cells are called annular cells. In other cells of the first-formed xylem, which is called protoxylem, the wall thickenings are in the form of spirals, producing spiral cells, which allow a certain amount of growth even when the thick wall is formed. In cells which differentiate later, when elongation has been completed, the thickening of the wall will be much more extensive, only irregularly distributed, narrow slits being left unthickened. These slits extend transversely in the wall of the cell. Such cells are called scalariform cells. Finally cells are formed in which special thin places, often circular in outline, with overhanging walls are left. These are the pits which allow communication from cell to cell. Cells having them are called pitted cells. Differentiation of the xylem cells continues until most of the inner part of the procambial strand has been changed to xylem cells. Those which form after the narrow protoxylem cells are called metaxylem cells. Protoxylem and metaxylem together make up the primary xylem.

The cells on the outside of the procambial strand become the primary phloem cells. These are the sieve tubes and companion cells. Early stages in the formation of these cells are much like those of xylem cells, elongation first occurring and then changes in the cell wall. In the formation of phloem cells, a single cell divides into two which become very unequal; the larger one continues to increase in size and loses its nucleus; the smaller one frequently divides again. The walls of these cells remain comparatively thin, with characteristic perforated thin places, called sieve plates, in the walls of the larger cells, which are the sieve tubes. The smaller cells, called companion cells, are characterized by a dense cytoplasmic content, small vacuoles and prominent nucleus. They are connected with the sieve tubes by numerous small thin places, called simple pits, in their walls. Phloem cells are channels in which food material passes through the stem. In addition to these various cells, the phloem contains parenchyma cells which are used for storage of materials and in some plants long thick-walled fibers, called phloem fibers.

Parenchyma and fibers also occur in the xylem elements. Between the xylem and phloem elements there is a band of cells which remain unmodified and become an important tissue in many stems. This is the **cambium**, which by its divisions gives rise to the secondary tissues which compose the bulk of the stems of woody plants. These secondary tissues are the secondary xylem and phloem, and differ only slightly from the primary xylem and phloem, being unlike mainly in their origin.

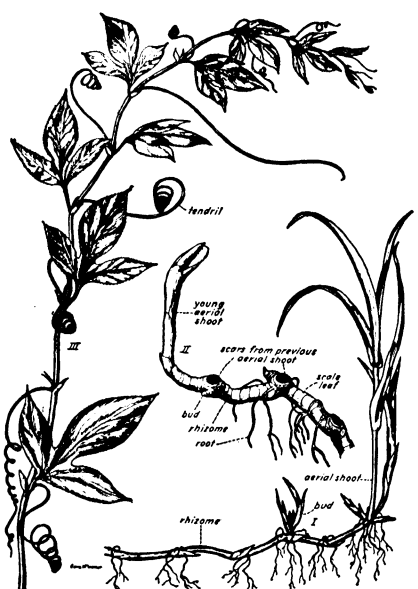
In the center of the stem is the pith, composed of large, thin-walled cells arranged in irregular fashion. They function principally as places of storage of food.

In nearly all monocotyledons, no cambium is formed, therefore the monocot stem is composed entirely of primary tissues. The arrangement of these tissues is vastly different from that of the stems of dicotyledons. The vascular tissues occur in the form of separate small bundles which are scattered throughout the stem. It is impossible to distinguish any limit separating cortex from pericycle and pith. In many monocots the central portion of the stem is entirely free from bundles and recognized as a pith. Often the pith breaks up, forming a hollow stem.

All **Gymnosperms** have woody stems. The development and structure of these is quite similar to that of dicotyledons, but, except in a few uncommon species, the xylem is composed entirely of tracheids and no companion cells are formed in the phloem.

In most plants the function of the stem is to display the leaves and reproductive organs in the most favorable position and to carry materials from one part of the plant to another. In many plants the stem is a highly specialized structure with different functions. Often these specialized stems take over the function of one of the other organs of the plant.

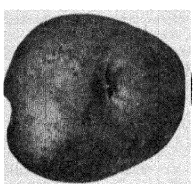
The outer tissues of the stems of nearly all plants are green. Therefore some **photosynthesis** takes place in these tissues. There are many plants in which the stem is the principal, if not the only, place where photosynthesis occurs. In many cases, as in some of the **Spurges** and **cacti**, the appearance of the stem differs very little from that of any other plant; but leaves are very much reduced or entirely lacking, all photosynthesis occurring in the stem. In other species of cactus, such as the Prickly Pear and the widely cultivated crab or Christmas cactus, the stem is very much flattened, but still distinctly recognizable as a stem. In some plants, however, the modification has



Types of modified stems. I, rhizome of quack grass (*Agropyron repens*); II, rhizome of Solomon's seal (*Polygonatum commutatum*); III, stem of passion flower (*Passiflora incarnata*) with tendrils which are modified stems.

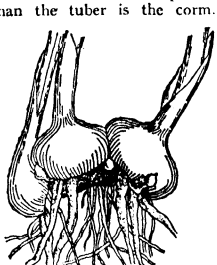
become extreme. The ultimate branches of the stem have become very much flattened and have a shape which gives them every appearance of a leaf. Only their position in the axil of a tiny scale, the real leaf, betrays their true nature. The dainty Smilax, or *Myrsiphyllum asparagoides*, of the florist, has branches of this kind. So also does the Butcher's Broom, a marsh plant of Europe, which is widely cultivated and appears during the Christmas season, stained a brilliant scarlet. The inconspicuous greenish-white flowers of this plant occur in the center of that part which is commonly assumed to be a leaf. The tiny needle-like "leaves" of the garden asparagus are really branches.

In a few plants the stem becomes a very important reproductive part. Runners, long slender branches from the base of the stem, grow out horizontally over the surface of the ground, and root at their tip. There a new plant is formed. With death and disintegration of the connecting stem, the young plant becomes separate from its parent. This is a form of vegetative reproduction. A stolon differs very little from a runner; it is a prostrate branch which regularly roots at its nodes, and sends up new plants not only at its tip but also from the nodes. Rootstocks or **rhizomes** are spreading underground branches which produce **adventitious roots** at their nodes and often spread widely.



Potato tuber with scale-like leaf at "eye."

Many rhizomes become very fleshy because of an accumulation in them of food materials. Their principal function then is storage. Storage occurs in the stems of many different plants. If only a portion of the rhizome becomes enlarged, it is called a tuber. The common white potato is a very familiar tuber, which is formed at the tip of a slender rhizome. The "eyes" of the potato are really the nodes of the stem; from them buds will give rise to branches when the potato grows. More modified than the tuber is the corm. This is a short thick rootstock. Often it is much broader than it is long. Buds are formed on the upper surface of the corm. Each of these buds grows into a new plant, exhausting the substance of the old corm and forming a new one at its base. Corms known to all are those of *gladiolus* and *crocus*, which are usually incorrectly called bulbs. A bulb is a fleshy bud, composed of a short thick stem and many fleshy leaves or leaf bases. Onions form true bulbs, as do tulips, hyacinths and many lilies.



Corms of *Gladiolus* consisting chiefly of fleshy stems.

The materials stored in the stems so far considered are mainly reserve food substance. Other stems become swollen with stored water. Many cacti and Euphorbias have stems of this sort.

Thorns are stems or branches which have become stiff and pointed and serve to protect the plant. Tendrils are organs which support a plant as it grows up through other plants. Not all tendrils are stems. Some, like those of the grape, are definitely so; others are leaves or parts of leaves. Usually plants which have tendrils have slender stems which lack sufficient strength to support themselves. Plants of this type are vines. There are several types of vines, or climbing plants. One of them supports itself by twining tightly around any available support. The direction of twining is very constant for any species, some invariably turning in a clockwise direction and others counterclockwise.

Other climbers support themselves by **adventitious roots** which form in abundance and cling tightly to any support. Other climbing plants are supported solely by the presence of many spines or prickles, often hooked, or pointed backwards so that the stem does not easily slide off any object on which it rests. Climbing roses illustrate this type of climber. But many tropical vines are much better illustrations. Often these grow to great lengths, hanging in long festoons from the tops of tall trees, or growing in tangled masses over low shrubby plants. In these tropical climbers, which are commonly called lianas, the stems often assume curious flattened or fluted or irregular shapes. In diameter they vary from a fraction of an inch to many inches; they may attain a length of 400 or 500 feet. They are one of the most characteristic and annoying features of the tropical rainforest. (See also **Cambium, Wood.**) (R.M.W.)

STENOPODIUM. The **biramous appendage** of **crustaceans** in its slender form. (A.W.L.)

STEPHANITE. The mineral stephanite, **silver, antimony sulfide,** $5Ag_2S.Sb_2S_3$ is found in short prismatic or tabular **orthorhombic** crystals. It is a brittle mineral; hardness, 2.–2.5; specific gravity, 6.2–6.3; metallic luster; color, black; **streak,** black; opaque.

Stephanite occurs associated with other silver minerals and is believed to be primary in character. Foreign localities are in Czechoslovakia, Saxony, the Harz Mountains, Sardinia; Cornwall, England; Chile and Mexico. In the United States it is found in Nevada, where it is an important silver ore. It was named for the Archduke Stephan of Austria, mining director of that country at the time this mineral was first described. (E.S.C.S.)

STEPTOE. A hill or mountain whose top projects above a lava flow which has surrounded its lower flanks. (R.M.F.)

STEREOISOMERISM. Isomerism and Stereoisomerism.

STEREOPTICON. Projection Optical.

STEREOTROPISM. Movement in plants.

STERILITY. Inability to reproduce; barrenness. Sterility may be the fault of husband or wife or both. Sterility in either sex may be due to: (1) anatomical defects, congenital or acquired; (2) disease or the results of disease or injury in the reproductive organs, especially by venereal disease; (3) glandular disturbances especially those concerning the **thyroid, pituitary, adrenal, ovarian** and **testicular** glands; (4) poor health, due either to chronic disease or deficiency in diet.

In the hands of capable doctors, pregnancy will result in twenty to forty percent of the cases, and involves first, finding the cause and proper treatment along the following lines: that is, treatment of infection, correcting of any systemic disorder, glandular and certain operative measures. (R.S.M.)

STERILIZATION. Any procedure by which an individual is made incapable of reproduction. Sterilization of the feeble minded, insane, or criminal insane, or for therapeutic measures is a simple procedure. No mutilating operations are done and there is no loss of sex feeling, no change in appearance, behavior, or sensation. In the male a small incision is made in the upper part of the scrotum and a small piece of the vas is removed, thereby preventing the passage of sperm cells to the outside. In the female, through a small incision into the **peritoneal** cavity small pieces of both fallopian tubes are removed. (R.S.M.)

STERLET. Pisces, Chondrostei. A **sturgeon,** *Acipenser ruthenus,* of moderate size found in the Black and Caspian seas and in rivers of Siberia and Europe. As a food fish it is one of the most desirable members of the group, both for its flesh and for its caviar. (A.W.L.)

STERN-GERLACH EXPERIMENT. An experimental test by O. Stern and W. Gerlach (Germany, 1924) of the magnetic moment of **atoms.** A stream of metallic atoms, issuing from a vaporizing furnace through a narrow slit, entered a strong magnetic field. The magnetic intensity was perpendicular to the atom stream, and had a strong gradient in its own direction. If magnetic moments of atoms are due to revolving electrons, the atoms should, according to classical theory, begin to precess at all angles about the field direction, and the atomic beam should simply broaden into a band. According to the quantum theory, they should precess at certain angles only, and the original stream should be divided into several distinct streams. Actually it proved to be divided into two, oppositely deflected streams. From this the experimenters concluded that the atoms tested have but one "magneton" each. (See **Magnetism** and **Precession.**) (L.D.W.)

STERNITE. Skeletal system.

STERNUM. The breast bone. Skeletal system. (A.W.L.)

STEROLS. Alcohols and Ethers.

STETHOSCOPE. An instrument used to transmit and to amplify various sounds produced by certain organs of the body. The stethoscope in its common form is composed of a cup shaped device and two pieces of rubber tubing each running from this to an ear piece that fits in either ear. This instrument is used particularly in listening to heart, lung, and **pleural, arterial, venous,** and **intestinal** sounds. (R.S.M.)

STIBIUM. Antimony.

STIBNITE. The mineral stibnite, **antimony sulfide,** Sb_2S_3, is found in radiated groups of acicular **orthorhombic** crystals or in other sorts of aggregates, as well as blades, also as columnar or granular masses. It shows a highly perfect pinacoidal cleavage; conchoidal fracture; hardness, 2.; specific gravity, 4.5–4.6; luster, metallic and very brilliant on cleavage faces or freshly fractured surfaces. Its color is a steely gray; the streak very similar in color, may be covered with a black, sometimes iridescent tarnish.

Stibnite is the most common antimony mineral known and is the chief ore of that metal. It is believed to be a primary ore mineral and occurs with other antimony minerals and **galena, sphalerite,** silver ores, etc. It is found in Germany, Rumania, Czechoslovakia, Italy, Borneo, Peru, Japan, China, Mexico; and in the United States in California and Nevada.

The name stibnite is derived from the Latin word for antimony, *stibium.* (E.S.C.S.)

STICK INSECT. Walking-stick.

STICKLEBACK. Pisces, Teleostei. Small marine and fresh-water fishes (**Pisces**) of the family Gasterosteidae, characterized by a series of strong spines along the back in front of the dorsal fin. (A.W.L.)

STIFFENER. Bridge, Monocoque.

STIGMA. 1. A secondary sexual mark of **insects.** In many species of **butterflies** it consists of a patch on the wing of the male bearing modified scales on a more or less modified area of the wing membrane. 2. Used by some entomologists in place of **spiracle.** 3. (In botany). The receptive part of the gynoecium or pistil of the **flower,** to which the pollen grain is carried in the act of **pollination.** In many flowers the surface of the stigma is sticky and so receives and holds the pollen grains more surely. (A.W.L., R.M.W.)

STILBITE (DESMINE). The mineral stilbite, $(Na_2Ca)O \cdot Al_2O_3 \cdot 6SiO_2 \cdot 6H_2O$, is a **zeolite,** the compound **monoclinic** crystals of which are usually grouped in approximately parallel positions, forming sheaf like aggregates, which have a soft pearly luster, whence the name stilbite from the Greek meaning luster. The less commonly used term desmine is likewise from the Greek, meaning a bundle. Stilbite has one perfect cleavage; uneven fracture; is brittle; hardness, 3.5–4; specific gravity, 2.–2.2; luster, vitreous to pearly; color, usually white but may be brownish, yellowish, red or pink. Its streak is white, and it is transparent to translucent. Like the other zeolites stilbite occurs in cavities in **basalts** and **traps,** rarely in **granites** and **gneisses.** Of the many foreign localities may be mentioned Trentino, Italy; the Harz Mountains; Valais, Switzerland; Arendal, Norway; the Ghats Mountains of India; and Mexico. The Triassic traps of New Jersey and Pennsylvania furnish specimens as do also rocks of the same age in Nova Scotia. (E.S.C.S.)

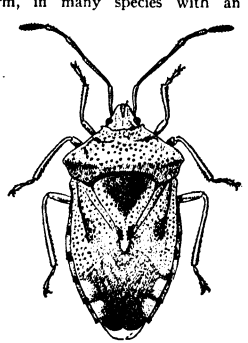
STILL-BIRTH. The birth of a dead **fetus.**

STILT. Aves, Charadriiformes. *Himantopus.* A bird (**Aves**) with unusually long legs, a long neck, and a long slender beak, slightly upcurved. Related to the avocets. In spite of their attentuated lines the stilts are beautiful and graceful birds. Their plumage is chiefly black or gray and white, but the beak and legs of some species are pink or red. There are only a few species but they are represented in all parts of the world. (A.W.L.)

STILT BUG. Insecta, Hemiptera. A **bug** with a slender body and very long slender antennae and legs. The few species make up the family Neididae. They are sluggish insects of no economic importance. (A.W.L.)

STIMULANT. Any agent or **drug** that increases the activity of an organ. Such drugs are **caffeine, strychnine, adrenalin, camphor, ammonia, digitalis** and its allies, etc. These drugs act principally on the nervous, respiratory or cardiac systems. Various remedial measures that are stimulating are cold air and water, and regulated exercises. (R.S.M.)

STINK BUG. Insecta, Hemiptera. A flattened **bug** of generally ovate form, in many species with an angular outline. Most species are moderately large, reaching a length of about one-half inch. The many species, constituting the family Pentatomidae, are also characterized by the fetid odor of the secretion discharged from glands opening on the lower surface of the body.



Stink bug.

One species, the harlequin cabbage bug or calico-back, is a troublesome pest. It is best controlled by clean cultivation of fields, hand picking of bugs and their eggs, and the use of trap crops, planted early to attract the insects.

Some members of the group eat other insects and are probably beneficial in destroying pests, but un-

fortunately even the harmless species may contaminate berries with their unpleasant odors (A W L)

STINKSTEIN. Limestone.

STIPES. Maxilla.

STIPULES. Leaf.

STOAT. Mammalia, Carnivora A slender short-legged animal, *Mustela erminea,* related to the weasels and sometimes called the greater weasel It has been regarded by some zoologists as common to both hemispheres, living in northern latitudes, but authorities now consider the common North American weasel to be a distinct, although closely related, species Except in the extreme southern parts of their range, both of these animals turn white in the winter, retaining a black tip on the tail In this stage they are often called ermine (A W L.)

STOCK. In geology, a mass of **igneous rock** not of great areal extent, generally with a circular or elliptical cross section, which has been intruded vertically into previously existing formations

In some cases stocks may represent the lower portions of volcanic conduits (R M F)

STOKER. The stoker is a machine for feeding **coal** into a **furnace,** and supporting it there during the period of **combustion.** It may also perform other functions, such as supply of air, control of combustion, distillation of the volatile matter Stoker development has reached the point where stokers can offer substantial fuel savings over hand firing even under small and medium-sized boilers Much depends upon suiting the stoker to the coal that is to be fired on it The character of the volatile matter is studied and arrangement made for burning all of it through the introduction of over-fire air when necessary. The ash characteristics also influence stoker selection. The stoker ought to be responsive to variable load Control of combustion necessitates a variable drive of the stoker. Formerly all drive was by steam engines exhausting to feed-water heaters Development of more convenient and compact methods of driving stokers, and the diminishing significance of exhaust steam to the heat balance has pushed engine drive into the background and brought electric and turbine drive to the fore

Present-day stokers fall into three classes overfeed, underfeed, and traveling, or chain grate Approximate continuous capacities of these different types in terms of their surface over which combustion is spread are

Overfeed, 15-25 pounds per square foot per hour
Natural draft chain grate, 35 pounds per square foot per hour
Single retort underfeed stoker, 40 pounds per square foot per hour
Forced draft chain grate stoker, 50-60 pounds per square foot per hour
Multiple retort underfeed stoker, 50-60 pounds per square foot per hour

Stokers most in use nowadays are the chain grate (Figure 1) and underfeed types A chain grate stoker is a broad endless belt composed of short compact links This belt passes over two sprockets so that it makes a flat upper surface upon which coal may rest. One of the sprockets is power driven, so that there is a very slow motion of the grate in a direction which will drag coal from the bottom of the hopper, carry it into the furnace, and finally dump the ash into a hopper The rate of combustion is varied by simultaneous control of air pressure, velocity of the grates, and thickness of the fuel bed Heat from the incandescent zone is radiated to the ignition **arch** and reflected back to the green fuel bed at its entry to the furnace The volatile matter that is driven off is mixed with air admitted through and over the green fuel bed, and, being confined to the arch, is passed through the hottest zone of the furnace The carbon left behind then reaches the ignition point and burns, giving up heat, part of which is radiated back to the incoming green coal There is no means of breaking up a crust formed by a coal which will soften and fuse together, but the chain grate stoker will burn coals that would be too fine or easily packed for use in an underfeed stoker, as well as coals that clinker badly

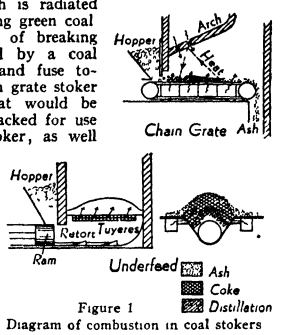


Figure 1
Diagram of combustion in coal stokers

The natural draft chain grate stoker is adaptable to small or medium-sized boilers, operated at fairly steady loads This type of stoker is being used less and less, more favor being given to the single retort underfeed stoker At their best point they will use from 70% to 80% excess air Coal of fine sizes sifts through between the grate bars and causes losses unless a system is installed for its recovery. However, they have burned lignite in a very successful manner The chain grate type is applicable to burning fine coals of high ash content and clinkering characteristics A large floor area is required This stoker is hard to bank and is very sensitive to furnace design

The efficient combustion of certain classes of coal requires that the coal be gasified under conditions which will prevent the coal from fusing into an air-tight crust A coal that has a tendency to fuse together into a solid cake of coke must be burned in an underfeed stoker, in which the fresh coal is fed to the fire zone by being pushed up from underneath This type of feed creates a heaving action at the fire line, which tends to prevent the formation of a crust An under feed stoker consists of a retort, usually trough-shaped in industrial stokers, but resembling a pot in the domestic type The coal is forced into this retort by an endless screw or ram in such a way as to accomplish the feed action outlined above Air is supplied at the sides of the retort under pressure sufficient to enable it to penetrate the zone of incandescence. Heat from an incandescent zone of burning carbon is radiated and conducted downwards into the green fuel which is being crowded up to the ignition line from below The volatile matter which is given off is mixed with air supplied from tuyeres, also below the ignition line The inflammable mixture then passes directly through the hottest zone of the furnace—the incandescent fuel bed—insuring that all parts of it reach the ignition point The ever-upward motion of the fuel keeps the bed well broken up, allowing free passage of gases and oxygen to all parts of it

The single retort underfeed stoker is well adapted to a wide range of coals and to all sizes up to 1000 boiler horsepower As it sets low and requires no ash basement, it is easily applied to almost any existing boiler For these reasons, and because of its inherent smokelessness, it is especially adaptable to industrial service Good operation is secured in small as well as large sizes with everyday boiler efficiencies ranging from 65% to 70%. The most efficient types have auxiliary moving grates to break up the fuel bed that overflows the retort The size of a retort is limited by the ability of the air to penetrate from the tuyeres to the zone of burning Large underfeed stokers can not be built with single large retorts, for this reason; rather, they

must be built with a number of parallel retorts. However, the multiple retort underfeed stoker does not resemble a number of single retort stokers placed side by side. Instead, the retorts are sloped downwards slightly, and the coal emerges from the retort on to an overfeed section, where the residual carbon is burned.

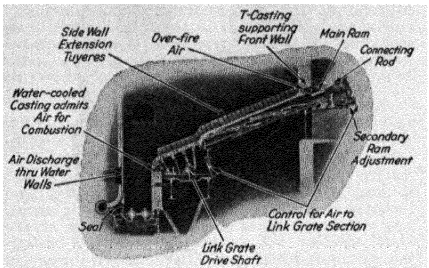


Figure 2. Side view multiple retort underfeed stoker.

The multiple retort underfeed and forced draft chain grate types are essentially large, high capacity boiler types having large initial cost and installation expense. A basement ashpit is required for both types. Skilled operators are needed, especially for the chain grate type, but they can readily obtain from 70% to 80% boiler efficiency, using about 50% excess air. From the foregoing remarks, it is evident that these stokers are central station types. The forced draft chain grate stoker is conceded to be the only type for anthracite or coke breeze. The ignition arches required increase the cost of the furnace. The complication of air zoning the plenum chamber must be accepted in order to control air in an efficient manner. Its flexibility and banking characteristics are better than the natural draft type but not so good as the underfeed.

Considerable similarity is apparent in multiple retort underfeed stokers as far as the underfeed portion is concerned, but examination of the overfeed portions discloses major differences. Ash is handled by dump plates or by clinker grinders. (F.T.M.)

STOKES' LAW. Luminescence; Viscosity.

STOKES' THEOREM. Stokes' theorem is an important mathematical result used in mathematical physics particularly. It transforms a **line integral** in space into a **surface integral** or vice versa. It was given by the great English mathematician and physicist Sir George Gabriel Stokes (1819–1903).

Let P, Q, R be **functions** of x, y, z, which, together with their first **partial derivatives**, are **continuous** in a region V of space, and let S be a **surface** lying in V and bounded by the curve C; let α, β, γ be the **direction angles** of the normal to S. Then Stokes' theorem is:

$$\int_C (P\,dx + Q\,dy + R\,dz) = \iint_S \left\{\left(\frac{\partial R}{\partial y} - \frac{\partial Q}{\partial z}\right)\cos\alpha + \left(\frac{\partial P}{\partial z} - \frac{\partial R}{\partial x}\right)\cos\beta + \left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right)\cos\gamma\right\} dS.$$

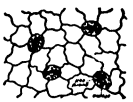
In **vector** language and vector notation, this theorem may be stated: The **surface integral** of the **curl** of a **vector function** $\mathbf{F}$ of position taken over any surface region S is equal to the **line integral** of $\mathbf{F}$ taken around the boundary C of the region:

$$\iint_S (\nabla \times \mathbf{F}) \cdot \hat{\mathbf{n}}\, dS = \int_C \mathbf{F} \cdot d\mathbf{r}.$$

(L.L.S.)

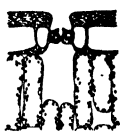
STOLON. In botany a stolon is a branch which grows out horizontally from the base of the **stem,** takes root and gives rise to a new plant at the **nodes** or at the tip.

In zoology a shoot growing from the base of an animal or a **colony,** from which other individuals arise by budding. (R.M.W., A.W.L.)



A portion of the lower epidermis of a geranium leaf.

STOMA. A stoma is a minute pore through the epidermis of the leaves and other aerial parts of plants. Typically each stoma is formed by a pair of cells called guard cells, having an elongated shape and with characteristically thickened walls. Frequently the entire apparatus, the two guard cells and the opening between them, is called the stoma.



Sunken stoma of carnation.

While the stomatal apparatus is rather variable in form, it is sufficiently general to permit accurate description of the usual form. The opening is very minute, ranging from forms 10 by 3 microns to those 5.5 by 1 micron, with an average area less than 100 square microns. With the guard cells, the stomatal apparatus is frequently oval or even circular when viewed from the surface; in other plants, notably in grasses, it is elongated and somewhat rectangular. The guard cells contain a considerable amount of **cytoplasm** surrounding a central **vacuole.** In the cytoplasm there is a **nucleus** and many **chloroplastids.** The guard cells are the only cells of the epidermis which ordinarily contain chloroplastids. The wall of the guard cells is equally distinctive. Sections cut transverse to the long axis of the guard cell show that the upper and lower walls of the cell are greatly thickened, often with conspicuous flanges extending outward over the edge of the opening. The wall against the adjoining epidermal cell is thin and elastic. The wall on the side of the pore is also thin, at least in part. In many plants these guard cells are much smaller than the surrounding epidermal cells, so that each stoma is located at the bottom of a minute pit. Often the epidermal cells around it project over the stoma. In many plants all the stomata are located in grooves in the leaf.

The function of the stoma is to permit free exchange of gases between the interior of the leaf and the external atmosphere, and to control the rate of this exchange, at least in part. The most important of these gases are water vapor, carbon dioxide and oxygen.

Two theories have been advanced to explain the cause of stomatal movement. The older theory is based on the presence in the guard cells of starch, formed by **photosynthesis.** Activation by sunlight causes some of this starch to change to sugar, which causes an increase in the osmotic (See **Osmosis**) tension of the cell. As a consequence water is drawn in from the adjoining epidermal cells where the osmotic pressure is lower. This increased water content causes the guard cell to swell. As a result, since the thick upper and lower walls are rather rigid, and the wall next the epidermal cell thin, the latter gives way, causing the wall next the stomatal aperture to pull back, opening the pore. Later the sugar may be converted to starch, the osmotic tension decreasing so that the movement of water into the cell then ceases, and the guard cells close together. According to the second theory, more recently advanced, it is the presence of certain **colloidal** substances in the guard cell which cause these changes. Respiration goes on continually in the guard cells, as in all living cells; as a result of respiration, carbon dioxide is formed in the cell. In darkness or insufficient light this carbon dioxide unites with the water present in the cell to form carbonic acid. In daylight the carbon dioxide is used up by the photosynthesis going on in the chloroplastids in the guard cells. Because of this the acidity of the cell

decreases, until its contents become neutral or slightly alkaline. An alkaline environment causes the colloids in the cell to take up more water and swell. This water is drawn from the adjoining epidermal cells. The result is that the pore between the two guard cells enlarges, due to the pulling apart of the later.

The stomata play an important part in **transpiration.** Water brought into the **mesophyll** cells of the **leaf** is secreted from them, and evaporates into the intercellular spaces of the mesophyll. This water vapor then diffuses outward through the stomata, unless it happens that the atmosphere outside is already saturated with water.

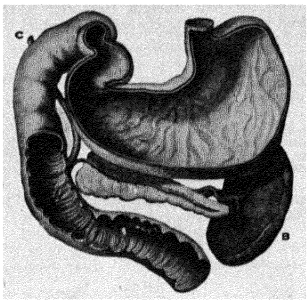
In spite of their minute size, stomata are of vast importance to the plant. They are present in such large numbers that their combined area is about one-tenth that of the surface containing them. A square inch of surface of the cucumber leaf contains over 425,000 stomata. In many plants the stomata are found only in the lower epidermis; in others, especially those having more or less erect leaves, the stomata are found on both surfaces. In plants like the **water lilies,** with leaves floating on the surface of the water, stomata are on the upper surface only.

When the stomata are open, a considerable quantity of water passes outward from the leaf and is lost. This loss of water from the leaf is called transpiration, and is a very important factor in the movement of **sap** through the plant. The quantity of water passing from a leaf is very great, a single mature corn plant losing two to three quarts per day. In terms of a normally planted field this means a yearly loss of water equivalent to a ten-inch rainfall. The loss is principally controlled by the action of the guard cells; if too much water is lost, the leaves may roll up tightly, as happens in corn, or fold together, or wilt and droop. If the loss still continues, recovery may be prevented and the plant dies.

In spite of this great loss of water from the soil through the plant, the presence of an adequate plant cover serves materially to conserve the soil water. First because direct evaporation from the surface of the soil is largely prevented; second, because the accumulation of organic matter in the soil as a result of the plant covering increases the water-holding capacity of the soil; and again because the plants effectively prevent rapid running off of any rain water which falls on the ground. A good growth of vegetation, especially over land of little economic value, is therefore of very great value to the land. (R.M.W.)

STOMACH. The pouch-like structure, part of the **digestive system,** which serves as the temporary collecting place for the food as it leaves the **oesophagus.** It lies high up on the left side of the abdomen just beneath the **diaphragm.** It lies obliquely extending from the extreme left side beneath the ribs across the midline of the abdomen about three inches above the navel. The size of the stomach varies as to the contraction of its muscular walls, the amount of food that it contains and the pressure on its outside walls, due to the adjacent small and large intestine. The entrance to the stomach from the oesophagus is known as the cardiac orifice and the exit of the stomach is known as the **pylorus** or pyloric orifice. Both of these openings are closed by circular muscle fibers known as **sphincters,** except when food is passing through them. The walls of the stomach are made up of oblique longitudinal and circular smooth muscle fibers not under voluntary control. This arrangement in its walls allows for progressive wave-like movement of the food toward the pyloric opening, and also for a thorough mixing of the food. The glands of the stomach secrete mucus, **hydrochloric acid** and a substance that is converted into **pepsin** when it mixes with the acid.

Functions of the stomach are to mix the food with the gastric juices, and to pass it into the **duodenum** in small portions at intervals. The movements of the stomach also serve to reduce the size of the swallowed food particles. Very little actual **digestion** takes place in the stomach. **Protein** digestion begins in the stomach but is incomplete. In general the food is prepared for



View of stomach and duodenum with part of anterior portion removed. *A,* pancreas; *B,* spleen; *C,* common bile duct.

the digestive action in the small intestine. The acid of the stomach has further a definite germicidal action on the swallowed food.

Since the secretion and movement of the stomach is controlled by the involuntary or sympathetic nervous system, anger, fear or worry interfere with or can completely stop the function of the stomach. Exercise taken too soon after meals has similar effect. This produces stasis of the food within the stomach with resultant fermentation and gas formation, thus producing symptoms known as dyspepsia or indigestion.

The common disorders affecting the stomach are (1) hyperacidity, usually produced by worry, strain or overwork, (2) **cancer** formation, (3) **ulcer** formation, (4) hypoacidity, lack of or absence of hydrochloric acid. (R.S.M.)

STOMATOPODA. Synonym of Hoplocarida. **Crustacea.** (A.W.L.)

STOMODAEUM. A tube lined with tissue derived from the surface of the body, associated with the alimentary tract (**digestive system**). The tube forms as a depression in the outer surface and deepens until it meets the lining of the enteric cavity and breaks through into it. The gullet of sea anemones is one form of stomodaeum. In animals with a tubular alimentary tract it forms the anterior part of the tube, consisting of the oral cavity in **vertebrates** and of the entire fore gut of **insects.** This region of the insect alimentary tract includes the oral cavity, **pharynx, oesophagus, crop,** and **gizzard.** (A.W.L.)

STONE CANAL. Water vascular system.

STONECHAT. Aves, Passeriformes. A bird (**Aves**), *Saxicola torquata,* of central and northern Europe. The male has a black head and back, a white collar, and reddish under parts; the female is more brownish. (A.W.L.)

STONE FLY. Plecoptera.

STONE ROLLER. Pisces, Teleostei. A bottom-feeding fish, *Campostoma anomalum,* of moderate size found in small streams from Wyoming to New York and south to the Gulf. It lives on plant matter. (A.W.L.)

STORAGE BATTERY. Accumulator; and Battery.

STORK. Aves, Ciconiiformes. Birds of the Old World and South America. They are large, attaining a length of about four feet, and have long legs and a long straight beak. The common white stork of Europe, *Ciconia alba,*

which nests on the tops of chimneys is the best-known species Others occur in Europe, Asia, Africa, Australia and South America Among the last are some of the giant storks, also called **jabirus**. The **adjutant** or marabou storks of Africa and India are peculiarly untidy looking birds, due to the almost bare skin of the head and neck with its few straggling feathers

The name stork is confused to a slight extent with that of the related herons, as in the case of the whale-headed or shoe-billed species, of the White Nile This species, called both heron and stork, has an enormous and powerful beak, both broad and deep and provided with a strong hook at the tip. (A W L)

STRABISMUS (SQUINT OR CROSS-EYE). The inability to fixate the sight of both eyes on a given point at the same time, one eye or the other alone sees the object at any given moment, but never both at the same time Strabismus can be corrected by non-operative measures such as glasses and training These measures, however, are only useful early, as after the sixth year operation is generally necessary The operative treatment is very successful and is done by the shortening and lengthening of certain eye muscles (R S M)

STRAIGHT LINE, IN A PLANE. The equation of any straight line is of the first degree, i e, is a **linear equation**, in the **rectangular coordinates** x and y

The **locus** of any linear equation (first degree equation) in rectangular coordinates x and y is a straight line

A straight line parallel to the Y-axis has an equation of the form $x = a$ where a is the X-intercept, a line parallel to the X-axis has an equation of the form $y = b$, where b is the Y-intercept

The fundamental type forms of the equation of a straight line in rectangular coordinates are the following

The equation of a line with **slope** m and Y-intercept b is

$$y = mx + b \quad \text{(Slope-intercept form)}.$$

The equation of a line with slope m and passing through the point (x_1, y_1) is

$$y - y_1 = m(x - x_1) \quad \text{(Point-slope form)}$$

The equation of a line passing through the two points (x_1, y_1) and (x_2, y_2) is

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1} \quad \text{(Two-point form)}$$

The two-point form may also be written in the determinant form

$$\begin{vmatrix} x & y & 1 \\ x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \end{vmatrix} = 0$$

The equation of the straight line with intercepts a and b is

$$\frac{x}{a} + \frac{y}{b} = 1 \quad \text{(Intercept form)}$$

The equation of the line whose normal (perpendicular) from the origin makes an angle ω with the X-axis and is of length p is

$$x \cos \omega + y \sin \omega - p = 0 \quad \text{(Normal form)}$$

To reduce an equation $ax + by + c = 0$ of a line to the normal form, divide all the terms of the given equation by $\sqrt{a^2 + b^2}$

In **polar coordinates**, the equation of a line may be written

$$r \cos (\theta - \omega) = p,$$

where p is the length of the perpendicular to the line from the origin and ω is the angle which this perpendicular makes with the X-axis.

Special cases are If $\omega = 0$, the line is perpendicular to the polar axis and the equation becomes $r \cos \theta = p$ If $\omega = \frac{\pi}{2}$, the line is parallel to the polar axis and the equation is $r \sin \theta = p$

A straight line through the origin (pole) in polar coordinates has the equation $\theta = \alpha$, where α is its inclination angle

The condition that the three lines whose equations in rectangular coordinates are $a_1x + b_1y + c_1 = 0$, $a_2x + b_2y + c_2 = 0$, $a_3x + b_3y + c_3 = 0$ shall intersect in a common point is

$$\begin{vmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{vmatrix} = 0$$

The angle between two lines whose slopes are m_1 and m_2 is given by the formula

$$\tan \theta = \frac{m_1 - m_2}{1 + m_1 m_2}$$

The perpendicular distance from a line whose equation is in the normal form $x \cos \omega + y \sin \omega - p = 0$ to the point (x_1, y_1) is given by the formula

$$d = x_1 \cos \omega + y_1 \sin \omega - p$$

The perpendicular distance from the line whose equation is $ax + by + c = 0$ to the point (x_1, y_1) is given by

$$d = \frac{ax_1 + by_1 + c}{\pm \sqrt{a^2 + b^2}}.$$

If $L_1 = 0$ and $L_2 = 0$ are the equations of two given straight lines, then $L_1 + k L_2 = 0$ is the equation of the system of all straight lines passing through the intersection of the given lines, when k takes all positive and negative values (including 0)

If the equations of two given lines are $x \cos \omega_1 + y \sin \omega_1 - p_1 = 0$ and $x \cos \omega_2 + y \sin \omega_2 - p_2 = 0$, the equations of the bisectors of the angles between them are

$$x \cos \omega_1 + y \sin \omega_1 - p_1 = \pm (x \cos \omega_2 + y \sin \omega_2 - p_2)$$

(L L S)

STRAIGHT LINE, IN SPACE.

Consider any line l in space Through the origin O of a system of rectangular coordinate axes in space draw a line OP parallel to the given line l, and let the direction angles of the line OP be α, β, γ Then the **direction cosines** of the line are the cosines of these angles α, β, γ

If α, β, γ are the direction angles of any line, then

$$\cos^2 \alpha + \cos^2 \beta + \cos^2 \gamma = 1$$

If a, b, c are numbers proportional to the direction cosines of a line, then the direction cosines are given by

$$\cos \alpha = \frac{a}{\pm \sqrt{a^2 + b^2 + c^2}}, \cos \beta = \frac{b}{\pm \sqrt{a^2 + b^2 + c^2}},$$

$$\cos \gamma = \frac{c}{\pm \sqrt{a^2 + b^2 + c^2}}$$

If two lines have direction angles α, β, γ, and α', β', γ', then the angle θ between them is given by

$$\cos \theta = \cos \alpha \cos \alpha' + \cos \beta \cos \beta' + \cos \gamma \cos \gamma'$$

Two lines are parallel when their corresponding direction angles (and direction cosines) are equal

Two lines are perpendicular when the sum of the products of their corresponding direction cosines is 0

The locus of two simultaneous **linear equations**

$$A_1x + B_1y + C_1z + D_1 = 0, \quad A_2x + B_2y + C_2z + D_2 = 0$$

is a straight line, unless the coefficients of x, y, z are proportional

A parametric form of the equations of a straight line are

$$x = x_1 + t \cos \alpha, \quad y = y_1 + t \cos \beta, \quad z = z_1 + t \cos \gamma'$$

where P_1 is a point on the line, α, β, γ are direction angles of the line, and t is a variable parameter

The symmetric form of the equations of a straight line is:

$$\frac{x - x_1}{\cos \alpha} = \frac{y - y_1}{\cos \beta} = \frac{z - z_1}{\cos \gamma},$$

where (x_1, y_1, z_1) is a point on the line, and $\cos \alpha$, $\cos \beta$, $\cos \gamma$ are the direction cosines of the line. Another form of the symmetric equations is:

$$\frac{x - x_1}{a} = \frac{y - y_1}{b} = \frac{z - z_1}{c},$$

where a, b, c are numbers proportional to the direction cosines of the line.

The two-point form of the equations of a straight line is:

$$\frac{x - x_1}{x_2 - x_1} = \frac{y - y_1}{y_2 - y_1} = \frac{z - z_1}{z_2 - z_1}.$$

The plane $Ax + By + Cz + D = 0$ and the line

$$\frac{x - x_1}{a} = \frac{y - y_1}{b} = \frac{z - z_1}{c}$$

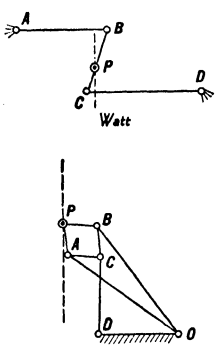
are perpendicular if

$$\frac{a}{A} = \frac{b}{B} = \frac{c}{C},$$

and are parallel if $aA + bB + cC = 0$.

A plane passing through a given line and perpendicular to one of the coordinate planes is called a projecting plane of the given line. (L.L.S.)

STRAIGHT LINE MOTION. If a **mechanism** has links designed so that a point on one of them moves in a straight line, that mechanism is one of a particular class known as the straight line mechanism if it is devoid of sliding links. The accompanying figure shows the Watt motion, an approximate straight line mechanism, and the Peaucellier, an exact straight line motion. The point P, which is located on the intermediate length BC in the Watt straight line mechanism, moves, within limits set by the mechanism, in what is nearly a straight line. For best results, this point P should be located by the ratio



Straight line mechanism.

$$\frac{AB}{CD} = \frac{PC}{PB}.$$

In the Peaucellier mechanism, line OD is fixed, links OA and OB are equal, link CD equals OD, and links PB, BC, CA, and AP are equal. Within the limits of its motion, this mechanism traces at point P a straight line perpendicular to the line OD. (F.T.M.)

STRAIN. Deformation and **Elasticity.**

STRAMONIUM. Potato Family.

STRANGLING FIG. Fig. Moraceae.

STRATIFICATION. Bedding.

STRATIFIED DRIFT. Glacial Deposits.

STRATIGRAPHIC THROW. Fault.

STRATIGRAPHY. The study of the origin and chronological successions of the observable rocks of the **lithosphere,** in which each lithologic unit is considered to be a formation. The term formation is usually confined to bedded or stratified rocks, including lava flows and volcanic ashes. The major principles involved in the correlation (dating) of formations are: 1—The law of superposition, or that the chronological sequence of any stratigraphic section depends upon the original order in which the formations were laid down; thus the fundamental basis of Stratigraphy is **Structural Geology.** 2—Index Fossils, or those species of fossils whose stratigraphic age are already known. 3—**Lithology.** Igneous rocks may be dated by the age of the sedimentary rocks which they intrude, or overlie; or by **radioactive minerals.** (R.M.F.)

STRATOSPHERE. Atmosphere.

STRATOSTAT. Balloon.

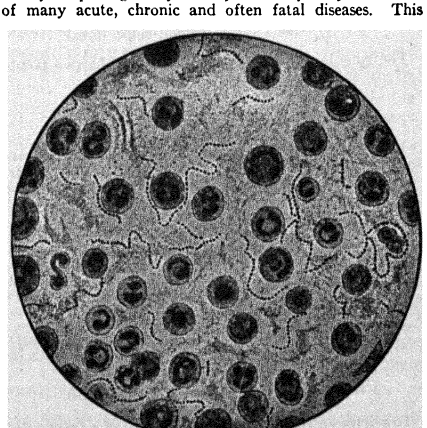
STRAWBERRY. Rose Family.

STREAK. This term, as used by the mineralogist, denotes the color of a powdered **mineral.** Usually determined by rubbing the mineral on a piece of unglazed porcelain, called a streak plate. All metals, and most minerals showing a metallic **luster,** show the same color whether in the solid or powdered form. The **silicates** and most of the minerals having a non-metallic luster, show different colors according to whether each is viewed in mass or as a powder. (R.M.F.)

STREAMLINE. Drag.

STREPSIPTERA. An order of peculiar parasitic insects called stylopids by entomologists. They live in the bodies of other insects, including **wasps** and **Homoptera,** and are not likely to be seen without special efforts to find them. The female remains in the host as a grublike individual but the male becomes a winged adult whose hind wings alone are developed for flight. The **metamorphosis** begins with an active **larval** form which seeks and enters a host and undergoes a gradual transformation through several molts leading to the ultimate grublike form. (A.W.L.)

STREPTOCOCCI. A large morphological group of organisms (See **Bacteria**) of many strains, differing widely in pathogenicity. They are frequently the cause of many acute, chronic and often fatal diseases. This



Streptococci from a case of empyema (Jakob). The *streptococci* appear in chain formation lying among pus cells. (From Todd and Sanford, *Clinical Diagnosis by Laboratory Methods,* W. B. Saunders Co.)

group of cocci are characterized by multiplying by division in one plane of space only. Therefore, in the stained preparation on a slide the cocci appear in chain formation.

Pasteur recognized the *Streptococcus* in 1878 in studies on sepsis following childbirth Koch saw the organisms in pus from wound infections about the same time

There is such variation and overlapping among the various strains of *Streptococci* that no true absolute classification is known Some may be classified according to cultural characteristics, toxic effect on red blood cells, chemical reactions, etc. Certain *Streptococci* do not require the presence of **oxygen** for growth and are therefore called anaerobic strains The *Streptococci* that produce toxins which destroy red blood cells are called the hemolytic variety Still other *Streptococci* produce a greenish discoloration or growth and are classed as *Streptococcus viridans* They are the cause of subacute bacterial **endocarditis**. Many sub-classifications are known

Many strains of this organism are not harmful to man The pathogenic strains produce an extra-cellular toxin or poison and many of the symptoms of *Streptococci* infection are caused by these toxins.

Localization of spread of this type of infection depends on the virulence of the particular strain, the ability to produce toxins, and the resistance of the individual

Many superficial infections of the skin are caused by this organism Many of the infections of wounds are due to it **Osteomyelitis**, ear, throat, sinus infections, **empyema**, **peritonitis**, are commonly of *Streptococcus* origin It is often encountered as a secondary invader especially in the **pneumonias**, and complicating diseases such as **measles**, **influenza** and the common cold This form of pneumonia is particularly dangerous **Meningitis** due to this organism is often fatal **Erysipelas** and **scarlet fever** are caused by another closely related strain Tendon sheath infections, puerperal sepsis and the majority of **septicemias**, as well as many other infections, are usually caused by it

There are certain allergic diseases, certain forms of **arthritis**, and acute **rheumatic fever**, which are believed to be due to or at least related to *Streptococci* As to the relationship between ultra-microscopic **viruses** and certain strains of *Streptococci* there is conflicting opinion

Antitoxin therapy does not prove generally successful except in scarlet fever and erysipelas

Recently a chemical, **sulfanilimide**, has been used in certain forms of streptococcus infection with particularly good results (R S M)

STREPTONEURA. Gasteropoda.

STRESS. A stress is the quantitative expression of a condition within an elastic material due to deformation, or strain, brought about by external forces, inequalities of temperature, or otherwise Its measure is always the ratio of a force to an area By some, stress is interpreted as a force distributed over an area, and the above ratio is called the "unit stress" Central, torsional and bending **loads** cause stress The total resisting force acting at any section of the body divided by the area of the section is the average stress, commonly expressed in points per square inch The unit stress is the resisting force on a small unit of area The component of a stress which acts at right angles to a surface is known as the normal stress If this stress is produced by a load whose **resultant** passes through the **center of gravity** of the area, it is called an axial or direct stress and is always uniformly distributed over the area A normal resisting force which causes the fibers to increase in length is a tensile stress, while one which shortens the fibers is a compressive stress The latter is often called a bearing stress The component of any stress which lies in the plane of the area is a shearing stress. (See **Elasticity.**)

Direct tensile or compressive stresses are known as primary stresses The bending stress, resulting from deflection, is called a secondary stress. The stresses developed in a column due to the lateral deflections are of a secondary nature. The rigidity of the riveted or welded joints of a truss which has deflected due to the axial **deformation** of its members causes bending stresses in the members which are classified as secondary stresses The resistance offered by a body to a combination of direct and bending loads is frequently called a combined stress. A normal stress which occurs at a point in a plane on which the shearing stress is zero is known as a principal stress If this normal stress is tensile it is often called a diagonal tension stress

The internal resisting force which arises in a restrained body due to temperature changes is a thermal stress The adhesive resistance which is developed in the concrete surrounding the steel reinforcing rods when a reinforced concrete member is subjected to load is known as **bond** stress Safe unit resisting forces which are used in design are called working stresses These are usually taken as a percentage of the **ultimate stress** of the material. (C W C)

STRESSED SKIN. This is a term used in aeronautical parlance to describe the construction wherein the covering of the **fuselage** or **wing** is used for structural purposes as well as aerodynamic It is carried out in metal covered **airplanes**, and is opposed to the unstressed skin construction of the fabric covered structure Stressed skin construction seems to be more suitable for large transport type airplanes, and in that field finds its greatest use The covering employed is usually duralumin, either smooth or corrugated By use of this construction a wing structure may be made so rigid and strong that a monoplane transport wing can be built without external bracing' This is the secret of the aerodynamic cleanness and high speed of the American twin-motored transport airplane See **Monocoque.** (F T M)

STRETCHER. Masonry.

STRIAE. The scratches on bedrock or on pebbles and boulders which are the result of glaciation These are called glacial striae to distinguish them from the striae which occur on the surfaces of fault planes (R M F)

STRIGIFORMES The owls An order of birds with the hooked beak and talons of birds of prey but differing from the hawks and related forms in having the eyes directed forward and in their nocturnal habits. (A.W L)

STRIKE. For the use of this term in geology, see **Anticline.**

STRIKE-FAULT. Fault.

STRINGER. Bridge.

STROBILATION. An asexual process of reproduction by terminal budding Some of the **annelid** worms reproduce in this manner and the proglottids of tapeworms (**Cestoda**) are formed by a similar process, leading to the application of the term strobila to the segmented portion of the body The production of jellyfishes by their scyphistoma larvae is another example (A W L)

STROBILUS. A strobilus is a group of **sporophylls** or **spore**-bearing leaves aggregated together to form a compact cone-like structure. (R M W)

STROKE (APOPLEXY OR CEREBRAL ACCIDENT). The onset of a stroke is sudden and may or may not be accompanied by paralysis or unconsciousness It is due to a circulatory accident in the brain, either by rupture of a blood vessel, **thrombosis** or clotting in a vessel, or an embolus (clot) lodging in one of the vessels of the bram (See **Apoplexy**) (R S.M)

STROMATOLITH. A term proposed by Foye, in 1916, for banded **gneisses** composed of alternate layers of igneous and metamorphic (**schistose**) rocks. Compare with **lit-par-lit.** (R M F)

STRONTIANITE. The mineral strontianite is **strontium carbonate**, $SrCO_3$, usually occurring in whitish yellow or whitish green masses of radiated acicular crystals, or in fibrous or granular form When distinctly crystallized it is obviously **orthorhombic**, but such crystals are rare It has a nearly perfect prismatic **cleavage;** uneven fracture, brittle, hardness, 3–3 5, specific gravity, 3 68–3 72, luster, vitreous, color, as above, also green, gray and colorless, streak, white, transparent to translucent Strontianite occurs in veins chiefly in limestones, occasionally in the crystalline rocks, and usually associated with **calcite** and **celestite.** It is found in the metalliferous veins in the Harz Mountains and Saxony It is commercially important in Westphalia where it is mined for use in the beet sugar industry In the United States, crystalline masses and geodes of strontianite are found in Schoharie County, New York, long a famous locality for this mineral (E S C S)

STRONTIUM. Symbol Sr Atomic number. 38 Atomic weight 87 63 Density 2 6. Melting point. 800° C Boiling point 1150° C Isotopes 86 (10%), 87 (6 6%), 88 (83 4%)

Strontium is a silver-white metal, soft as lead, malleable, ductile, oxidizes rapidly on exposure to air, burns when heated in air emitting a brilliant light and forming oxide and nitride, reacts with water yielding strontium hydroxide and **hydrogen** gas Discovered by Hope and by Klaproth in 1793, and isolated by Davy in 1808

Strontium occurs chiefly as sulfate (**celestite,** $SrSO_4$) and carbonate (**strontianite,** $SrCO_3$), although widely distributed in small concentration The commercially exploited deposits are mainly in England The sulfate or carbonate is transformed into chloride, and the electrolysis of the fused chloride yields strontium metal

Acetate Strontium acetate ($Sr(C_2H_3O_2)_2$), white crystals, soluble, by reaction of strontium carbonate or hydroxide and **acetic acid,** and then crystallizing

Carbide· Strontium carbide (SrC_2), black solid, by reaction of strontium oxide and **carbon** at electric furnace temperature, decomposes water yielding **acetylene** gas and strontium hydroxide

Carbonates Strontium carbonate ($SrCO_3$), white solid, insoluble, (1) by reaction of strontium salt solution and **sodium** carbonate or bicarbonate solution, (2) by reaction of strontium hydroxide solution and **carbon dioxide,** decomposes at 1200° C to form strontium oxide and carbon dioxide, is dissolved by excess carbon dioxide, forming strontium bicarbonate, strontium bicarbonate ($Sr(HCO_3)_2$), solution, by excess carbon dioxide and strontium hydroxide solution

Chloride Strontium chloride ($SrCl_2\ 6H_2O$), white crystals, soluble, by reaction of strontium carbonate or hydroxide and **hydrochloric acid,** and then crystallizing Anhydrous strontium chloride ($SrCl_2$) absorbs dry **ammonia** gas

Chromate: Strontium chromate ($SrCrO_4$), yellow precipitate, by reaction of strontium salt solution and **potassium** chromate solution.

Cyanamide· Strontium **cyanamide** ($SrCN_2$), mixed with cyanide ($Sr(CN)_2$), by heating strontium carbide at 1200° C with **nitrogen** gas

Hydride· Strontium hydride (SrH_2), white solid, by heating strontium metal or amalgam in **hydrogen** gas at 250° C, reactive with water, yielding strontium hydroxide and hydrogen gas

Hydroxide Strontium hydroxide ($Sr(OH)_2$), white solid, (1) by reaction of strontium oxide and water, (2) by precipitation of strontium salt solution with **sodium** hydroxide solution, yields hydrate ($Sr(OH)_2\ 8H_2O$) on crystallizing, decomposes upon heating at about 850° C. to form oxide (SrO) and water.

Nitrate: Strontium nitrate ($Sr(NO_3)_2$), white crystals, soluble, by reaction of strontium carbonate or hydroxide and **nitric acid,** and then crystallizing, used in pyrotechnics for the production of red light.

Oxides: Strontium oxide (SrO), white solid, melting point about 2400° C, reactive with water to form strontium hydroxide, strontium peroxide ($SrO_2\ 8H_2O$), white precipitate, by reaction of strontium salt solution and **hydrogen** or sodium peroxide yields anhydrous strontium peroxide (SrO_2) upon heating at 130° C in a current of dry air.

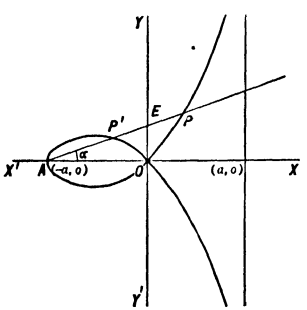
Oxalate Strontium oxalate (SrC_2O_4), white precipitate, by reaction of strontium salt solution and **ammonium** oxalate solution

Sulfate Strontium sulfate ($SrSO_4$), white precipitate by reaction of strontium salt solution and **sulfuric acid** or **sodium** sulfate solution, insoluble in acids, by heating with carbon yields strontium sulfide, by boiling with sodium carbonate solution yields strontium carbonate

Sulfides Strontium sulfide (SrS), grayish-white solid, by heating strontium sulfate and **carbon,** reactive with water to form strontium hydrosulfide solution, strontium hydrosulfide ($Sr(SH)_2$) solution, (1) by reaction of strontium sulfide and water, (2) by saturation of strontium hydroxide solution with **hydrogen sulfide,** strontium polysulfides are formed by boiling strontium hydrosulfide with **sulfur**

Volatile compounds of strontium, such as the chloride, color the bunsen flame a brilliant red (R K S)

STROPHOID. The strophoid is a plane curve which may be defined geometrically as follows Through a



Strophoid

fixed point $A(-a,o)$ on a set of rectangular axes draw any line AE and on this line locate points P and P' such that $oE = EP = EP'$ As AE rotates about A, points P and P' describe the strophoid

The **parametric equations** of the curve are

$$x = a \sin \alpha,\ y = a \tan \alpha(1 + \sin \alpha)$$

The equation in **rectangular coordinates** is

$$x^3 + xy^2 + ax^2 - ay^2 = 0 \qquad \text{(L L S)}$$

STRUCTURAL COLOR. Interference.

STRUCTURAL GEOLOGY. The study of the arrangement, or rearrangement, of the materials which form the **lithosphere** or outer rocky portion of the earth The general subject of structural geology is related to a number of other phases of geology, including **metamorphism** and the structure of the earth as a whole Ordinarily the term is confined to the study of the deformational or structural features of the observable portion of the lithosphere, including the making of geologic maps (geologic surveying) Structural geology is, therefore, intimately related to stratigraphic geology (**Stratigraphy**). While the primary object in a problem in structural geology is to determine the character as well as the space, time relationship of the deformations, the primary object in stratigraphy is to determine the order of geological events. From a prac-

tical point of view there is a close relation between structural and stratigraphic geology. In **petrology**, the structure of a rock refers to the arrangement of the mineral constituents. A number of different types of folds and faults are described under the subject of structural geology. During recent years the science of **geophysics** has supplied a number of methods and techniques which are highly essential to modern research in structural geology. (R.M.F.)

STRUCTURAL MOUNTAINS. Mountains.

STRUT. A strut is a structural member subjected to **compression.** Its conditions of loading and analysis are the same as for **column.** If there is any difference between strut and column, it rests on the following points. A column is usually thought of as being a fairly large compression member, vertical in position. Small columns are frequently called struts; also, struts are compression members which are incorporated into structures in many positions besides vertical. (F.T.M.)

STRUTHIDEA. Aves, Passeriformes. An Australian bird (**Aves**), probably related to the shrikes. Its colors are gray, black and brown and the beak is short and curved. (A.W.L.)

STRUTHIONIFORMES. The true **ostriches.** An order of birds with long legs and necks, and vestigial wings. They are native to Africa, ranging as far as Syria and Mesopotamia. (A.W.L.)

STRYCHNINE. *Strychnos Nux-vomica.* Loganiaceae. Strychnine is a product obtained from the seeds of a medium-sized tree native to India and the East Indies. This tree is often cultivated in the tropics. It has opposite simple leaves with a glossy surface, and small yellowish flowers. The fruit is an orange-colored berry. From the coats of the seeds is obtained the **alkaloid** strychnine, one of the most bitter substances known. Strychnine is used as a poison for rodents and other vermin, and, in medicine. In therapeutic doses it is a stimulant and tonic resulting in increased tone of the muscles, especially the muscles of the intestinal tract. It causes a definite stimulation to the higher centers of the brain, similar to the action of caffeine but less marked. It is often used for weak and debilitated subjects and during convalescence. It is a mistaken idea among some physicians and especially laymen that strychnine is a stimulant to the heart. Strychnine poisoning either through accident or with suicidal intent is not uncommon and the death following this type of poisoning is particularly violent and agonizing. Following a poisonous dose of strychnine the muscles twitch, muscular spasms appear and are soon followed by convulsions. During the poisoning the mind remains acutely clear and there is great apprehension on the part of the patient and great muscular pain during the convulsions. The convulsions increase in rapidity and degree and are initiated by any slight stimulus even such as turning on a light or any sudden sound. Death takes place from asphyxia due to continuous spasm of the respiratory muscles.

Immediate treatment for this poisoning is the giving of strong tea or any compound of **tannic acid** which forms with the strychnine in the stomach an insoluble compound. Once the strychnine is absorbed, treatment consists of intravenous injection of fluids in large amounts, and **ether** or **avertin** anesthesia to counteract the convulsions.

A related South American tree, *Strychnos toxifera,* is the source of curare poison, used by the native Indians as an arrow poison. To obtain the poison, the bark is scraped off and macerated in water. (R.M.W., R.S.M.)

STUPOR. Partial unconsciousness. In stupor the patient can be aroused as a rule by various stimulating measures. Stupor is seen in certain diseased conditions, but is more often associated with overdoses of drugs or alcohol. (R.S.M.)

STURGEON. Pisces, Chondrostei. Fishes (**Pisces**) of moderate to very large size, found in the oceans and fresh waters of the entire northern hemisphere. Their chief external characteristic is the series of bony plates arranged in rows along the back and sides, separated by wide spaces containing only small hard elements.

The sturgeons are excellent food fishes and are the source of caviar.

Sturgeon.

Among the true sturgeons the small **sterlet** (*Acipenser ruthenus*) and the giant hausen (*A. huso*) of Asiatic and European waters are noteworthy. The group also includes the shovel-beaked sturgeons (*Scaphirhynchus*) of the Mississippi River system and the rivers of central Asia, and the paddle fishes (*Polyodon*) of the same order are sometimes called toothed sturgeons. (A.W.L.)

STURM'S THEOREM. A method for locating the real **roots** of a **polynomial equation** is given by Sturm's theorem, which may be stated as follows:

Let $P(x) = 0$ be a polynomial equation with real coefficients and without multiple roots. Modify the usual process (Euclid's algorithm) for finding the **highest common factor** of $P(x)$ and its first **derivative** $P_1(x)$ by exhibiting each remainder as the negative of a polynomial P_i, thus:

$$P = q_1P_1 - P_2,\ P_1 = q_2P_2 - P_3,\ P_2 = q_3P_3 - P_4, \ldots,$$
$$P_{n-2} = q_{n-1}P_{n-1} - P_n,$$

where P_n is a constant $\neq 0$. If a and b are real numbers, with $a < b$, neither of which is a root of $P(x) = 0$, then the number of real roots of $P(x) = 0$ between a and b is equal to the excess of the number of variations of sign of

$$P(x),\ P_1(x),\ P_2(x), \ldots,\ P_{n-1}(x),\ P_n,$$

for $x = a$ over the number of variations of sign for $x = b$. Terms which vanish are to be dropped out before counting the variations of sign. (L.L.S.)

STY. Infection of a **sebaceous gland** of the lashes near the margin of the eyelids. They are frequently seen in run-down conditions and in certain errors of refraction of the **eye.** (R.S.M.)

STYLE. Flower.

STYLET. Small sharp structures used for piercing. The term applies to the calcareous **spines** of the **proboscis** of some **nemertine** worms and to the slender piercing organs of some insect mouths. The latter are modified **mandibles** and **maxillae.** (A.W.L.)

STYLOLITE. A columnar-like structure, at right angles, or highly inclined to the bedding planes of certain **limestones,** believed to be produced by differential vertical movements induced under great pressure. The term is derived from the Greek words meaning column and a stone. (E.S.C.S.)

STYLOMMATOPHORA. Gasteropoda.

STYLOPID. Strepsiptera.

SUBAERIAL FAN. Alluvial fan.

SUBCUTANEOUS. Situated under the skin, as a subcutaneous **tumor** or **abscess,** etc. (R.S.M.)

SUBCUTICULA. The tissue beneath the cuticula of flukes and tapeworms (Cestoda) In these parasitic forms of flatworms (Platyhelminthes) the body is covered with a resistant noncellular cuticula and the ectodermal cells have sunk into the parenchyma, so that the layer immediately within the cuticula is composed of a mixture of ectodermal and mesodermal cells and muscle fibers (A W L)

SUBERIN. This is a waxy substance which is found in the walls of cork cells in the outer tissues of stems, roots, and other parts of the plant It is very impervious to water and so prevents the loss of water from the living cells of the plant It is very similar to cutin, which forms in the walls of epidermal cells and makes them waterproof (R M W)

SUBLIMATION. This term applies to the transition, under suitable conditions, directly between the vapor and the solid state of a substance. If solid iodine is placed in a tube and slightly warmed, it will vaporize and the vapor will reform into crystals on the cooler parts of the tube Many crystalline substances, both metallic and non-metallic, may be similarly sublimated in a vacuum, fairly large crystals of selenium have been thus prepared The most familiar sublimates are frost and snow. As in the case of other changes of state, sublimation is accompanied by the absorption or evolution of heat, the quantity of which per unit mass is called the "heat of sublimation" of the substance (See Vapor Pressure, and Distillation, Evaporation, and Drying.) (L D W)

SUBMAXILLARY GLAND. Salivary gland.

SUBMENTUM. Labium.

SUBNEURAL GLAND. A gland found below the brain in the ascidians Its duct leads to the ciliated funnel, an organ supposed to be sensory The function of the gland is unknown (A W L)

SUBNORMAL OF A CURVE. Tangents and Normals to a Plane Curve.

SUBSEQUENT STREAMS Consequent streams.

SUBSILICIC A term proposed by Clarke, in 1911, to replace "basic" (R M P)

SUBSOIL. Soil.

SUBSTATION. The substation of a power plant is the locality wherein generator voltage is transformed to transmission line voltage and high-tension switching is performed It is usual to install the high-tension equipment of the central station outdoors There are several reasons for this practice The large clearances required for high-voltage conductors are readily and inexpensively obtained

The housing of a high-voltage substation incurs a high-voltage lead-in line, a hazardous feature that is eliminated in the outdoor type Also, substation extensions and additions of feeders are more readily accommodated than in a closed structure The outdoor type step-up substation represents a maximum of reliability and safety with a minimum investment If well designed and maintained, it does not detract from the appearance of the power station

The substation may be a simple structure if the entire station output is taken out over one or two transmission lines, but if the station is a dispatching center for a network and switching of a number of incoming and outgoing lines is undertaken in the station switchyard, the structure will be more extensive and complicated The substation framework is made of structural steel or wood, the latter rarely being used with other than very small plants

Electrically, the substation can be planned (1) with the transformer part of the transmission line, (2) with the transformer part of the generator leads, (3) with the transformer an individual item, intermediate between low- and high-tension buses.

Within comparatively recent years considerable thought has been expended in the beautification of substations. The substation is often located in a residential district where an unsightly building would cause a decrease in real estate values and so arouse the opposition of property owners As a result, the tendency is towards pleasing substation design, and many have been built which outclass, in beauty, the residences which surround them The steel structure outdoor substation may also be made an asset in creating public good will To do this, it is symmetrically proportioned, kept well painted, fenced, and neatly wired Flood lighting, grass plots, and shrubs have also been used in the beautification of this type of structure. (F T M)

SUBSTITUTION METHOD. Physical Measurements.

SUBSURFACE WATER. Ground water.

SUBTANGENT TO A CURVE. Tangents and Normals to a Plane Curve.

SUBTRACTION. Subtraction is the inverse operation to addition The result of subtracting one number from another is called the difference of the two numbers. The difference $a - b$ between two numbers a and b is that number c such that $b + c = a$ It follows that $(a - b) + b = a$ and $(a + b) - b = a$ That is, the operations of addition and subtraction are mutually destructive each undoes the effect of the other

To subtract one number from another, change the sign of the number to be subtracted and proceed as in addition (L L S)

SUBUMBRELLA. Medusa.

SUCCESSION. The transition from one type of fauna to another within a given area Beginning with bare ground, plants are known to pass through a succession whose major phases are herbaceous vegetation, shrubs, and finally forest, with many minor transitions in each phase The fauna inevitably changes with the changing flora, since animals are directly or indirectly dependent on the plants for food Its changes are also dependent, however, on the physical conditions of the area, including climate and seasonal cycles, and in some cases the animals themselves cause changes which affect further development of the fauna The problems of succession have been subjected to extensive study in the field of ecology, and actual successions in observed areas are a matter of detailed record. (A W L)

SUCCESSIVE DERIVATIVES. Higher Derivatives.

SUCCESSIVE INTEGRATIONS. Double Integrals, and Triple Integrals.

SUCCULENTS. Succulent plants are those which are fleshy, that is, have their stems or leaves greatly enlarged to serve as storage organs Succulents occur wild in regions in which there is a very limited supply of available water, as in the desert lands of western America, central Asia, and many parts of Africa Among stem succulents the outstanding representatives are the members of the Cactus family, with the milkweed and spurge families also ranking high Leaf succulents include many plants such as *Sedums*, *Crassulas*, *Bryophyllums*, and *Gasterias* Many of the leaf succulents are plants of extremely curious habit In some, the leaves are so swollen with stored water that they form a nearly spherical mass growing almost buried in the ground in others the masses of leaves form compact

rosettes at the tips of the branches, while in others the swollen leaves appear like small green beads along a slender stem

Because of their odd and often ornamental habit, succulent plants are frequently grown in cultivation, especially as house plants. Many are especially desirable for this purpose, since they require little care and are remarkably tolerant to all conditions except too much water, which will cause quick rotting and death to many of them Many of this group of plants produce large gaudy flowers which add to their popularity as house plants (R M W)

SUCKER. Pisces, Teleostei A fish (**Pisces**) which lives near the bottom of streams, feeding on vegetation and small animals The mouth is usually provided with fleshy lips and in some species opens at a downward angle These fishes constitute the family Catostomidae, including the **mullets** and **buffaloes** as well as the species commonly called suckers They are not highly valued as food fishes, but the common sucker (*Catostomus commersoni*), often abundant in small streams and lakes, is excellent although bony (A W L)

SUCKING FISH. Remora.

SUCROSE. Carbohydrates.

SUCTORIA. Ciliophora.

SUDBURITE. The term proposed by H P Coleman, in 1912, for a type of basaltic lava frequently characterized by **amygdaloidal** and **pillow** structures, and chemically the effusive form of **norite** Type locality, Sudbury, Ontario, Canada (R M F)

SUGAR. Sugar is the name given to a group of chemical compounds included in the **carbohydrates** They are composed of carbon, hydrogen, and oxygen, usually in the proportions of $C_6H_{12}O_6$ or $C_{12}H_{22}O_{11}$ Sugars are colorless compounds, either solid or liquid, and many form aqueous solutions having a sweet taste Commercial sugar is sucrose or saccharose, which has the chemical formula $C_{12}H_{22}O_{11}$, and occurs in many plants, mostly in amounts too small to be of importance commercially A few plants, however, contain this sugar in their sap in considerable quantity. The most important sugar-containing plants are sugar cane and the **sugar beet** Sweet **Sorghums**, several **Palms**, and Sugar Maples also yield sugar

Sugar Cane *Saccharum officinarum* Gramineae This plant is a perennial grass, growing best in regions having a continuous hot climate and abundant moisture The plant possesses a shallow fibrous root system and thick underground rhizomes from which rise the erect stems 1–2 inches in diameter and 6–15 feet in height These stems are many jointed, solid, and bear at the nodes broad leaves with clasping bases Each leaf is three or more feet long The inflorescence is a loose panicle, which is rarely produced on plants grown outside the tropics The **spikelets** of the **panicle** are two-flowered, the lower one sterile, the upper fertile At the base of the spikelet is a tuft of long silky hairs The grain is very small, rather silky, and rarely viable, especially in plants grown in less favorable regions

Propagation of sugar cane is therefore done by means of stem cuttings rather than seed In this propagation, young stems are cut up into sections, each containing three buds These sections are planted in holes in the ground and covered with about two inches of soil Sprouts appear above ground in about two weeks and grow rapidly The crop is ready for the first harvest in twelve to fifteen months; successive crops may be gathered yearly thereafter for a number of years, varying greatly with the nature of the soil

In harvesting the stout stems are cut down, stripped of their leaves and top, and hauled to the factory as soon as possible. There the canes are passed between heavy variously toothed rolls, which crush and shred them The crushed material is passed through a series of heavy rolls which squeeze out much of the juice Hot water is sprayed over the stem mat as it passes through the rollers, ensuring extraction of greater amounts of the juice The residue remaining after extraction is called **bagasse**, and is used as a fuel to run the mill The extracted juice is strained to remove solid materials, then heated and allowed to stand in tanks so that any dirt present in the liquid may settle out The clear liquid is then treated with lime, or other chemicals which remove additional impurities, which unite with the lime and rise to the surface of the liquid as a scum, or settle to the bottom as a sediment The clear liquid is then evaporated under partial vacuum to a syrup Boiling is continued in vacuum pans until the syrup becomes very thick and concentrated, at which time small crystals begin to appear These crystals increase in size as more liquid is added and boiled down When the desired crystal size is reached, the concentrated syrup is removed to centrifugal machines consisting of perforated cylindrical baskets within heavy jackets Rapid revolving of these baskets causes the liquid portion of the syrup to be thrown out through the holes to the sides of the container The crystalline portion remains in the basket This is washed to remove any syrup which remains as a film over the crystal surface, then removed and dried. The use of sugar is too well known to need mention. It is an important source of energy and also much used to impart a sweet flavor to substances which might be unpleasant otherwise. As a by-product of this process a thick viscous brown liquid is obtained This is molasses, which is used for cooking, for stock feeding, and for the manufacture of rum and alcohol.

Sugar Maple *Acer saccharum* Another source of sugar, of limited importance commercially, is the sugar maple, *Acer saccharum*, a deciduous hardwood tree of eastern North America The sugar is obtained from the sweet sap of the tree To obtain this sap, small holes are bored into the sapwood near the base of the trunk, a channeled spout driven into each hole, and a bucket hung on the spout Clear snappy cold nights and warm quiet days favor the flow of sap, which may run three or four gallons to a tree daily for a period of three or four weeks The colorless sap is poured into slightly tilted flat pans so corrugated that the sap gradually flows downward Wood fires under the pan cause the thin layer of sap to evaporate rapidly, producing a thin brownish syrup which is mostly sucrose, but characteristically flavored by substances contained in the sap This syrup may be further concentrated until it crystallizes as a brown sugar, which is usually prepared in small cakes From a good tree two pounds of sugar or a quart of thick syrup may be obtained each year. Maple products are much used to flavor tobacco, and in candy manufacturing Maple syrup is frequently mixed with other syrups before marketing The principal producing regions are Vermont and New York, with other New England states and the states along the Great Lakes producing the rest.

Honey Another source of sugar is the nectar found in many flowers The amount found in each flower is too minute to be directly obtained by man Certain insects gather this nectar in quantities One insect in particular, the honey-bee, is an especially industrious collector of nectar This they store in waxen cells, first having partially digested the nectar Bees can be made to store much more honey than will be needed for carrying them through the winter This surplus honey is then available to man Certain flowers, notably clover, buckwheat, and lindens, give to honey obtained from them a particularly attractive fragrance Honey is used most commonly as a table luxury. (R M W)

SUGGESTION. Producing a condition in which activity, conduct, or thought is determined by impressions or ideas imparted by others Hypnotic suggestion, is suggestion received by a person in an hypnotic state. Post-hypnotic suggestion, the suggestion is imparted to the person while in an hypnotic state and the action suggested is carried out on the return to a normal state. (R S M)

SUINA. A division of the hoofed animals including the **pigs** and **peccaries** They differ from the other members of the order **Artiodactyla**, to which they belong, in the absence of horns, in the thick skin and bristly hair, and in the fact that they are not ruminants (A W L)

SULFANILAMIDE (Para - amino - benzene - sulfonamide) A recently discovered chemical compound that often has a remarkable therapeutic effect on streptococcal infections, reducing the mortality and morbidity in this type of infection It also seems to be of definite value in infections caused by other organisms, namely, those due to the *Gonococcus* (gonorrhea) and meningitis, due to the *Meningicoccus*

In 1935 Gerhard Domagk published his work on the therapeutic value of azo-dyes, demonstrating the value of azo-sulfonamide compound in *Streptococcus septicemia* in mice Other workers corroborated his results Later it was found that the azo linkage was not essential as the complex substance was broken down in the body to the simpler compound sulfanilamide It is also less toxic and is safest and easily given by mouth instead of by injection The first report on this work was by Lang and Bliss, of Johns Hopkins Medical School

The drug must be given under the direction of the physician, as certain dosages must be given which vary in different cases, and certain toxic manifestations may occur and must be guarded against

The conditions in which it has life-saving value include septicemia due to *Streptococci*, *Gonococci*, and *Meningicocci*, puerperal sepsis, erysipelas, certain forms of scarlet fever, septic sore throat, middle ear disease, inflammations, or other infections due to *Streptococcus*, gonorrhea, and cerebrospinal fever (R S M)

SULFATE. Sulfuric Acid

SULFIDE. Hydrosulfuric Acid.

SULFINIC ACIDS Thioalcohols and Related Compounds.

SULFINYL COMPOUNDS Thioalcohols and Related Compounds.

SULFITE. Sulfurous Acid and Sulfites.

SULFONIC ACIDS. Thioalcohols and Related Compounds.

SULFONYL COMPOUNDS. Thioalcohols and Related Compounds.

SULFUR. Symbol S Atomic number 16 Atomic weight, 32 06 The chemical element sulfur is known in two different forms, namely, (1) Alpha-**rhombic** sulfur, yellow, density 2 07, melting point 112 8° C to form gamma-sulfur, (2) Beta-**monoclinic** sulfur, yellow, density 1 96, melting point 110° C to form gamma-sulfur Below 96° C beta-monoclinic changes to alpha-rhombic The boiling point of sulfur is 444 6° C, as a brownish-red vapor turning deep red at 500° C and straw yellow at 650° C The discovery of sulfur is prehistoric Isotopes 32 (97 0%), 33 (0 8%), 34 (2 2%) Sulfur is largely consumed (1) in superphosphate fertilizer manufacture, (2) in insecticides, (3) in the manufacture of sulfite paper pulp from wood, (4) in the manufacture of sulfuric acid and sulfates, and (5) of sulfur dioxide and sulfites

Free sulfur occurs in nature in the alpha-rhombic form, with pyramidal or tabular crystals, but often occurs massive, in crusts, columnar, and in other forms It has cleavages parallel to the base, prism, and pyramid, but all rather imperfect, fracture is conchoidal to uneven Alpha-sulfur is brittle, hardness 1 5–2 5, specific gravity 2, luster, resinous, color, usually yellow, but may be brownish, reddish, or greenish, transparent to translucent

Alpha-rhombic and beta-monoclinic sulfur are soluble in **carbon** disulfide, and when the solution is allowed to evaporate spontaneously in air, the residual sulfur crystallizes as alpha-rhombic Sulfur burns with a beautiful violet transparent flame of characteristic odor when ignited in air at 250° C to form sulfur dioxide, and combines with many metals when heated, e g, **iron** powder to form ferrous sulfide Color and **viscosity** of sulfur change with change of temperature approximately as follows maximum of viscosity (50,000 times that of water at 17° C) is at about 200° C, at this temperature liquid sulfur is dark red, having arrived at this by passing through stages from pale yellow Viscosity at 300° C is about 2000 At about 200° C the liquid darkens almost to black If, at a temperature near the boiling point, liquid sulfur is poured into cold water, it forms a soft, elastic, duct le mass like rubber, which in a few days at ordinary temperatures changes to alpha-rhombic sulfur When liquid sulfur is kept at a temperature only slightly below the melting point for a sufficient time for part of the liquid to crystallize, and the remaining liquid poured off, beta-monoclinic crystals are obtained, which within a few days at ordinary temperatures change to alpha-rhombic sulfur

Sulfur occurs as free sulfur in many volcanic districts, and may have been formed in part by **sublimation**, by decomposition of hydrogen sulfide, or metallic sulfides, or by organic agencies It is often associated with **limestones** and **gypsum** Sulfur is found in Spain, Iceland, Japan, Mexico, and Italy (especially Sicily, which was the producer for the world until about the beginning of the twentieth century, when Herman Frasch, by inventing the superheated water method of mining sulfur, made available the great Louisiana and Texas deposits This method of mining is at the same time a method of purifying sulfur, as in the process of heating, accompanying materials remain unmelted at the temperature at which sulfur melts and is drawn off) In the Louisiana and Texas deposits the sulfur is associated with gypsum, occurring in the cap-rock overlying the salt plugs that have pierced the strata underlying the Gulf coastal plain In the United States sulfur is also found in California, Colorado, Nevada, and Wyoming Sulfur also occurs as (1) sulfides, e g, iron disulfide, **pyrite** (FeS_2), lead sulfide, **galenite** (PbS), copper iron sulfide, copper pyrite ($CuFeS_2$), zinc sulfide, **zinc blende** (ZnS), mercury sulfide, **cinnabar** (HgS), and (2) as sulfates, e g, calcium sulfate, **gypsum** ($CaSO_4 \cdot 2H_2O$), barium sulfate, **barite** ($BaSO_4$)

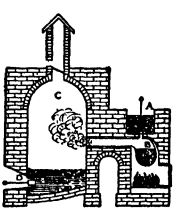


Diagram of furnace for the sublimation of sulfur. *A*, sulfur as charged to furnace, *B*, sulfur melted by heating and vaporized, *C*, chamber maintained below the melting point of sulfur for the direct condensation of sulfur as finely divided solid (sublimed sulfur)

Acids Sulfur is a constituent of several acids In increasing order of oxidation the following are those which contain sulfur and oxygen but not carbon, hydrosulfuric acid (H_2S), thiosulfuric acid ($H_2S_2O_3$); tetrathionic acid ($H_2S_4O_6$), hyposulfurous acid ($H_2S_2O_4$), sulfurous acid (H_2SO_3); dithionic acid ($H_2S_2O_6$), persulfuric acid ($H_2S_2O_8$), chlorosulfonic acid ($Cl\,SO_2OH$) liquid, boiling point 155° C, reactive with ex-

plosive violence with water forming sulfuric acid plus **hydrochloric acid**, and formed by distillation of concentrated sulfuric acid and **phosphorus** pentachloride or oxychloride; fluosulfonic acid ($F \cdot SO_2OH$); those which contain carbon (thioic acids): thiocarbonic acid (H_2CS_3); ethane thiolic acid (CH_3COSH); ethane thionic acid ($CH_3 \cdot CSOH$); ethane thionthiolic acid, methane carbodithioic acid ($CH_3 \cdot CSSH$); methyl sulfonic acid ($CH_3 \cdot SO_2OH$); methyl sulfinic acid ($CH_3 \cdot SOOH$).

Bases: Sulfur is a constituent of some bases, e.g., trimethyl sulfonium hydroxide ($(CH_3)_3SOH$).

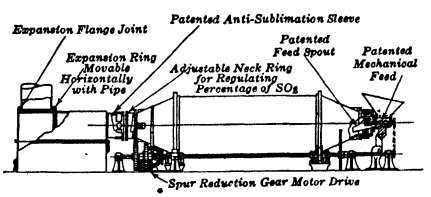
Bromide: Sulfur bromide (S_2Br_2), dark red liquid, boiling point 56° C. at 0.2 mm. pressure.

Chlorides: Sulfur chloride, sulfur monochloride (S_2Cl_2), yellowish-brown liquid, of irritating odor, boiling point 139° C., formed by reaction (1) of **chlorine** and sulfur heated, (2) of chlorine and **carbon** disulfide, and separated from **carbon** tetrachloride by fractional distillation. It dissolves sulfur readily, and is used in the process of vulcanization of rubber; sulfur dichloride (SCl_2), dark red fuming liquid, boiling point 59° C., formed by reaction of sulfur monochloride and chlorine in the presence of a trace of iodine; sulfur tetrachloride (SCl_4), unstable above —20° C., formed by saturating sulfur monochloride with chlorine at —22° C.; thionyl chloride ($SOCl_2$), colorless liquid, boiling point 78° C., fumes in moist air to yield **hydrochloric acid** and sulfurous acid, formed by reaction of sulfur trioxide and sulfur monochloride at about 80° C.; sulfuryl chloride (SO_2Cl_2), colorless, fuming liquid, boiling point 69° C., with water yields hydrochloric acid plus sulfuric acid, formed by reaction of chlorosulfuric acid heated with a **catalyzer**, e.g., **mercuric** sulfate; thiocarbonyl chloride ("thiophosgene," $CSCl_2$), red fuming liquid, boiling point 73°, formed by reaction of carbon disulfide and chlorine followed by treatment with **stannous** chloride.

Fluorides: Sulfur hexafluoride (SF_6), colorless, odorless, tasteless gas, melting point —55° C., remarkably stable, unaffected by fused alkalis, formed by reaction of sulfur and **fluorine**; thionyl fluoride (SOF_2) and sulfuryl fluoride (SO_2F_2) are gases which react with water to give hydrofluoric acid in both cases plus sulfurous and sulfuric acids, respectively.

Hydride: Hydrogen sulfide (H_2S), colorless gas, odor of rotten eggs, poisonous, density 1.539 grams per liter, 0° C., 760 mm., or 1.190 when air equals 1.000, melting point —83° C., boiling point —60° C., not decomposed at 350° C., burns in air to form sulfur dioxide and water, preferred reagent in solution for the preparation of many metallic sulfides, e.g., copper sulfide. Made by action of dilute **hydrochloric** or sulfuric acid on a sulfide, such as **ferrous** sulfide or **calcium** sulfide, and used either as gas or solution. As a solution in water, see Hydrosulfuric acid, below.

Oxides: Sulfur dioxide (SO_2), colorless gas, sharp characteristic odor, density 2.9269 grams per liter, 0° C., 760 mm., or 2.264 when air equals 1.000, melting point —73° C., boiling point —10.0° C., critical temperature 157° C., critical pressure 78 atmospheres, very soluble in water forming sulfurous acid, formed by the burning in air of (1) sulfur, (2) sulfur containing organic material, e.g., coal, protein, (3) sulfides. Used (1) as a refrigerant, (2) in the preparation of sulfur trioxide, sulfuric acid, sulfites, (3) as a disinfectant, (4) in bleaching; sulfur sesquioxide (S_2O_3), by dissolving sulfur in sulfur dioxide, or by reaction of sulfur trioxide and hydrazine; sulfur trioxide (SO_3), (1) alpha-sulfur trioxide, colorless liquid, boiling point 45° C., crystallizes to needle crystals of melting point 17° C., fumes in air, reacts with water vigorously, (2) beta-sulfur trioxide (probably S_2O_6), white solid, looks like asbestos, fumes in air, reacts with water somewhat less vigorously than the alpha form yielding sulfuric acid. Sulfur dioxide and oxygen of air react when heated in the presence of a catalyzer, e.g., platinized asbestos, to yield sulfur trioxide; sulfur heptoxide (S_2O_7), sublimes at 10° C., formed by the reaction of ozone and sulfur dioxide or trioxide, unstable; sulfur tetroxide (SO_4), solid, formed by the action of the silent electric discharge on sulfur dioxide plus oxygen, unstable.

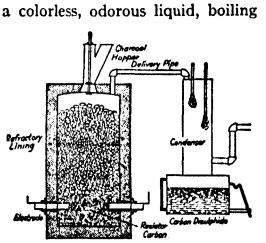


Sulfur burner.

Sulfides: Sulfides of many elements are known. Metallic sulfides are (1) soluble, e.g., **sodium, potassium, ammonium** sulfides (Na_2S, K_2S, $(NH_4)_2S$); (2) reactive with water, e.g., **calcium** sulfide (CaS) to form calcium hydrogen sulfide and calcium hydroxide, **aluminum** sulfide to form hydrogen sulfide and aluminum hydroxide; (3) insoluble, e.g., **silver** sulfide (Ag_2S) brown, **lead** sulfide (PbS) brown, **copper** sulfide (CuS) black, **ferrous** sulfide (FeS) black, **zinc** sulfide (ZnS) white, **arsenious** sulfide (As_2S_3) yellow; and (4) organic sulfides are noteworthy, e.g., methyl sulfide (dimethyl sulfide $(CH_3)_2S$), phenyl sulfide (diphenyl sulfide $(C_6H_5)_2S$), carbon disulfide (CS_2), carbonyl sulfide (COS).

Hydrosulfuric acid and soluble sulfides are important chemical reagents for the precipitation of insoluble sulfides, which are produced and separated from each other by means of their characteristic solubilities in various acids, and in excess sodium or ammonium sulfide.

Carbon disulfide is a colorless, odorous liquid, boiling point 46° C., inflammable, explosive when mixed with air and ignited, and poisonous. Carbon disulfide dissolves sulfur, yellow phosphorus, iodine, bromine, chlorine, hydrocarbons, oils, fats. Made by reaction of carbon (coke) and sulfur in an electric furnace, and recovered by condensation of the vapor. Used (1) as a solvent, (2) as an insecticide, (3) in the manufacture of carbon tetrachloride.



Electric furnace for the manufacture of carbon disulfide.

Other compounds of sulfur are discussed as follows:

Benzothiophene. See **Thiophene and Related Compounds.**

Dithionates. See **Dithionic acid and Dithionates. Dithionic acid.**

Hydrosulfides. See **Hydrosulfuric acid and Sulfides;** and **Thioalcohols and Related Compounds. Hydrosulfuric acid.**

Hyposulfites. See **Hyposulfurous acid and Hyposulfites. Hyposulfurous acid.**

Isothiocyanates. See **Thiocyanic acid and Thiocyanates.**

Esters. See **Sulfuric acid and Sulfates; Sulfurous acid and Sulfites; Thiocyanic acid and Thiocyanates.**

Mercaptans. See **Thioalcohols and Related Compounds.**

Mustard gas. See **Thioalcohols and Related Compounds.**

Persulfates. See **Persulfuric acid and Persulfates. Persulfuric acid.**

(*Continued on page* 1083.)

SCHEME SHOWING THE INTERRELATIONSHIPS OF SULFUR-CONTAINING SUBSTANCES

Hydrogen sulfide	SULFUR In nature	Sulfur dioxide	Sulfur trioxide
Hydrosulfuric acid		Sulfurous acid	Sulfuric acid Most abundantly used acid
Metallic sulfides Pyrite, galenite, sphalerite, chalcopyrite in nature		Metallic sulfites	Metallic sulfates Gypsum, barite, strontianite, magnesium sulfate in nature
Insoluble sulfides Of silver, lead, mercury, arsenic, antimony, tin, bismuth, copper, cadmium, iron, cobalt, nickel, manganese, zinc		Insoluble sulfites Except sodium, potassium, ammonium	Insoluble sulfates Of lead, mercurous, barium, strontium, calcium
Soluble sulfides Of sodium, potassium, ammonium		Soluble sulfites Of sodium, potassium, ammonium	Soluble sulfates Of sodium, potassium, ammonium
Reactive with water Of magnesium, calcium, strontium, barium			Reactive with water Upon heating magnesium, zinc, aluminum
Organic sulfides Sulfonium-compounds		Organic sulfites	Organic sulfates
		Sulfinic acids Sulfinyl-compounds	Sulfonic acids Sulfonyl-compounds

Thiophene Penthiophene Thiazole Cystine In proteins	Thioic acids Thiocyanic acid Thiourea Thiocarbonic acid	Thiosulfuric acid Tetrathionic acid Hyposulfurous acid	Dithionic acid	Persulfuric acid

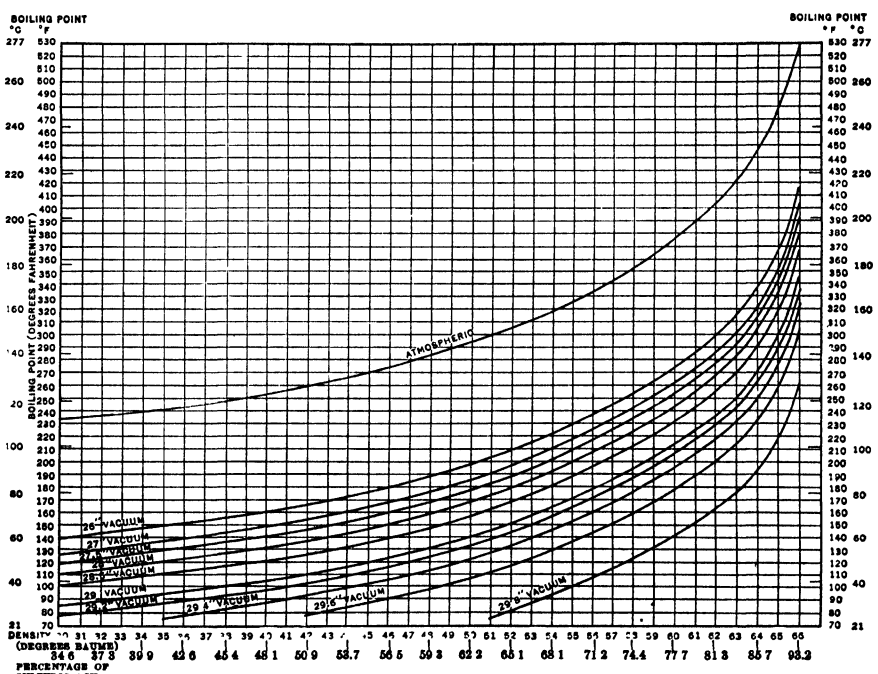
SCHEME SHOWING INTERRELATIONSHIPS OF SULFUR-FUNCTION ORGANIC COMPOUNDS

Related to	 Hydrogen sulfide	 Sulfurous acid	 Sulfuric acid
>CH of benzene	Thiophene Penthiophene		
−CH₂OH >CHOH >COH of alcohols and phenols	Thioalcohols (−SH) Thioethers (>S) Tertiary sulfonium compounds Thiophenols		
−CHO >CO of aldehydes and ketones	Thioaldehydes Thioketones		
H—COOH Carboxylic acids	Thioic acids Thiolic Thionic Thionthiolic	Sulfinic acids Sulfinyl (Sulfoxides) (>SO)	Sulfonic acids Aminosulfonic Phenolsulfonic Sulfonyl (Sulfones)
HO—COOH Carbonic acid	Thiocyanates Isothiocyanates Thioureas Thiocarbonic acid (H_2CS_3)		(R.K.S.)

Sulfates See **Sulfuric acid and Sulfates.**
Sulfides See **Sulfur, Sulfides, Hydrosulfuric acid and Sulfides, Thioalcohols and Related Compounds.**
Sulfinic acids See **Thioalcohols and Related Compounds.**
Sulfinyl-compounds See **Thioalcohols and Related Compounds.**
Sulfites See **Sulfurous acid and Sulfites.**
Sulfones. See **Thioalcohols and Related Compounds.**
Sulfonic acids See **Thioalcohols and Related Compounds.**
Sulfonium-compounds See **Thioalcohols and Related Compounds.**
Sulfonyl-compounds See **Thioalcohols and Related Compounds.**
Sulfoxides See **Thioalcohols and Related Compounds.**
Sulfuric acid.
Sulfurous acid.
Sulfuryl chloride See **Sulfur, Chlorides**
Tetrathionates See **Tetra thionic acid and Tetrathionates.**
Tetrathionic acid.
Thioacids See **Sulfur, Acids.**
Thioalcohols
Thioaldehydes.
Thiocarbonates See **Thiocarbonic acid and Thiocarbonates.**
Thiocarbonic acid.
Thiocyanates See **Thiocyanic acid and Thiocyanates.**
Thiocyanic acid.
Thioethers See **Thioalcohols and Related Compounds.**
Thioketones See **Thioaldehydes and Thioketones.**
Thiols. See **Thioalcohols and Related Compounds.**
Thiolic acid See **Sulfur, Acids.**
Thionic acids See **Sulfur, Acids.**
Thionyl chloride See **Sulfur, Chlorides.**
Thiophene.
Thiophenols See **Thioalcohols and Related Compounds.**
Thiosulfates See **Thiosulfuric acid and Related Compounds.**
Thiosulfuric acid.
Thiourea.

SULFUR DIOXIDE. Sulfur.

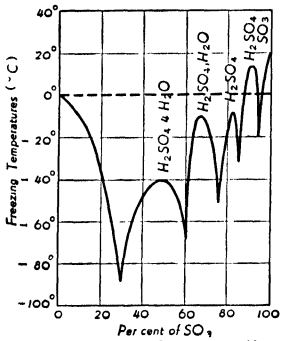
SULFURIC ACID AND SULFATES. Sulfuric acid, "oil of vitriol" (H_2SO_4), a colorless oily liquid, is encountered as a colorless solution, commercially of strength 60° Baumé (specific gravity 60° F, water at 60° F, 1 7059, 77 67% H_2SO_4, 22 33% water), 66° Baumé (specific gravity at 60° F, water at 60° F, 1 8354, 93 19% H_2SO_4, 6 81% water), specific gravity 1 835 (approximately 95% H_2SO_4), oleum 20% (20% free SO_3, 80% H_2SO_4, 85 3% total SO_3, specific gravity at 20° C, 1 927), oleum 40% (40% free SO_3, 60% H_2SO_4, 89 0% total SO_3, specific gravity at 20° C, 1 966) Sometimes colored brown to black by carbon With the exception of the varieties of oleum (or "fuming sulfuric acid"), the highest strength of sulfuric acid ordinarily used is 66° Baumé (93 19% H_2SO_4), but in the manufacture of sulfuric acid and oleum by the contact process a strength of 98% to 99% is produced Sulfuric acid 100% may be made by the proper admixture of sulfur trioxide and



Boiling point of various strengths of sulfuric acid water mixtures

water, or by crystallization from sulfuric acid 98% upon cooling There is a maximum constant boiling point 317° C (768 mm) at 98% H_2SO_4 (distillate) for mixtures of H_2SO_4 and water, and of H_2SO_4 and SO_3

The freezing point relations of water-sulfur trioxide mixtures is shown in the diagram Sulfuric acid when mixed with water generates much heat. A commonly used strength for dilute sulfuric acid is 24 5 grams H_2SO_4 per 100 milliliters of solution (5 normal)

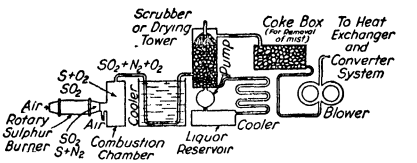


Freezing point curve of system sulfuric acid—water—sulfur trioxide (Mellor, *Modern Inorganic Chemistry*, Longmans, Green & Co)

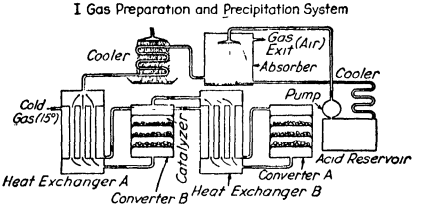
Dilute sulfuric acid reacts (1) with many hydroxides, e g, **sodium** hydroxide, to yield two series of sulfates (the acid is dibasic), e g, sodium sulfate or sodium hydrogen sulfate, depending upon the ratio of acid to base reacting, (2) with many ordinary oxides, e g, **magnesium** oxide, to yield the corresponding sulfate, e g, magnesium sulfate, solution, (3) with some carbonates, e g, **zinc** carbonate, to yield the corresponding sulfate, e g, zinc sulfate solution plus **carbon dioxide** gas (calcium carbonate is soon coated by a layer of calcium sulfate, which prevents further reaction), (4) with some sulfides, e g, **ferrous** sulfide, to yield the corresponding sulfate, e g, ferrous sulfate plus hydrogen sulfide gas, (5) with many metals, e g, zinc, if not too pure (but not copper), to yield the corresponding sulfate, e g, **zinc** sulfate solution plus **hydrogen** gas, (6) with solutions of same salts to yield the corresponding sulfate, e g, **barium** chloride, changed to barium sulfate precipitate, **calcium** citrate, malate, tartrate to calcium sulfate precipitate and the free organic acid in solution

Higher strengths of sulfuric acid react similarly in kind to the cases of (1), (2), (3), (6) above, but not, in general, in the remaining cases (4) Sulfides react to yield the corresponding sulfates, but accompanied by **sulfur**, (5) reactions of metals depend upon the metal and the strength of sulfuric acid **Copper** and concentrated sulfuric acid yield copper sulfate and **sulfur** dioxide gas Iron reacts similarly, yielding ferric sulfate in the place of copper sulfate Concentrated sulfuric acid is (7) thus an oxidizing agent, and a further example is the oxidation of **sulfur** to sulfur dioxide (the reacting sulfuric acid is reduced to sulfur dioxide), (8) a sulfonating agent, e g, **naphthalene** sulfonated to naphthalene sulfonic acids (mono- alpha or beta, di- several), (9) an esterification agent, e g, methyl **alcohol esterified** to dimethyl sulfate ($(CH_3O)_2SO_2$), melting point —32° C, boiling point 189° C, or methyl hydrogen sulfate ($CH_3O\ SO_2OH$), ethyl alcohol esterified to diethyl sulfate ($(C_2H_5O)_2SO_4$), melting point —26° C, boiling point 208° C, or ethyl hydrogen sulfate ($C_2H_5O \cdot SO_2OH$), (10) a dehydration agent, e g, **formic acid** into **carbon monoxide**, sugar blackened with separation of carbon; (11) an addition agent, e g, ethylene into ethyl hydrogen sulfate, (12) a non-volatile acid upon heating, e g, with **sodium** chloride or nitrate, **hydrogen chloride or nitric acid**, respectively, is volatilized and sodium sulfate or sodium hydrogen sulfate remains as a residue

In order to obtain sulfuric acid, two sources of sulfur are available for conversion into sulfur dioxide, which is the first stage These are (1) sulfur, (2) metallic sulfides, namely, **pyrite** (iron disulfide (FeS_2)), and **copper, lead, zinc** sulfides of smelter operations In all these cases sulfur element is converted into sulfur dioxide gas by roasting in a current of air In the second stage of the process sulfur dioxide is converted into sulfur trioxide by either of two methods, (1) "contact process," (2) "chamber process," both of which are catalytic In the contact process sulfur dioxide, carefully purified, is mixed with air, and passed over a specially prepared



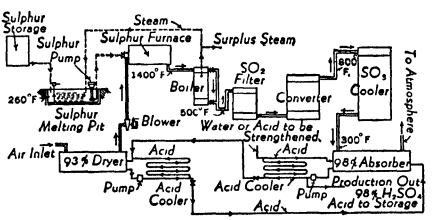
I Gas Preparation and Precipitation System



II Heat Exchanger, Converter, and Absorption System

Sketch—Contact process for sulfuric acid (platinum catalyst)

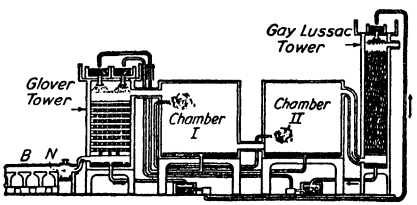
catalyzer The catalyzer commonly used is finely divided **platinum** (derived from platinum salts) on the surface of **asbestos, magnesium** sulfate, or **silica** gel, which act as porous, large surface supports Vanadium pentoxide distributed on such a support as silica gel is also used The third stage of the process involves the absorption of sulfur trioxide in water to form sulfuric acid Experiment has demonstrated that the most satisfactory absorbent is 98% to 99% sulfuric acid Acid of this strength is maintained in the absorber When "oleum" is desired, water is not added.



Flow-diagram, "Chemico" contact sulfuric acid plant

In the chamber process, the above second and third stages are combined by introducing into large lead-lined chambers the required ratios of **sulfur** dioxide, water mist, and **nitrogen** oxides Carefully designed towers are arranged (a) Glover tower, *before* the chambers, to introduce the nitrogen oxides previously dissolved in sulfuric acid ("Gay-Lussac acid"), and to cool the sulfur dioxide-air mixture from the burners, (b) Gay-Lussac tower, *after* the chambers, to recover the reduced and unused nitrogen oxides by dissolving them in sulfuric acid ("Glover acid") An incidental stage in the chamber process is the concentration of "chamber acid" (62% to 70% H_2SO_4) by evaporation in acid-resistant pans, such as fused quartz, or by spray evaporation to the desired concentration

The uses of sulfuric acid have been suggested by the chemical reactions previously cited, and the largest quantities are used (1) in the production of **explosives**,



Chamber process for sulfuric acid.

where it is used as "mixed acid"; (2) in refining **petroleum** distillates, usually "oleum" used; (3) in the production of superphosphate **fertilizer** and phosphoric acid, ordinary "chamber acid" used; (4) of hydrochloric and nitric acids; (5) of sulfates; and (6) in the cleaning of metals, e.g., iron.

All metallic sulfates, except **barium** sulfate, **strontium** sulfate, **lead** sulfate, **mercurous** sulfate, are soluble in water, but **calcium** sulfate and mercuric sulfate are only slightly soluble.

Metallic sulfates, upon heating, behave in an individually characteristic manner, e.g., sodium sulfate stable, sodium hydrogen sulfate into sodium pyrosulfate, barium sulfate stable, ferric sulfate into ferric oxide plus sulfur trioxide (an early method for obtaining sulfur trioxide). Sulfates give a white precipitate, insoluble in hydrochloric acid, with barium chloride solutions. (R.K.S.)

SULFUROUS ACID AND SULFITES. Sulfurous acid (H_2SO_3) is a colorless solution formed when **sulfur** dioxide gas is dissolved in water, and the presence of sulfur dioxide imparts its own odor. Sulfur dioxide may be completely expelled from sulfurous acid solution by boiling.

As a bleaching agent, sulfurous acid is used for whitening wool, silk, feathers, sponge, straw, wood; as a bleaching and preservative agent for dried fruits, and decolorizes a solution of rosaniline (fuchsine, magenta).

Sulfurous acid is a strong reducing agent, being oxidized to **sulfuric acid** (1) on standing in contact with air, (2) by **chlorine**, **bromine**, **iodine** yielding **hydrochloric**, **hydrobromic**, **hydrioidic acids**, respectively, (3) by **nitric** or **nitrous acid** yielding nitric oxide, (4) by **permanganate**. Sulfurous acid is itself reduced by **zinc** and dilute sulfuric acid, to **hydrogen sulfide**. Sulfurous acid is formed (1) by dissolving sulfur dioxide gas in water, (2) in effect, by reaction of sulfite or bisulfite solution and an acid.

Sodium sulfite (Na_2SO_3) and sodium hydrogen sulfite ($NaHSO_3$) are formed by reaction of sulfurous acid and sodium hydroxide or carbonate in the proper proportions and concentrations. Sodium sulfite dry, upon heating, yields sodium sulfate and sodium sulfide. Sodium pyrosulfite, "sodium metabisulfite" ($Na_2S_2O_5$), is a common sulfite. Crystalline sulfites are obtained by warming the corresponding bisulfite solutions. **Calcium** hydrogen sulfite ($Ca(HSO_3)_2$) is an important substance used in conjunction with excess sulfurous acid in converting wood to paper pulp. Sodium sulfite and **silver** nitrate solutions react to yield silver sulfite, white precipitate, which upon boiling decomposes forming silver sulfide, brown precipitate. **Barium** sulfite is soluble (a white precipitate formed by the addition of barium chloride to sulfite solution containing hydrochloric acid is barium sulfate in consequence of the previous oxidation of sulfite).

As an esterification agent, sulfurous acid forms dimethyl sulfite ($(CH_3O)_2SO$), boiling point 126° C., and diethyl sulfite ($(C_2H_5O)_2SO$), boiling point 161° C. Sulfites give a white precipitate with barium chloride, soluble in hydrochloric acid with evolution of sulfur dioxide. Sulfites decolorize iodine in acid solution. (R.K.S.)

SUMMER EGG. A form of egg produced by some species of **crustaceans**, usually during the summer. These eggs have thin shells and are parthenogenetic (i.e., they develop without being fertilized), in contrast with the eggs of biparental generations. The significance of such specialization in the reproductive processes is considered under **parthenogenesis**. (A.W.L.)

SUMNER LINE. The Sumner Line is a **line of position** obtained by the observation of the **altitude** of some celestial object. It receives its name from its discoverer, Captain Thomas H. Sumner. The circumstances leading to its discovery are exceedingly interesting and indicate the great value of the line. His personal description of the discovery is given in Chapter XV of the American Practical Navigator, Bowditch, Edition of 1930.

Every celestial object must be at the **zenith** for some point on the surface of the earth. In case the celestial object is the sun this point is called the subsolar point; in case it is a star the subastral point; the moon, the sublunar point; etc. The **geographical coordinates** of the subsolar point may be immediately determined for its **longitude** will be the **Greenwich apparent time** and its **latitude** will be the **declination** of the sun. For a substellar point the longitude is the **Greenwich sidereal time** and the latitude the declination of the star. If the earth be assumed spherical, an assumption which is admissible in practically all navigational problems, circles may be drawn about the substellar or subsolar point. On any such circle the **geocentric zenith distance** of the object will be equal to the radius of the circle, measured in minutes of arc (**nautical miles**) along the spherical surface of the earth. Hence to draw a line of position all that would be necessary would be to measure with a **sextant** the **apparent altitude** of the object, reduce this to a **geocentric altitude**, and then obtain the geocentric zenith distance. Having located the position of the subsolar point on the sphere, the circle of position could be immediately drawn about the subsolar point with the geocentric zenith distance as radius. This ship must lie on this circle of position.

To obtain sufficient accuracy by this simple method of drawing the circle of position would require the use of a sphere of tremendously inconvenient proportions. However, every point on the circle must have a particular latitude and longitude. From an observed altitude the navigator may obtain the true geocentric altitude and with two or more assumed latitudes, separated by perhaps twenty miles and relatively close to his **dead reckoning** position, compute the corresponding longitudes by any of the methods for determination. These points of **longitude** when plotted on a chart must lie on the line of position, which may be drawn through them. In case the object is within forty-five degrees of the meridian, longitudes should be assumed from the dead reckoning and corresponding latitudes computed by any of the methods for **determination of latitude.**

The line drawn through any two points thus computed is in reality a chord of the circle of position, but, unless the object is very close to the observer's zenith (i.e., the observer is very close to the substellar point), the curvature of the circle will be so slight that the chord and the circle will be congruent. Instead of the chord of the circle of position a tangent may be computed. From an observed altitude, reduced to the correct geocentric, a longitude may be computed from a dead reckoning latitude, or a latitude from a dead reckoning longitude. The **azimuth** of the object is also obtained, either by computation for **determination of azimuth** or from **azimuth tables**, using the one dead reckoning and corresponding computed coordinate. A line drawn through the established position and perpen-

dicular to the azimuth, which corresponds to the direction of the substellar point and hence is the radius of the circle, will be a tangent of the circle of position and will coincide with the circle over a considerable length unless the zenith distance of the object is very small

The so-called modern methods of laying down lines of position from observations of altitude will be found under the article on **Saint Hilaire** Methods of carrying lines of position forward or backward will be found under **fix.** (W K G)

SUN. The sun is without question the most important of all of the celestial objects, not only to the earth, but also to all other members of the **solar system** Whatever life exists on the earth, or elsewhere in the solar system, is absolutely dependent upon the **radiation** from the sun for its existence All forms of energy which we employ on the earth come from the sun, either by its present radiations, as in the case of water power or wind power, or from its radiations in the past, as in the case of coal or oil Even the **tidal energy,** which comes principally from the moon, is influenced to a considerable extent by the position of the sun relative to the moon From the purely scientific point of view, the sun is of tremendous importance to the astronomer, since it is a typical **dwarf** star of the G_0 **spectral class,** and is close enough to the earth to permit of careful analysis

Somewhat detailed descriptions of the different portions of the sun and its surrounding atmosphere will be found in articles on the **photosphere,** the **reversing layer, chromosphere, corona, prominences,** and **sunspots** The mean distance of the sun, as determined from many measurements of **solar parallax,** is 149,450,000 kilometers, or 92,897,000 miles The mean diameter is 1,390,600 kilometers, or 864,000 miles; about 109 1 times the diameter of the earth Since volume is proportional to the cube of the diameter, we find that the volume of the sun is 1,300,000 times that of the earth In order to get some concept of these sizes and distances consider the sun as a globe two feet in diameter, the earth on this same scale would be a sphere only 0 22 inch in diameter, and would be distant from the sun 215 feet On this same scale the nearest **star** would be 11,000 miles away! The mass of the sun may be determined from the gravitational attraction which it exerts upon the earth and is found to be 331,950 times that of the earth, or $1\ 982 \times 10^{23}$ grams (or 2×10^{27} tons) From the mass and the volume the mean density of the sun is found to be about one-fourth that of the earth, or 1.4 times that of water. The gravitational force on the surface of the photosphere is 27 6 times that on the earth, which is equivalent to saying that a person weighing 100 pounds on the earth would weigh nearly one and one-half tons on the sun

From a large number of observations of sun spots and also by spectroscopic observations the rotation period of the sun has been found to be different at different distances from the sun's equator At the equator the sidereal period of rotation is about 24 65 days; in latitude 30°, 25 85 days, in latitude 60°, 30 93 days; and at the poles about 34 days Such a varying rotation period indicates certainly that the sun is not a solid, but there is no adequate explanation for the differing rotation periods, even for a gaseous object The sun's equator is inclined to the plane of the ecliptic by $7^d\ 10'.5$

Observations of the **continuous spectrum** from the sun and the application of the **laws of radiation** indicate that the effective temperature of the surface of the sun is about 5750° K From the value of the **solar constant** we calculate the rate of radiation from the surface of the sun as 80,500 **calories** per square centimeter per minute, equivalent to about 84,000 horsepower per square meter. Residents of northern climates will appreciate this amount of energy better when they realize that it would melt a sheet of ice forty feet thick in about one minute! The problem as to the source of this tremendous amount of energy is a vexing one, as is the whole problem of radiation from the stars Various theories regarding the conditions in the interior of a star and possible sources of the energy will be found discussed in the article on **stars.** In this article there will also be found a theory regarding the evolutionary process of the stars and hence of the sun (W K G)

SUN BITTERN. Aves, Gruiformes. A South American bird (**Aves**), *Europyga helias,* of moderate size, related to the cranes (A.W L)

SUN COMPASS. The sun compass is a device utilizing the direction of the sun for direction or orientation purposes The instrument operates on much the same principle as that of the **sun dial** In the sun dial the gnomon for casting the shadow is set accurately parallel to the earth's axis of rotation and the direction of the shadow indicates local apparent **time.** In the sun compass the dial is set for local apparent time and the direction of the shadow is used in connection with a **compass card.** In actual use the instrument is quite complicated, for it must be set for terrestrial **latitude, longitude,** and local apparent time It has been of great service in connection with flights in the polar regions of the earth, where the weakness and uncertainty of the horizontal component of the earth's magnetic field render the use of the magnetic **compass** very dangerous (W K G)

SUNDEWS. *Drosera* species **Insectivorous plants.**

SUN DIAL. It is logical to suppose that from the earliest times mankind has used the apparently moving sun as a means for reckoning time As the sun apparently moves across the heavens during the day the position and length of the shadow cast by an opaque rod will continually change The positions or lengths of this shadow may be used for the purpose of subdividing the period between sunrise and sunset Any device which utilizes the shadow cast by the sun for the purpose of subdividing the day into equal parts is known as a sun dial

It is difficult to say just when the first sun dial was constructed The earliest written record that we have is found in Isaiah XXXVIII 8, which was written approximately 700 years before the Christian era The earliest instrument which has come down to us is a device which was built in Egypt but for which the exact date of construction is unknown The first dial was constructed for Rome in about 146 B C Sun dials came into general use during the thirteenth century, and the development of the different types advanced rapidly following this period By the time that mechanical clocks and watches made their appearance in the eighteenth century a multitude of different types of sun dials had been constructed and many volumes written regarding the theory of the various devices

There are two fundamental types of sun dials. The most common type of fixed dial is that which marks the divisions of the day by the direction which the shadow of the sun has at any particular instant The dial itself may be set at any desired angle, but the most common is the type in which the plate is horizontal and the style, which casts the shadow, is so placed as to be parallel to the axis of rotation of the earth The second fundamental type of dial makes use of the fact that the length of the shadow of the sun varies throughout the day, being the shortest at noon and the longest at sunrise and sunset. Practically all portable sun dials are of this type. The great difficulty with this type of dial is that, because of the change in **declination** of the sun with **season,** it is necessary to have different scales of time for different periods of the year.

It is impossible in a work of this character to discuss the multitude of ingenious and beautiful types of sun dials that have been used in the past for the purpose of keeping time and are in use at present as ornaments or items of curiosity. In adjusting the horizontal type of sun dial, such as may be purchased from a number of dealers in garden supplies or curios, it is important to remember that the style should be parallel to the axis of the earth That is, it should lie exactly in the true north-south plane, and the north end should be so elevated that the angle which the style makes with the horizontal plate is equal to the latitude of the observer When properly adjusted the sun dial will read local apparent time This time will differ from that ordinarily kept by watches both by the **longitude** difference between the position of the dial and the **standard time meridian** and also by the **equation of time** (W K G)

SUNFISH. Pisces, Teleostei A name of varied uses, applied to fresh-water and marine fishes (**Pisces**) of three distinct forms and many species, all superficially similar in the short, high, and compressed body One species, *Lampris luna*, is found in the Mediterranean and the northern Atlantic It attains a length of four feet and is bluish with silver spots and red fins Another group of several species related to the globe fishes is characterized by the very short truncated tail and by the enormous size that they attain One species is known to reach a weight of 500 pounds These giant sunfishes are widely distributed in temperate and tropical seas

In marked contrast the familiar fresh-water sunfishes of North America are among the small pan fish related to the basses They vary from a maximum length of five inches to about ten The common sunfish or **pumpkin-seed** reaches about eight inches The various species are found in streams and ponds, especially the latter, and rank as superior food fish and fair game fish They take dry or wet flies and on light tackle are a valuable supplement to the larger bass in the waters of heavily settled areas (A W L)

SUNFLOWER. *Helianthus annuus* **Composite Family**

SUN SPIDER **Solpugida.**

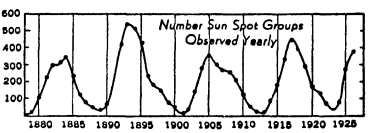
SUN SPOTS. As the term implies, sun spots are spots on the surface of the sun which make their appearance on the **photosphere** There is no record of when these phenomena were first observed Frequently, they are so large as to be seen with the unaided eye when the brilliancy of the sun is cut down either by thin clouds or by darkened glass There are Chinese records of sun spots long prior to the early part of the seventeenth century, when **Galileo** first observed them through his telescope

In the first place, it must be clearly understood that sun spots are not really dark They are merely darker than the surrounding regions of the photosphere, and, if the brilliant photosphere were not present, the sun spots themselves would appear intensely brilliant A typical sun spot has a dark irregularly shaped central portion known as the umbra, surrounded by a lighter region known as the penumbra Because of the distance of the sun, the smallest sun spots which can be observed must be at least 150 miles in diameter Spots with diameters of 40,000 to 50,000 miles are quite common, and instances have been recorded where a number of spots were so close together that the penumbra blended into one area nearly 150,000 miles across

Sun spots are usually relatively short lived About a quarter of them last but a single day, and as many again from two to four days In a few cases large spots have persisted for over a month, the longest case on record being a large group of spots which lasted for nearly eighteen months.

Sun spots confine themselves almost exclusively to the solar latitude zones between 5° and 40° north and south of the solar equator. The total number of spots on the surface of the sun varies, with a somewhat regular periodicity of approximately eleven years. The accompanying figure shows the total number of spots observed during each single year from 1879 to 1926. It will be noted that the shape of the curve and the interval between maxima and minima is not the same for each cycle Along with the variation in number of sun spots there goes a shift in the average location of the spots At the beginning of a cycle the spots are located at the outer regions of the latitude zones, i e, between 30° and 40° solar latitude As the number increases the maximum number of spots is located in about 16° latitude, and by the end of the cycle the spots are about 5° from the solar equator The beginning of the new cycle is heralded by the appearance of a few spots at considerable distance out from the equator.

Many attempts have been made to correlate the number of sun spots with all sorts of terrestrial phenomena The only certain correlation is between number of sun spots and electrical and magnetic disturb-



The Sun Spot number cycle The point for each represents the number of sun spot groups observed during that year The curve shows the roughly periodic variation in the numbers (From a diagram by Nicholson)

ances on the earth At the time of maximum sun spots there will be a maximum number of displays of **aurora** and magnetic storms At these times also there is considerable interference with telegraph lines and also with radio reception There is some little evidence that the mean temperature of the earth is about a degree lower at time of sun spot maximum Recent studies of rainfall data and growth of vegetation, as represented by tree rings, show a periodic variation with an eleven-year cycle

Sun spots are observed to have a distinctly whirling character, not unlike cyclonic storms in the atmosphere of the earth They are distinctly **magnetic** in character, spots in which the whirling motion is in one direction, all having one magnetic polarity, while spots whirling in the opposite direction will have the opposite magnetic polarity When two spots are observed relatively close together, as is frequently the case, the two are whirling in opposite directions, and hence have opposite magnetic polarity

It is believed that sun spots are caused by a whirling mass of gas just below the surface of the photosphere Hot gases are brought up until they break through the photosphere, where the sudden reduction in pressure causes them to cool and spread out over the surface, causing a relative darkening The influence of spots is felt clear out through the atmosphere of the sun, for at the time of sun spot maximum there is also a maximum number of **prominences.** The shape of the solar **corona** is also influenced by the number of spots on the surface of the sun In spite of the tremendous amount of attention that sun spots have received, there is no adequate explanation as to their origin (W K G)

SUNSTONE. **Feldspar.**

SUN-STROKE (HEAT STROKE OR HEAT EXHAUSTION). This condition is due to exposure to high temperatures The heat-regulating mechanism is overwhelmed and the resulting symptoms vary from almost instantaneous death to marked prostration. Un-

consciousness is usually present early in the attack. The temperature in the severe cases can rise to 109° F Beyond this point recovery usually does not take place The symptoms accompanying this condition resemble **surgical shock** (except for the high temperature) The milder degrees of sun-stroke usually produce weakness, dizziness, stupor, increased temperature, although at times the temperature may be subnormal

The treatment consists of cold baths, ice packs, stimulants, and in some cases phlebotomy and morphine If the patient survives for forty-eight hours, recovery is usually the rule. (R S M)

SUNU. Mammalia, Artiodactyla *Nesotragus* A large African **antelope** related to the sing-sing The species is black with white rings around the eyes and white under parts and ears The horns are long and thin (A W L)

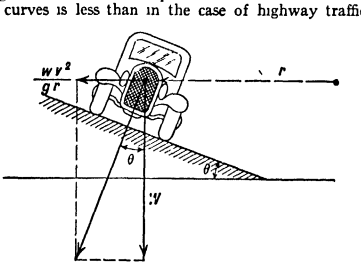
SUPERCHARGE. The power obtained from an **internal combustion engine** cylinder is dependent on the effectiveness with which the cylinder can be recharged on each suction stroke High rotative speed, heated charge, high altitude, and an obstructed intake, all conspire to create inefficiency in the induction The cause of this may be variously the desire to obtain maximum power by stepping up engine speed, operation at an altitude, as in mountains, or in aeronautical work, or the heating of the charge by carburetor heater, or hot intake passages These may be partially offset by supercharging Supercharging originated over twenty years ago, but did not receive much attention until after the World War During the war the supercharging of internal combustion engines received a great impetus through the development of the airplane supercharger This carried over into the field of Diesel engineering

High-performance **airplane** engines, and commercial engines designed for high altitude flying, are supercharged, and a built-in supercharger has become standard equipment on certain of the high-output models of radial engines The supercharging consists of compressing the mixture of rarefied air and gasoline delivered by the carburetor by means of a rotating impeller, so that the density of the charge entering the cylinder is more nearly that for which the engine was designed In this way the normal decrease of output of the gasoline engine at altitudes is eliminated except for the small amount of power required to drive the supercharger In some cases this power is derived from the exhaust gases driving a gas turbine, but this also represents a power drain on the engines, since it necessarily creates a higher back pressure on the exhaust system **Diesel engines** are sometimes supercharged to compensate for loss of capacity at high altitudes, or to increase the sea level power of an engine There is some use of supercharging in current stock automobile models The supercharging in this case is the result of an effort to increase the compression ratio of the engine, thus providing higher output per unit of cylinder volume, and higher thermal efficiency (F T M)

SUPERCONDUCTIVITY. An abnormally high electrical **conductivity** appearing quite abruptly in certain metals when cooled through a very low, characteristic transition temperature In 1911 Onnes, at Leyden, found that a column of frozen mercury with which he was experimenting, and which had a resistance of 0 084 ohm at 4 3° K, acquired a vanishingly small resistance (less than 0 000003 ohm) when cooled to 3° K The resistance was measured by the potential drop while carrying a known current The more familiar metals exhibiting this property are magnesium, zinc, cadmium, mercury, aluminum, tin (tetragonal only), and lead Alloys of these metals also show the effect, as do some alloys of metals not mentioned; e g, the alloy composed of two parts of gold and one of bismuth, also some compounds, as lead sulfide and tungsten carbide (though neither tungsten nor carbon is superconductive) The transition points are always within a very few degrees of absolute zero For columbium it is 9 2° K, for columbium carbide, 10 1° K, for magnesium it is only 0 7° K. The transition is sharper for metallic **monocrystals** than for microcrystalline masses

One of the most remarkable aspects of the phenomenon, discovered by Onnes and Tuyn, is the apparent "perpetual motion" of a current in a superconducting circuit, such as a lead ring immersed in liquid helium The current may be started inductively by cooling the metal in a magnetic field and then withdrawing the field, whereupon the current continues to flow indefinitely. If two points on such a ring are connected to a galvanometer and the ring parted between these points while it is thus conducting, the current will stop, but not until it causes a throw in the galvanometer The superconductive state may be removed, not only by heating but by applying a magnetic field of above a certain threshold intensity, or by using too strong a current Another curious phase may be described as the almost perfect diamagnetism of metals when superconductive, the magnetic **permeability** being reduced practically to zero These phenomena are not explained on any simple theory There is no evidence of any structural change, and the relations observed between superconductivity and thermal conductivity, specific heat, etc, at low temperatures do not throw much light on the question (L D W)

SUPERELEVATION When the plane of a roadway is tilted on a curve (commonly known as banked), it is said to be superelevated The purpose of superelevation is to permit a vehicle to round a curve on a roadway at high speed without danger of overturning or skidding The superelevation can be made so that the resultant of dead weight and centrifugal force passes through the vertical plane of symmetry of the vehicle In this condition, no side sway would be felt by the occupants However, the superelevation necessary to accomplish this is different for each vehicle speed, so that it is apparent that the superelevation of a highway presupposes an average vehicle speed The same is true of railways, although the variation of speeds with which the trains round curves is less than in the case of highway traffic



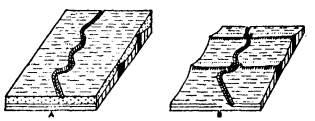
To illustrate how the superelevation depends upon vehicle speed, let it be assumed that an automobile approaches a curve on a highway at a speed of V (feet per second) If the radius of the turn is r, the centrifugal acceleration is $\frac{V^2}{r}$ Furthermore, assume that the weight is W pounds While negotiating the curve, the car is subject to two forces, one, the weight vertically downward, the other, centrifugal force acting horizontally away from the center of curvature, and having a magnitude $\frac{WV^2}{gr}$ The surface of the road must be perpendicular to this resultant for no side sway If superelevation is given as the angle of bank (see figure), the angle of superelevation

tion θ has a tangent equal to centrifugal force divided by weight. This tangent is $\frac{v^2}{gr}$, demonstrating that the superelevation must be made with respect to the radius of curvature and the velocity of the vehicle. It is independent of the dimensions and weight of the vehicle. (F.T.M.)

SUPERHEAT. Superheat is the addition of heat to produce **steam** at a higher temperature than saturation. Superheat is possible when the steam is led away from the water from which it was boiled. For this reason, superheaters are installed in **boilers** so that the final product may be elevated in temperature from 50 to 200 or 300 degrees Fahrenheit above the saturation temperature. The temperature added is called the degree of superheat, and the equipment to superheat is known as a superheater. The effectiveness with which a vapor may be employed as a working medium in a power cycle is enhanced by superheating it. The less erosive character of dry steam and the lower heat losses from pipes carrying dry steam, have made superheating very desirable, so that most boilers are equipped with superheaters at present. Superheaters are classified as convection or radiant types, depending upon whether they receive their heat from flue gas, or by direct radiation. Superheaters partaking of characteristics of both convection and radiation types are known as interdeck, because of their location between decks of boiler tubes. Superheaters are generally tubular in form, consisting of several bends of tubes connected in parallel between headers. The tubes are either small plain tubes, or large finned tubes equipped with a central core which prevents an unsuperheated core of steam moving down the center of the tube. Heat transfer in superheater tubes is not as good as in boilers, because of the failure of dry steam to wet the tube walls. Thus, steam must move through superheater tubes at high velocity in order to cool them sufficiently. A considerable friction loss ensues, but the resulting drop of pressure has to be accepted as necessary to create the required rate of heat transfer. (F.T.M.)

SUPERHETERODYNE. Receiver.

SUPERIMPOSED RIVER VALLEY. A river valley which is independent of present structural control may be described as either superimposed or antecedent.



Diagrams illustrating the development of a superimposed river valley.

In the former case it is implied that the river has been able to maintain its course across resistant structures such as ridges, because it started as a consequent stream and has been "let down" on the underlying or non-conformable structure. (R.M.F.)

SUPERLINGUA. Paragnatha.

SUPERSATURATED SOLUTION. Solutions.

SUPERSATURATED VAPOR. A supersaturated vapor is one which remains dry, although its heat content is less than that of dry and saturated steam at the pressure. Supersaturation is an unstable condition, and is found in the **steam** emerging from the nozzles of a **steam turbine.** The abnormality of the phenomenon is similar to that of supercooling. An experiment often performed in physics laboratories is the careful, slow cooling of water in a vessel absolutely free from vibration or motion. In a perfectly quiescent state, the water may be slowly cooled to below the normal freezing temperature without appearance of ice. In the supercooled state a slight jar on the containing vessel will immediately create a return to normal condition, with a rise of temperature to the freezing point, and the appearance of crystals of ice in the water. Supersaturation probably results from the very rapid expansion of steam in the nozzle, permitting the traverse of a short distance before the condensation of moisture is completed. At a certain definite point, however, known as the Williams limit, the supersaturation vanishes, and the steam regains the wet state which would be normal in view of the pressure and the heat content. Supersaturation of vapor is impossible in the presence of numerous changed ions or dust particles. (F.T.M.)

SUPERSONICS. Ultrasonics.

SUPRARENAL GLAND. Also called adrenal. **Endocrine gland.** (A.W.L.)

SURCHARGE. Retaining Wall.

SURFACE INTEGRAL OF VECTOR FUNCTION. Let $\mathbf{F}(\mathbf{r})$ be a **vector function** of the position vector $\mathbf{r}$, let S be a region on a curved **surface**, and let $\mathbf{n}$ be a unit normal vector, normal to S at any point of the region, and let θ be the angle between $\mathbf{F}$ and $\mathbf{n}$. Then the **surface integral** $\iint_S F \cos\theta \, dS$ is called the surface integral of the vector function $\mathbf{F}$, and is denoted by

$$\iint_S \mathbf{F} \cdot \hat{\mathbf{n}} \, dS. \qquad \text{(L.L.S.)}$$

SURFACE INTEGRALS. Let $f(x, y, z)$ be a **function** which is **continuous** within and on the boundary of a region S on a given curved **surface**. Let this region be divided up into n sub-regions ΔS_k, and let (x_k, y_k, z_k) denote any point in ΔS_k. Form the sum

$$\sum_{k=1}^{n} f(x_k, y_k, z_k)\Delta S_k = f(x_1, y_1, z_1)\Delta S_1 + \cdots + f(x_n, y_n, z_n)\Delta S_n.$$

The **limit** of this sum as each $\Delta S_k \to 0$ (and $n \to \infty$) is called the surface integral of $f(x, y, z)$ over the region S, and is denoted by

$$\iint_S f(x, y, z) dS.$$

Let $R(x, y, z)$ be a continuous function in a region S on a curved surface; divide S into sub-regions ΔS_k as before, and let $\Delta\sigma_k$ be the projection of ΔS_k on the XY-plane. Then the limit of the sum

$$\lim_{\Delta\sigma_k \to 0} \sum_{k=1}^{n} R(x_k, y_k, z_k)\Delta\sigma_k$$

is defined as a surface integral of $R(x, y, z)$ and may be denoted by $\iint_\sigma R(x, y, z) d\sigma$. In rectangular coordinates, the element $d\sigma$ becomes $dxdy$, and the integral is written $\iint_S R(x, y, z) dxdy$. Similarly we may define surface integrals $\iint_S Q(x, y, z) dzdx$ and $\iint_S P(x, y, z) dydz$.

These surface integrals usually occur in combination as a sum, usually written in the form

$$\iint_S (P dydz + Q dzdx + R dxdy). \qquad \text{(L.L.S.)}$$

SURFACE OF REVOLUTION. The surface generated by revolving a plane curve about a line lying in its plane is called a surface of revolution.

Examples are: the **sphere,** right circular **cylinder** and **cone, ellipsoid** of revolution, **hyperboloid** of one and of two sheets of revolution, and **paraboloid** of revolution.

To find the equation of a surface generated by revolving a curve in one of the coordinate plates about one of the axes in that plane Substitute in the equation of the curve the square root of the sum of the squares of the two variables not measured along the axis of revolut on for that one of these two var.ables which occurs in the equation of the curve. (L L S)

SURFACE TENSION. Fluid surfaces exhibit certain features resembling the properties of a stretched elastic membrane, hence the term surface tension Thus, one may lay a needle or a safety-razor blade upon the surface of water, and it will lie at rest in a shallow depression caused by its weight, much as if it were on a rubber air-cushion A soap bubble, likewise, tends to contract, and actually creates a pressure inside, somewhat after the manner of a rubber balloon The analogy is imperfect, however, since the tension in the rubber increases with the radius of the balloon, and the pressure inside, which would otherwise decrease, remains approximately constant; while the liquid "film tension" remains constant and the pressure in the bubble falls off as the bubble is blown

Whenever two dissimilar substances make contact at an interface, the inequalities of molecular attraction (cohesion), together with other forces in operation, tend to change the shape of the interface until, in accordance with the **least energy principle**, the potential energy of the whole molecular system attains a minimum value If both substances are fluid, the surface does actually adjust itself to this condition For example, a drop of oil suspended at rest in another liquid of the same density assumes a spherical form because the minimum-energy curvature is the same for all points of the surface But if the drop is rotating, centrifugal forces alter the equilibrium and the drop becomes spheroidal, or in the case of a drop hanging from the end of a pipette, gravity enters as a component and the drop becomes pear-shaped (See also **Capillarity.**)

In any case, the value of the surface tension at any interface is determined by the nature and the physical condition of the two substances in contact The surface tension of a liquid (against air) decreases with rising temperature An empirical formula known as the Eotvos-Ramsey-Shields law expresses it as proportional to $t_c - t - 6°$, in which t is the temperature of the liquid and t_c is its critical temperature, both in degrees centigrade According to Macleod, the surface tension of a liquid against its saturated vapor is expressed by $K(\rho_L - \rho_V)^4$, in which ρ_L and ρ_V are the densities of liquid and vapor and K is an approximate constant for a given substance At the critical point, when the densities become equal, the surface tension should be zero and thus no longer impede diffusion, this conclusion is in slight disagreement with the Eotvos-Ramsey-Shields law above (L D W)

SURFACES. A surface may be represented analytically by, (1) an **explicit** equation form $z = f(x,y)$, or (2) by an **implicit** equation form $F(x,y,z) = 0$, where x,y,z denote **rectangular coordinates,** or **spherical coordinates,** or **cylindrical coordinates,** or (3) by a set of **parametric equations** $x = f(u,v)$, $y = g(u,v)$, $z = h(u,v)$.

To study the surface defined by a given equation, find the traces of the surface on the coordinate planes, obtained by putting each coordinate x, y, z equal to 0 in turn, and then find sections of the surface by planes parallel to the coordinate planes, obtained by putting each coordinate equal to constant values in turn By putting together these plane sections, one obtains an idea of the nature of the surface (L.L S)

SURGE TANK. The surge tank is a water tank employed to absorb irregularities in flow It may be used where the total amount of water flowing around the closed cycle is constant, but where the volume passing one point in the cycle varies from that at another For example, in a condensing power plant, the rate at which feedwater is pumped back to the boiler may be different from that at which steam is supplied to the turbine, although the integrated flows over a definite time interval would be the same. A surge tank interposed between the point of discharge of condensate from the condenser, and the intake to the boiler feed pump, would have a water level which would rise and fall to take care of these irregularities, and in this surge of water in the tank there would be compensation for the different rates of flow

A hydro-electric plant is frequently provided with a surge tank which is attached to the **penstock** near the plant, by means of a vertical stand pipe The use of the surge tank is to cushion the penstock **water hammer** which would otherwise arise when turbine gates are suddenly closed The surge tank is doubly valuable to a penstock because it will not only absorb energy during the deceleration, but will also provide a ready reservoir from which the turbines can draw temporarily, as when they are started during normal operations, or when the sudden heavy demand causes rapid opening of the gates. (F T M)

SURICATE. Mammalia, Carnivora An animal of southern Africa, *Suricata tetradactyla,* related to the mongooses and with them belonging to the civet group It is of moderate size, gray with transverse dark bands on the back and a whitish crown, and has rather short legs It makes an interesting pet This species shares the name meerkat with one of the mongooses (A W L)

SURVEYING. This term covers the art of determining the shape, contour, position, or dimensions of any part of the earth's surface, and further, of representing this information on paper Maps and profiles are the usual method of representing the results of a survey The data from which these drawings are constructed is obtained by field work, which consists in measuring distances and angles both horizontal and vertical When the area surveyed is less than 100 square miles in extent, it is considered a plane surface, and the surveying of it is called plane surveying Surveys of larger tracts of the earth's surface must recognize the fact that the earth's surface is curved This class of surveying is known as geodetic surveying, and of necessity is more difficult and exacting However, in no case is a survey to be considered as an exact representation of the area which was surveyed All surveying is, of course, accurate precise work, necessitating the use of specially designed instruments However, the degree of precision obtainable varies with the class of survey and the need for precise results The precision attained in a survey is represented by percent of difference allowable in two measurements of the same distance, or allowed error of closure of a closed survey The many divisions of this subject are treated separately in this volume See **Maps, Azimuth, Bearings, Metes and Bounds, Land Subdivision, Level, Transit, Declination, Plane Table, Level Rod, Stadia, Differential, Curve, Tangent Offset, Topography, Contour, Compass, Triangulation, Traverse.** (F T M)

SURVIVAL OF THE FITTEST. Evolution.

SUSLIK. Gopher.

SUSSEXITE. The term proposed by J Kemp in 1892 for an igneous rock composed chiefly of **nepheline** and **aegirine,** and essentially free from **feldspar.** Type locality Sussex County, New Jersey (R M F)

SUSU. Dolphin.

SUTURE (1) The line of union of the adjacent flat bones making up the skull (2) The surgical sewing up of a wound or incision. Suture material is generally classified either as absorbable or non-absorbable. Absorbable suture material is made of either plain or chromic catgut. Non-absorbable suture material is

either silk, linen, fine wire, or strands of synthetic composition.

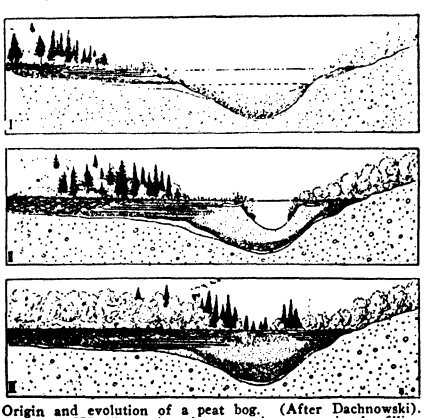
A fascial suture is a suture fashioned of a strip of **fascia** which is usually removed from the thigh where it covers the external muscles. Such sutures are often described as living sutures as they often act similarly to a graft. They are used principally in the repair of large **herniae** where the tissues are weak. (R.S.M.)

SWALLOW. Aves, Passeriformes. An insect-eating bird (**Aves**) with a short wide beak, long and relatively narrow wings, weak feet and legs, and usually a forked tail. The distribution of the swallows is worldwide. They constitute the well-marked family Hirundinidae.

The swallows' nests are built in burrows, holes in trees, and about human dwellings, hence some of the species are familiar friends. In North America the purple martin (*Progne subis*) is widely known from the large colonies that nest in bird houses year after year. Among the true swallows of this continent the barn swallow (*Hirundo erythrogaster*) is among the most beautiful and is undoubtedly the most widely known. The bank (*Riparia riparia*), cliff (*Petrochelidon albifrons*), and rough-winged (*Stelgidopteryx ruficollis*) swallows are also widely distributed and locally common, though less beautiful than the tree swallow and the western violet-green swallow (*Tachycineta thalassina*). The glossy blue and green shades of the upper parts of the last two species are very striking, but both species are found in wild areas, hence they are less familiar than those mentioned above. (A.W.L.)

SWALLOWTAIL. Insecta, Lepidoptera. A large **butterfly,** usually with slender tails extending from the hinder angles of the hind wings. The many species of swallowtails belong to the family Papilionidae. They are widely distributed in the tropical and temperate zones, especially in the former where some are very beautiful and brilliantly colored. Twenty-one species occur in North America. Most of them are yellow with black markings or vice versa but the common pawpaw swallowtail of the eastern and southern states is greenish-white with black bands and some red marks. Some of our species have metallic blue or green scales on the hind wings. Although some species lack the tails, they are also called swallowtails by association with the typical forms. (A.W.L.)

SWAMP. Where the flatness of the land, the presence of impervious soils or bed rock, or abnormal amounts of plant material obstruct or entirely prevent the normal drainage of an area, an excess of moisture will accumulate to the point of saturation and a swamp will come into existence. While most swamps are level this is not a necessary condition, for hillside swamps are by no means uncommon, due to a constant supply of percolating ground water which maintains the swampy condition.



Origin and evolution of a peat bog. (After Dachnowski). I, II and III, illustrating the successive stages in the filling of a pond by the growth of the peat bog. (Field, *Outline of Geology*, Barnes & Noble.)

Lake basins are occasionally filled with vegetation and sediment thus becoming swamps; these are frequently referred to as muskegs, a word of American Indian origin. Swamps may be formed on the flood plains of rivers as well as upon their deltas; they are characteristic of the flat ill drained areas of the Atlantic Coastal Plain, examples of which are the Great Dismal Swamp which covers about two thousand square miles in the states of Virginia and North Carolina, and the Everglades of Florida covering about four thousand square miles.

Coastal salt water swamps may develop in the zone between high and low tides or extend up river estuaries; examples of these are common along the Atlantic and Gulf coasts of the United States. In certain northern latitudes swamps develop into peat bogs. Peat bogs are an important source of fuel in Northern Europe, and also serve as an interesting illustration of the origin of **coal,** as exemplified in the **peat, lignite,** bituminous coal series. The accompanying figure illustrates the formation of a peat bog. (R.M.F.)

SWAN. Aves, Anseriformes. A large bird (**Aves**) related to the geese and of similar form and habits. They differ in the length of the neck, which is at least as long as the body in the swans. Although the more familiar species are white, some swans are marked with black and in Australia a species with almost entirely black plumage occurs. The two North American species, the whistling (*Cygnus columbianus*) and trumpeter (*C. buccinator*) swans, breed far to the north and are not often seen. The whistling swan also bears the name whooper in Europe. (A.W.L.)

SWEAT GLAND. A coiled tubular **gland** derived from the outer layer of the skin of **mammals** but extending into the inner layer. These glands are distributed over almost the entire surface of the body in man and many other species but are lacking from the skin of some marine and fur-bearing species.

The secretion of the sweat glands varies greatly. Human sweat is composed chiefly of water, with various salts and organic compounds in solution. It contains minute amounts of fatty materials, **urea,** and other wastes. In certain parts of the body the sweat glands are modified and produce wholly different secretions, including the wax of the outer ear. The sweat of other animals is normally different in composition from that of man.

The sweat glands perform an important function in the maintenance of body temperature by drawing heat from the surface of the body when the temperature of the air is too high to permit adequate radiation. Animals without sweat glands, such as the dog, accomplish the same result by panting, and so evaporating water from the moist lining of the oral cavity and **pharynx.** (A.W.L.)

SWEETBREAD. Originally the **thymus** gland of the calf as an article of food, and secondarily applied to the **pancreas.** The term now indicates the pancreas more often in popular usage. Both of these glands are to be regarded as delicacies which are not common enough to be of great dietary interest. The pancreas contains a fairly large amount of **vitamin B.** Otherwise neither gland is a valuable food save for its energy content. (A.W.L.)

SWEET FLAG. **Aroids.**

SWEET POTATO. *Ipomoea batatas.* Convolvulaceae. The plant is a trailing perennial, the stems of

which twine in sinistrorse direction around supporting objects. These stems arise from much thickened roots which are rich in **starch.** In cultivation many varieties have been developed, with many different leaf shapes. Dark green, heart-shaped leaves with shining surface occur in several varieties, while in others the leaves are variously lobed and dissected. The flowers, seldom produced in plants grown in northern latitudes, are about two inches across, purple, and borne either singly or in small axillary **cymes.** The fruit is a **capsule.**

Various methods of propagation are employed. Small roots may be planted whole, **adventitious buds** soon forming, and giving rise to shoots which appear above the ground in about four weeks. Root cuttings from growing plants may also be used, especially in regions where the growing season is long. On occasion stem cuttings may be used, but necessarily demand a long growing season and reach maturity very late in the season. Seed may be grown, but germination is slow and uneven, and the product not uniform.

The sweet potato is an American plant, a native of the West Indies and Central America. In cultivation it has gradually spread out of tropical lands, new varieties being developed to suit new localities. At present the crop is grown as far north as Cape Cod.

The principal use of the sweet potato is for human consumption, although some are fed to swine. The vines are frequently used as stock food. From the roots starch, flour, **glucose** and **alcohol** are extracted, to a limited extent.

Sweet potatoes are frequently called yams. This application of the name yam to the sweet potato is confusing, since the true yam is an entirely different plant, *Dioscorea batatas* (Dioscoreaceae), widely grown in tropical lands for its edible tubers, which are rich in sugar, watery, and soft when cooked. The flowers are white. Propagation is mainly by cuttings of tubers, each containing one or more eyes, or small buds, such as are found in the white potato tuber. Yams are widely used as food.

Another species of Ipomoea, *I. purpurea,* is the Morning Glory, frequently cultivated for its showy purple flowers. (R.M.W.)

SWIFT. 1. Reptilia, Sauria. **A lizard.** The name is applied without scientific accuracy to some of the **iguanas,** including small species of two different genera. Most of these lizards occur in the southwestern United States and Mexico but one species, the pine or fence lizard, *Sceloporus undulatus,* is found as far north as Michigan, New Jersey, and Oregon. 2. Aves, Micropodiformes. Small birds (**Aves**) with short wide beaks and long slender wings. They are superficially like the swallows but are more closely related to the hummingbirds. The numerous species of swifts are widely distributed in both hemispheres, five occurring in North America. The common chimney swift, *Chaetura pelagica,* which has abandoned its original habit of nesting in hollow trees to occupy our chimneys, is both widely distributed and abundant, while the remaining species are found only in the far west and southward. The swifts make their nests of various materials cemented together and fastened to their support with saliva, and one species of the Oriental region uses the secretion alone, without foreign materials. The nests of this species are attached to the walls of caves and are the famous edible bird nests of Chinese epicures. (A.W.L.)

Chimney swift, *Chaetura pelagica.* Sooty brown. Tail feathers sharply pointed. Long narrow wings.

SWIMMERET. The **biramous appendages** of the abdomen of a **crustacean.** Also called pleopods. (A.W.L.)

SWINE. Pig.

SWITCH. A switch is a device for making, breaking, or changing the connections of an **electric circuit.** A circuit breaker is a device constructed primarily for the interruption of a circuit under infrequent abnormal conditions. While the fuse is intended to protect against abnormal conditions of current it is not termed a circuit breaker or a switch.

There are many different types of switches. Not considering the numerous kinds of small snap switches, push button switches, instrument and control switches, the switches in common use are either knife switches, disconnecting switches (a type of knife switch), or oil switches. The knife switch may be single-, double-, or triple-pole, single- or double-throw, fused or plain, front-connected or back-connected. There are several special types such as field-discharge switches, motor-starting switches, quick-break switches, etc. The ordinary knife switch is arranged to be mounted on the front of the switchboard and thrown directly by hand. Rear mounted switches are operated by linkage connected to a handle projecting through the switchboard. These are used for higher voltages and for improved switchboard appearance. Knife switches are available in capacities up to 20,000 amperes and 750 volts. Like any other piece of electrical equipment, they must be selected and applied with due consideration to current carrying capacity and voltage rating.

The disconnecting switch (often called a "disconnect") is a form of knife switch used primarily to isolate apparatus for inspection or repair, or as a transfer switch so that connections may be changed. It is a switch for opening the circuit only after the current has been interrupted by other means.

Live parts of the oil switch are surrounded by oil retained in a tank. Oil switches are manually operated and not intended to be opened under other than normal load. (F.T.M.)

SWITCHBOARD. A power switchboard has one fundamental object—to distribute available electrical energy to one or more sources of load. Some of the fundamentals which are incorporated in a switchboard are:

1. The switching arrangements should not offer an undue risk to the men who will have to operate the switching apparatus, particularly under conditions arising from electrical failures of lines and apparatus.
2. The arrangement should provide for the economic operation of apparatus.
3. Simplicity is of utmost importance in switching equipment.
4. Coincident with simplicity there should be a reasonable degree of flexibility which has for its object the providing of some degree of continuity of service.
5. The mechanical arrangement and construction should be rugged and reliable.

The small switchboard and its supporting framework will provide a mounting for instruments, disconnecting switches, circuit breakers, generator and feeder control buses, and wiring.

The size of the panel is in keeping with the apparatus to be mounted thereon. Black marine finished slate is one of the most serviceable materials for switchboards. Natural black slate is used without the application of any artificial finish other than clear oil. Panel-supporting framework is made of angle iron or iron pipe.

The design of the rear of a switchboard is an indication of its real worth as an engineering production. Even more care is necessary than for the front as it is

here that the switchboard troubles most often occur, and the chance of their occurrence is multiplied if a careless or inconsistent design is adopted. It is a comparatively simple matter to produce a well-arranged, well-appearing front, but the rear of a board with its many details presents a problem which requires originality and systematic design on the part of the engineer, and a skilled and patient draftsman This is probably more true of the self-contained switchboard than of any other as the greater part, if not all, of the auxiliary apparatus is mounted upon or supported from the rear of the board This auxiliary apparatus consists chiefly of busbars, instrument wiring, instrument transformers, fuse blocks and fuses, main interconnections with their supports, instrument and discharge resistances and rheostats, but very often it is necessary that space be found for disconnecting switches, wattmeters, and relays

Considerable demand exists for the low-voltage board There is an increasing use of sheet steel panels in place of insulating panels for such service Among the advantages of the steel switchboards might be cited the dead-front construction, panel wiring completed at the factory, ease of shipping and installation, compactness, lower cost and lighter weight Two comparatively modern developments in switching emphasize this trend They are safety enclosed (or truck type) switchboard, and the metal-clad switchgear The truck type of equipment has busbars mounted in a steel housing completely fabricated at the factory, the design being such as to permit shipment so completely assembled as to reduce installation costs to the minimum The panel with circuit breaker, instrument transformers, relays, etc, is on a removable truck Housing and truck carry disconnecting devices for main and secondary circuits (F T M)

SWITCHING. Switching refers to the practice or policy used in connection with the subdivision and distribution of power from a central point to a number of radiating power lines Switching is practiced in most power stations, and in certain **substations** or switching centers There are three possible situations to be met, viz

1 Power may be distributed at the same voltage at which it is generated
2 Power may be distributed at a higher voltage than that generated
3 Power may be distributed at several voltages, one of which is the same as the generator

Naturally, switching employed to get the first named condition is simpler because it does not involve the use of transformers for changing voltage However, this switching arrangement is confined to small stations because ordinary transmission line voltages are very much higher than the usual generator voltage

The simplest switching arrangement possible is known as the single **bus** system A single bus is provided, to which are connected the generators and the feeder lines Both **generators** and feeders are connected to the bus through automatic circuit breakers and disconnecting switches For normal switching conditions, this simple arrangement will meet every requirement However, there is no flexibility, and the failure of any generator circuit requires the withdrawal of the corresponding machine and breaker from service. A double bus, single breaker system provides more flexibility at very little additional cost This switching arrangement is shown in Figure 1 Such an arrangement will eliminate the possibility of a long shut-down resulting from a bus failure It also permits maintaining service while working on either bus, such as cleaning the insulators, etc It does not, however, eliminate the necessity of withdrawing apparatus from service in case of trouble on the circuit breaker, and in some cases this system is extended to include a circuit breaker in the line to each bus

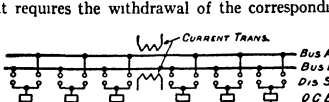


Figure 1 Double bus, single circuit breaker system.

In larger stations, or in more important switching centers, different types of switching systems have been developed, some of which are extremely complicated, but are justified by virtue of the service rendered A double bus, double breaker system, in which will be found both low and high tension buses, is shown in Figure 2 Here the outgoing lines (two in number) operate at a voltage higher than that of the generators (four) The increase of voltage is accomplished by transformers located between the high and low tension buses There are three transformers in parallel In this system the failure of any one bus, or any one circuit breaker, or any one disconnecting switch, will cause only momentary interruption of activity on that line, as in each case there is a spare unit The installation of duplicate equipment, or duplicate circuits, is very expensive, but the indirect cost to a power and light company of loss of customer goodwill through temporary interruptions of service, is considered great enough to justify such a switching system in the more important centers (F T M)

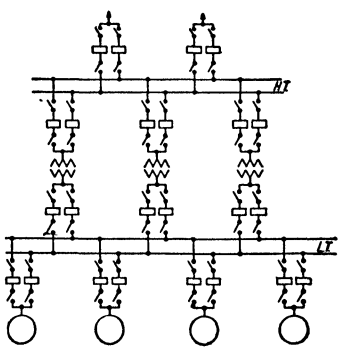


Figure 2 Bus system using double buses and double breakers

SWORD-BEARER. Insecta, Orthoptera A long-horned **grasshopper** of the group known as cone-headed grasshoppers from the conical prolongation of the head The sword-bearer is named from the long **ovipositor** of the female This organ is a slender slightly curved blade longer than the entire body The species is found in the northern states east of the Rockies (A W L)

SWORDFISH. Pisces, Teleostei A large marine fish (**Pisces**), *Xiphias gladius*, whose upper jaw is prolonged into a flat pointed process, the sword, about one-third the length of the body The dorsal fin is very large and scales are lacking These fishes reach a maximum length of about sixteen feet and a weight of several hundred pounds They are related to the sailfish

The sword is said to be used to spear larger prey and cases are on record of its being driven deep into the planking of wooden ships (A W L)

SWORDTAIL. Pisces, Teleostei *Xiphophorus*. A small fresh-water fish (**Pisces**) from Central America, popular among keepers of tropical aquaria The tail of the male is prolonged into a slender tapering lobe, straight or nearly so and sometimes longer than the body They belong to the **killifish** family (A W L)

SYCON. Porifera.

SYENITE. Syenite is a coarse grained, granular, therefore intrusive, **igneous rock** of the general composition of **granite** except that **quartz** is either absent or present in relatively small amount The **feldspars** are **alkaline** in character and the dark mineral is usually **hornblende.** Soda-lime feldspars may be present in small quantities The term syenite was originally applied to hornblende granite like that of Syene in Egypt from whence the name is derived Syenite is not a common rock, some of the more important occurrences being in New England, Arkansas, Montana, New York State (syenite gneisses), Switzerland, Germany and Norway (E S C S)

SYLVANITE. The mineral sylvanite is **telluride** of **gold** and **silver** approximating the formula $(Au,Ag)Te_2$ It is **monoclinic** occurring in bladed, columnar and granular forms as well as arborescent and branching It is a brittle mineral, hardness, 1 5–2, specific gravity, 7 9–8 3, luster, metallic, color and streak, steel gray to yellowish gray This mineral is found associated with gold and tellurides of gold and silver or with sulfides such as **pyrite.** It is found in Rumania, Australia, Colorado and California It was named for Rumanian Transylvania where it was first found

Krennerite is another telluride of gold and silver with a similar composition to sylvanite, but crystallizing in the orthorhombic system Calaverite is a gold telluride with only a small silver content (E S C S)

SYLVITE. The mineral sylvite is **potassium chloride,** KCl, occurring in cubes, or as cubes modified by **octahedra.** It is therefore **isometric** It has a perfect cubic cleavage, uneven fracture, is brittle, hardness, 2, specific gravity, 1 9, luster, vitreous, colorless when pure but may be white, bluish, yellowish or reddish due to impurities It is soluble It is much rarer than **halite** and has been found as sublimates at Mt Vesuvius and as bedded deposits at Stassfurt, Germany It is used as a source of potash salts Potassium chloride was called by the early chemists *Sal digestivus Sylvii* whence the name of the mineral (E S C S)

SYMBIOSIS. This name is applied to an association of two organisms in which each derives some benefit from the association The two organisms may both be plants Or one may be a plant, the other, an animal It is often difficult to determine exactly what each component gains when living together in this way When careful study shows that one organism gains much more than the other, the association is really one of parasitism A frequently cited example of true symbiosis is the **lichen,** a composite plant formed of a **fungus** and an **alga** growing together to produce an organism entirely unlike either component Here the fungus gains nutrient from the alga, presumably the alga gains protection and an increased supply of water However, it seems as though the fungus gained the greater benefit from its association with the alga Another example of symbiosis in which the two organisms are both plants is found in **mycorhizae.** Here fungus **hyphae** grow closely around or within the root tissues of some higher plant, which seemingly receives an increased supply of water and inorganic food materials from the presence of the fungus The latter obtains elaborated food stuffs Nodule-forming **bacteria** in roots may be considered an example of symbiosis

The dependence of plants on insects to effect **pollination** is not usually to be regarded as a case of symbiosis Symbiosis does, however, seem to exist in such plants as the **Yucca** and the **Fig,** which are entirely dependent on insects for pollination, while the **larva** of the insects live in the **ovary** and feed on the **ovules** of the plants pollinated Here obviously the two organisms are mutually benefited and dependent each on the other (See **Animal Association.**) (R M W)

SYMBOLS, CHEMICAL. Chemical Composition.

SYMMETRICAL or UNSYMMETRICAL FOLDS. Anticline.

SYMMETRY. The significance of this term in mathematics is treated in the article on **Locus of an Equation.** In zoology, symmetry is the arrangements of the parts of animal bodies in relation to centralized axes The bodies of some one-celled animals are asymmetrical and of others, notably the Heliozoa, spherically symmetrical with the hard parts of the skeleton radiating in various directions from a common center By far the most common forms of symmetry, however, are those known as radial and bilateral

Radial symmetry is especially common among the **sessile** animals such as **sea anemones** and the related **jellyfishes** whose movements are weak These animals have a principal axis passing through the mouth from which similar structures extend on several radii The same form of symmetry appears in the echinoderms although these animals begin life as bilaterally symmetrical larvae The radial symmetry of the adult accompanies sluggish movement and in some forms food-securing habits like those of sessile animals

Bilaterally symmetrical animals have similar halves flanking a median plane in the principal axis of the body Sense organs are concentrated near the end that goes first in locomotion, forming a head in which the mouth opens as a rule This end of the body is the cephalic end, in contrast with the opposite caudal end where the tail is attached in the vertebrates The originally upper and lower surfaces are also differentiated, since the animal rests on the latter while the former is exposed to surrounding influences, and the sides of the body are known as right and left This type of symmetry prevails in all actively moving animals

The value of each type of symmetry is clearly correlated with the mode of life in which it is found Sessile animals receive food and are subjected to dangers only when the responsible factors approach under their own powers of locomotion or on currents in the water It is an advantage to the animal to be able to perceive such factors as easily in one direction as another Bilaterally symmetrical animals move about in search of food, hence the end of the body that normally goes first has the chief need of powers of perception, while the upper and lower surfaces are exposed to different environmental conditions and the sides are similar in their contacts. (A W L)

SYMPATHETIC NERVOUS SYSTEM. Autonomic Nervous System.

SYMPHYLA. Small and rare animals living in moist debris at the surface of the ground They are related to primitive **insects** and **centipedes** and are usually regarded as a class of the phylum **Arthropoda** They have a pair of antennae but no eyes The segments of the body are well marked, bearing eleven or twelve pairs of legs The animals breathe by **tracheae.** (A W L)

SYNAPSE. The association between nerve cells of animals above the **coelenterates.** In coelenterates the nerve net is made up of cells whose processes are structurally connected but in the higher **nervous systems** the fine terminal branches of nerve processes merely come into close contact with those of adjacent cells While some structural continuity persists in these animals, the synaptic association is regarded as an important foundation for the highly specialized type of nervous coordination that reaches its most complex state in man (A W L)

SYNAPSIS. Meiosis.

SYNCARIDA. Crustacea.

SYNCHRONOUS CONVERTER. The rotary converter is a machine for converting alternating current into

direct current. The machine is able, also, to convert direct to alternating current, and when so operated, is called an inverted converter The rotary converter and the motor generator set compose equipment which accomplishes the conversion of alternating and direct current by rotation Other means, such as mechanical rectification and **mercury arcs**, are often used to rectify small currents, but large power conversions are always accomplished by rotary equipment, generally by rotary converters, since they are so much more compact and efficient than a motor generator As is explained under the heading of **generator**, the voltage induced in the windings of a direct current generator is alternating Therefore if the coils are properly connected with taps which are brought out to slip rings, alternating current may be taken from the slip rings Now since a direct current generator, shunt wound, may be operated as a motor, and since a synchronous generator may be operated as a synchronous motor, theoretically at least, the direct current generator with taps and slip rings added, could operate as direct-current motor, direct-current generator, alternating-current synchronous motor, or alternating-current synchronous generator, or, in combination, as alternating-current motor and direct-current generator, or direct-current motor and alternating-current generator The last two cases are rotary converters, one direct, the other inverted The design of the direct-current generator which forms the basis of the converter is quite different from that of an ordinary generator, and while, theoretically, the converter could be made by merely adding slip rings and taps to a direct-current generator, actually there is considerable difference between the design of a converter and either a direct-current generator or direct-current motor

The **armature** currents are smaller than that either of the equivalent motor or generator, because the conductors have only to carry a current which could be considered to be the difference between the direct current produced and the alternating current supplied to the motor Thus heating loss and other internal characteristics are different from that of a motor generator set To start the converter, that is, to bring it up to synchronous speed, it may be motored either from the direct current or alternating current side, or separately driven by a small motor When started as an induction motor, it must of necessity be a polyphase converter, and certain precautions must be observed to prevent short circuit of armature coils by interpole action, to synchronize at proper polarity, and to open the shunt field winding (F T M)

SYNCHRONOUS MOTOR. Motor.

SYNCLINE. The syncline is a structure in which the strata are bent downward in an inverted arch, the sides of which are designated the limbs The syncline may be a broad open fold or tightly compressed with steep dips, and **pitch** either upward or downward (R M F)

SYNCLINORIUM. Anticlinorium.

SYNCOPE. A fainting spell, in which the unconsciousness is due to a temporary cerebral anemia, i e, insufficient circulation of blood in the **brain.** (R S M)

SYNCYTIUM. A mass of **protoplasm** containing many **nuclei**, not separated by cell boundaries In some cases the syncytium is a network in which partially distinct cell bodies are connected by protoplasmic strands while in others the mass is broadly continuous The nerve net of the jellyfishes is an example of the former type and the plasmodium of Mycetozoa (**Sarcodina**) is a conspicuous illustration of the latter The plasmodium is formed by the joining of separate cells The formation of syncytia by repeated nuclear subdivision without accompanying division of the **cytoplasm** has also been observed (A W L)

SYNDROME. A group of symptoms characterizing or occurring in any abnormal state or disease (R S M)

SYNECOLOGY. Autecology.

SYNGAMY. A synonym of **conjugation.**

SYNGENETIC. Epigenetic.

SYNODIC PERIOD. The synodic period of any member of the **solar system** is the time required for the object to go from some particular position relative to the sun as seen from the earth back to the same position again In the case of the **moon** the synodic period is the time required for the moon to go from **conjunction,** or new moon, back to conjunction again This period of approximately 29 5 days is the original **month** as used by ancient astronomers in the construction of the **calendar**

Since a **planet** is best observed at **opposition,** the synodic period of the planet gives the interval of time between successive positions of favorable observation The synodic period is related to the sidereal period, i e, the actual period of revolution of an object about the sun, by a simple relationship

Let P be the sidereal period of the object,
S the synodic period of the same object,
E the sidereal period of the earth (approximately 365 25 days),

Then $1/S = 1/P - 1/E$ for planets with orbits inside that of the earth,
$1/S = 1/E - 1/P$ for planets with orbits outside that of the earth

(W.K G)

SYNOVIA. The transparent sticky fluid contained in a joint cavity, or tendon sheath It is secreted by the synovial membrane, the shiny smooth lining membrane of a joint or tendon sheath The fluid serves as a lubricant to the joint or tendon so that no friction occurs between opposing surfaces (R S M)

SYNOVITIS. Inflammation of a **synovial** membrane characterized by an increase in synovial fluid and pain about the part If the fluid in a joint becomes infected a suppurating joint is present requiring surgical treatment to drain the pus from the joint (R S M)

SYNTEXIS. The term proposed by Loewinson-Lessing, in 1899, for the generation of **magmas** either by remelting or assimilation of portions of the **lithosphere** regardless of the type or variation of its lithology Contrast with **anatexis.** (R M F)

SYNTHETIC DIVISION. Synthetic division is an abbreviated process using detached coefficients for finding the **quotient** of a **polynomial** in one variable x by a divisor of the form $x - r$, where r is a constant It may be indicated thus

To divide the polynomial $a_0x^4 + a_1x^3 + a_2x^2 + a_3x + a_4$ by $x - r$, the following scheme is computed

a_0	a_1	a_2	a_3	a_4	$\lfloor r$
	a_0r	A_1r	A_2r	A_3r	
$a_0,$	$A_1 = a_0r + a_1,$	$A_2 = A_1r + a_2,$	$A_3 = A_2r + a_3,$	$R = A_3r + a_4$	

Then the quotient is $a_0x^3 + A_1x^2 + A_2x + A_3$ and the remainder is R A similar process applies to a polynomial of any other degree

The synthetic division process may be described in words by the following rule

To divide a polynomial in one variable x by a binomial divisor of the form $x - r$, arrange the polynomial in descending powers of x, as $a_0x^n + a_1x^{n-1} + \cdots + a_{n-1}x + a_n$.

Arrange the detached coefficients a_0, a_1, . . , a_n in order in the first line, supplying any missing power of x with a zero coefficient, and write r at the right

Bring down a_0 in the first place in the third line. tiply a_0 by r, write the product in the second line i a_1, and write their sum in the third line directly underneath, multiply this sum by r, add the product to a_2, and write the sum underneath in the third line, etc, continuing in the same way until finally a product is added to the last coefficient a_n.

Then the last sum in the third line is the remainder, and the preceding sums are the coefficients of the powers of x in the quotient, beginning with x^{n-1} and arranged in descending order

If the remainder in this synthetic process is zero, the divisor is shown to be a factor of the given polynomial (L L S)

SYNTHETIC SUBSTITUTION. If the **synthetic division** process is carried out with a **polynomial** $P(x)$ and a divisor $x - r$, by the **remainder theorem** the last result R is the value $P(r)$ of the polynomial $P(x)$ when we substitute r for x, in this case, if we are concerned only with the remainder R (and not with the quotient), we may call the process synthetic substitution (L L S)

SYPHILIS. A chronic infectious systemic disease caused by the *Spirocheta pallida*, which may attack any organ or tissue in the body The organism shows a decided preference for the circulatory, nervous and bone systems and is the origin of many chronic constitutional diseases The disease appears in two forms, as acquired and as congenital syphilis, the latter being transmitted through the mother

The organism causing the disease is a small curved spiral form which is actively motile in fresh specimens Little is known about the life history of the parasite It can live throughout the life of man within the body tissues in a latent form and become an active or potential menace to life many years after the inception of the disease

There are two schools of thought as to the history of syphilis One school believes that it was introduced in Europe in 1493 by the Colombian sailors from the New World where they acquired it from the natives This is probably correct The other school believes that it has existed since ancient times. Up to the nineteenth century, syphilis and **gonorrhea** were thought to be the same disease In 1905 Schaudeim discovered the organism and thereby proved that syphilis and gonorrhea were separate diseases In 1910 Ehrlich discovered the arsenical compound "606," a specific for the destruction of spirochetes

The great majority of cases of syphilis are spread by promiscuous sexual intercourse A relatively small number of cases are spread by extra-genital modes Lip infection is the most common of these and is spread by the latter route through contaminated glasses, kissing, etc Nearly all prostitutes have syphilis and it is exceedingly rare for one to escape the disease for longer than a few months Syphilis may be innocently acquired, but it occurs infrequently and forms only a very small percentage of the cases Extra-genital infection is not always innocently acquired

Congenital syphilis is not inherited but is transmitted from the mother through the central circulation during intra-uterine life The mother may seem quite healthy after the birth of a syphilitic child, but a Wassermann test done on the mother's blood will be positive for syphilis At least ten to twenty percent of the inhabitants of all civilized countries have syphilis

The syphilitic organism is peculiar in that there are several strains of the organism, differing in their invasiveness or malignancy to the human body Certain strains of the organism have a predilection or affinity for certain kinds of tissue in the body. For instance, certain strains predominantly attack the nervous, the arterial, skin or osseous systems.

In a person exposed to syphilis, the organisms gain entry through an abraded surface usually some portion of the genital organs In the male it is usually found on the penis and is usually easily seen In the female it is found either on the mucous surface of the **vulva** or within the **vagina** where it may remain unnoticed.

The initial lesion, the chancre, appears at the site of the invaded area It develops within from two to four weeks after infection Before the chancre develops the organisms may have invaded the body tissues by way of the blood stream A fully developed chancre varies in shape, size and form, but in general is a raised, indurated hard nodular area This nodular area ulcerates in its center and a thin secretion is given off which is highly infectious By means of microscopic examination using the dark field, this secretion is found to teem with spirochetes The presence of the chancre marks the primary stage of syphilis If active treatment is begun and faithfully carried out, the best chance of a clinical cure occurs during this stage

The adjacent **lymph glands** usually become enlarged and tender although the chancre itself causes no pain. When a typical chancre has healed a scar usually remains at its site

During this primary stage, the spirochete may be spread throughout the system Organisms attacking the spinal cord or brain may remain dormant and not cause symptoms for as long as twenty to twenty-five years when locomotor **ataxia** or **paresis** develops Those organisms lodging in the circulatory system may go through a similar latent period before causing circulatory diseases

The secondary stage usually begins within three months after the primary chancre and is marked by constitutional symptoms that vary markedly in degree These symptoms result from the extreme degree of invasion of the tissues of the body by the parasite It is marked by fever, slight or extreme, moderate **anemia**, and a skin eruption The skin eruption is peculiar in that it may assume many varied forms It may resemble the skin eruption of measles, scarlet fever, or any of the other diseases that are characterized by skin lesions It may appear to be identical with chicken pox, smallpox, or the lesions of acne There is no skin disease that syphilis cannot simulate It may appear early or late, affect only a part of the body surface, may last for a few weeks, months, or even longer, or it may be absent altogether Other skin lesions that may occur are ulcerations of the skin on any mucous membrane surface of the body Pustular lesions are also seen

With the secondary stage it is common to have a sore throat with ulceration of the tonsils There is some enlargement of most of the superficial lymph nodes of the body **Arthritis** and inflammation of bones is seen Headache is common and usually indicates that the central nervous system has been involved

The tertiary stage is not sharply demarcated from the secondary stage The secondary stage may merge into the tertiary or several years of seeming health may intervene It is in this stage that heart and arterial damage first begin their symptoms as a rule The late skin lesions occurring in this stage show a great tendency to ulceration **Gumma** formation is typical—tumor-like masses of soft, gummy granulation tissue These may occur on the skin or in any tissue or organ of the body Occurring internally they may be mistaken for cancer The history of other syphilitic manifestations, a positive Wassermann test, and their disappearance with antisyphilitic treatment differentiates them from other growths Syphilis of the bones is common in this stage—**periostitis, osteomylitis** and other types of bone involvement Any organ in the body may be involved during this stage causing a disease picture resembling any disorder seen in medicine

The quaternary stage Many years after active manifestations of syphilis mentioned above, involvement of the brain or spinal cord, may occur The most common forms are locomotor ataxia and general paresis and are discussed separately

Congenital syphilis is the most frequent cause of death of the **fetus** in the last half of pregnancy. The mother

may have syphilis before or acquired it after conception. In any case it is passed to the child through the **placenta.** Those that are not born dead may appear healthy or may show well-marked evidence of the disease. Any form of the acquired form of syphilis, except the chancre may be seen in congenital syphilis.

When the disease is fully developed in the child at birth, a skin eruption is usually present and the child is poorly developed and emaciated. While all the organs may be involved, the **spleen, liver** and **bones,** besides the skin, show the greatest changes. The infant seldom lives long.

Other infants may appear healthy, showing no abnormality, and active syphilis develops after the second month. Catarrh of the nose, severe ulceration of the skin, falling out of hair or nails, hemorrhages, and internal lesions are some of the signs of active syphilis.

Those cases that survive and those that have a latent congenital syphilis show certain signs at any age that make the diagnosis apparent at a glance. Deformed teeth (Hutchinson's teeth) are often seen—teeth that may be notched, peg-shaped, narrow at the cutting edge or otherwise deformed. Definite bone disease, eye affections, arthritis, mental impairment, or internal lesions may be present, either singly or together. The brain and nervous system lesions are similar in character to those of acquired syphilis.

Syphilis may be carried through as many generations as are able to reproduce.

The outlook in syphilis depends on many factors, such as the duration and degree of the disease, the stage of the disease during which the treatment was begun, the resistance of the individual, the virileness of the strain of spirochete, and the habits of the patient. To be successful, treatment must be begun early and must be sufficiently intense. Ideally, all spirochetes in the body should be killed. Doubt exists, however, whether even by extensive treatment this occurs in all cases, even though they seem clinically cured. If syphilis is treated in the primary stage, a cure can be generally assured with sufficient treatment. If it is begun in the second, a cure is possible, although obtained with difficulty. In latent and tertiary cases the disease can often be arrested. In frank neural-syphilis response is not obtained with ordinary treatment and arresting of the disease is sought by special means and with great difficulty.

Cases of latent syphilis are discovered only by routine examination which includes blood tests, or through giving active syphilis to others. A person having latent syphilis may not have any of the signs or symptoms of syphilis that are recognized Cases that have been clinically cured and show a negative blood test may still develop syphilis of the central nervous system.

The principal drugs used in the treatment of syphilis are **mercury, iodides, bismuth,** and the various **arsenical** derivatives. Mercury is the oldest drug used in syphilis. While it may not destroy all the parasites, it represses their growth. It is primarily used because of its slow action as an accessory to the more rapid and powerful arsenic compounds. It is given either by needle, intramuscularly, or by rubbing in on the skin.

The arsenic derivatives, arsphenamine (606) (Salvarsan), neo-arsphenamine (Neo-salvarsan) are powerful, quick-acting spirocheticides. Their use will render an infectious person non-infectious in the shortest possible time. Other modifications of arsenic derivatives besides those mentioned above are used in special forms of syphilis, particularly of the central nervous system.

The average case of early syphilis should receive active treatment for a minimum period of eighteen months The patient should be checked for at least three years with tests of the blood and spinal fluid. Examination of spinal fluid is important (Wassermann and Kahn tests) for, while the blood tests may be negative, the spinal fluid may still be positive.

As to syphilis and marriage, decision is often difficult. The earliest possible minimum is three years after infection with the most intensive treatment begun early. In later stages of syphilis there is always the chance of infection, in some cases no matter how intensive the treatment.

As to life insurance in a treated or untreated syphilitic the risk to the company is definitely increased. (R S M)

SYSTEM. For the use of this term in geology, see **Period.**

SYSTEMIC HEART. The principal **heart** of the **cephalopod** mollusks, in contrast with the supplementary **branchial hearts.** The systemic heart includes two or four auricles which receive blood from the gills. The blood passes from the thin-walled auricles into a single muscular ventricle whose contractions propel the liquid through the arteries to the body. (A.W L.)

SYSTEMS OF ALGEBRAIC EQUATIONS. In the consideration of **equations** with more than one unknown, we may deal with single equations in several unknowns or with systems of such equations.

An **algebraic equation** with more than one unknown will, in general, be satisfied by an unlimited number of sets of values of the unknowns; such an equation is called an indeterminate equation

A set of algebraic equations with more than one unknown is said to form a system when the equations are considered together with the object of determining whether they are satisfied by one or more sets of values of the unknowns. The term "simultaneous equations" is often used to mean a system of equations.

A solution of a system of equations with more than one unknown is any set of corresponding values of the unknowns which satisfy the equations of the system. (L L S.)

SYSTEMS OF CIRCLES. Circle.

SYSTEMS OF EQUATIONS INVOLVING QUADRATICS. Quadratic Equations, Systems of.

SYSTEMS OF LINEAR ALGEBRAIC EQUATIONS. Linear Equations, Systems of.

SYSTEMS OF LINEAR DIFFERENTIAL EQUATIONS. Linear Differential Equations.

SYSTEMS OF LINES. Straight Line in a Plane.

SYSTEMS OF LOGARITHMS. Logarithms.

SYSTOLE. That period during which the **heart** muscle is contracting and the blood expelled from the ventricles of the heart into the aorta and arterial system (Compare **diastole**). (R.S.M.)

T

TABES. (1) A progressive wasting of the body or part of it. (2) *Tabes dorsalis* or locomotor **ataxia** is a syphilitic infection of the **spinal cord.** This form of syphilis occurs in about 5% of untreated syphilitics around the ages of 25 to 40 years, that is from 8 to 15 years after the original syphilitic infection. Cure is extremely difficult and often impossible. The longer the infection has been present the less chance there is of a cure or even of arresting the disease.

The symptoms of spinal cord **syphilis** are numerous and do not make their appearance in any set order. The first group of symptoms usually noticed are: (1) lightning pains, that is, severe shooting pains of a few seconds' duration, usually of the leg (or prolonged pains resembling "rheumatism"; (2) Absence of knee jerks; (3) Fixed and irregular pupils; (4) Difficulty in urination.

The second stage symptoms merge gradually with the first so that in addition to the foregoing symptom difficulty in walking and incoordination of all forms of muscular movement gradually increase The walk is often characteristic. The foot is raised high, thrown forward forcibly, and slapped to the ground.

In the last or third stage paralysis often occurs. There is increased mobility about the joints producing a "flail" joint Eye symptoms sometimes lead to blindness Impotence is usual. Paroxysms of acute pain simulating surgical lesions occur in various abdominal organs. These may last several days and may be accompanied by vomiting. Perforating ulcers appear on the feet, muscular wasting, weakness, and loss of control of muscle, progresses and death occurs finally from some terminal infection such as pneumonia.

The diagnosis is made from the symptoms, physical signs, and serologic tests of the blood and spinal fluid.

Treatment is carried out in courses lasting several years. The various anti-syphilitic drugs are used intramuscularly, intravenously and intra-spinally. In cases not responding to this form of treatment, the patient is inoculated with **malaria.** The high fever produced by this disease sometimes checks the syphilis of the nervous system. It is more often used with paresis which may also be present with *tabes dorsalis* The malaria is then cured with **quinine.** Other forms of fever therapy are used. (R.S.M.)

TACHYLYTE or **TACHYLITE.** Pure tachylite is a natural, **basic** black glass which may form along the chilled contacts of **dikes** or **sills.** It also occurs as a rind on basic **pillow lavas** which have been suddenly chilled by plunging into water. Occasionally it forms entire flows from certain Hawaiian volcanoes. (R.M.F.)

TACONIC REVOLUTION. Ordovician.

TACTILE ORGANS. Organs of touch. Sensory organs located at the surface of the body which are stimulated by pressure. The chief tactile organs of the human body are known as tactile corpuscles. They consist of an elliptical bulb about 1/300 inch or less in length, enclosed in a connective tissue sheath and divided incompletely by plates of the same tissue From one to several coarse nerve fibers enter the corpuscle and follow a winding course inside, ending between or on the connective tissue cells. These corpuscles are especially abundant in the skin of the finger tips and in other parts where the sense of touch is highly developed, hence there can be no reasonable doubt that they serve this sense They are related to other corpuscles of more limited occurrence which may also be tactile, and are supplemented in the skin by free nerve endings, some of them expanded into disklike nets, which are regarded as tactile.

In many invertebrates hairlike projections at the surface of the body serve for ready reception of tactile stimuli and in the vertebrates true hairs, often bristlelike, transmit such stimuli to the nerve endings at their bases. From the sensitiveness of the human scalp to light contacts transmitted through erect hairs it is easy to judge the value of these tactile hairs. They are well illustrated by the whiskers or vibrissae of the cat and other mammals. (A.W.L.)

TAGMA. Body regions of **Arthropoda.** The bodies of these animals consist typically of the head, **thorax,** and abdomen but many forms show a confluence of parts or further subdivision. The **centipedes** and millipedes (**Diplopoda**), with a few related forms, have only a head and a long segmented body also called the trunk. **Arachnida** and **Crustacea** have a **cephalothorax** or prosoma in which the segments belonging to the head and thorax are not sharply separated, and a segmented abdomen or opisthosoma Subdivisions of the abdomen such as appear in the centipedes are the anterior **mesosoma** and the posterior **metasoma,** sometimes called the postabdomen. The plural of tagma is tagmata (A.W.L.)

TAHR. Mammalia, Artiodactyla. A wild **goat,** *Hemitragus jemlaicus,* of the Himalayas. This species, together with two other Asiatic species, differs from the typical goats in the lack of a beard. It is found in forested regions at high altitudes but does not enter the open country of Tibet. (A.W.L.)

TAIL. A solid prolongation of the axis of the vertebrate body at the end opposite to the head. The tail contains a portion of the spinal column together with blood vessels, nerves and muscles, but it is entirely posterior to the body cavity which is confined to the trunk. By association with the tail, this end of the body is known as the caudal end, a term applied to all bilaterally symmetrical animals. Many caudal appendages are called tails by a similar association, although they are not true tails. Thus the tail of the fish in the ordinary use of the term is properly the tail fin.

The tails of many **vertebrates** are without apparent value but in some of the **primates** they are prehensile appendages, used in climbing, and the hoofed animals use them in driving away insects. The tail of the **alligator** is an effective weapon. (A.W.L.)

TAKIN. Mammalia, Artiodactyla. A hoofed animal, *Budorcas taxicolor,* found in eastern Tibet and adjacent regions It is a moderately large animal of heavy build, with strong curved horns. Related to the goats. (A.W.L.)

TALC. The mineral talc is a **magnesium silicate** corresponding to the formula $H_2Mg_3(SiO_3)_4$ which occurs as **foliated** to fibrous masses, its **monoclinic** crystals being so rare as to be almost unknown. It has a perfect basal cleavage the folia non-elastic although slightly flexible; it is sectile and very soft; hardness, 1; specific gravity, 2.5–2.8; luster, waxlike or pearly; color, white to gray or green; translucent to opaque. It has a distinctly greasy feel Talc is a **metamorphic** mineral resulting from the alteration of silicates of magnesium like **pyroxenes, amphiboles, olivine** and similar minerals. It is found chiefly in the metamorphic rocks, often those of a more basic type due to the alteration of the minerals above mentioned. Of the many foreign localities may

be mentioned the Austrian Tyrol, the St. Gotthard district of Switzerland, Bavaria and Cornwall, England. In Canada talc is found in Brome County, Quebec and Hastings County, Ontario. In the United States well known localities are to be found in Vermont, New Hampshire, Massachusetts, Rhode Island, New York, Pennsylvania, Maryland and North Carolina

A coarse grayish green talc rock has been called soapstone or steatite and was formerly much used for stoves, sinks, electrical switchboards, etc Talc finds much use as a cosmetic, for lubricants and as a filler in paper manufacturing Most tailor's "chalk" consists of talc. The origin of the word talc is not definitely known. (E S.C S)

TALUS. The mass of coarse rock fragments which accumulate at the foot of a cliff as a result of the processes of weathering and gravity In Great Britain the term scree is used for such material. (R M F)

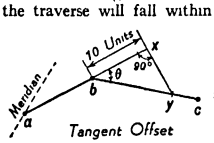
TAMANDUA. Mammalia, Edentata The lesser **anteater** of Central and South America, a species related to the great anteater and of similar form It differs in the short-haired prehensile tail, which is used in climbing The name is that of the genus, derived from the Portuguese (A W L)

TAMARAO. Mammalia, Artiodactyla A small **buffalo** native to the island Mindora in the Philippines It is related to the Indian buffalo and to the anoa (A W L)

TANAGER. Aves, Passeriformes An American bird (**Aves**) of brilliant coloration, related to the finches The tanagers are chiefly birds of the Central and South American tropics, where about four hundred species are found Of the few species that enter the United States only the scarlet tanager, *Piranga erythromelas*, is widely known The brilliant red of its body, contrasting with the black wings and tail, makes it one of our most striking species The dull olive plumage of the female exemplifies a common contrast between the sexes in the entire group (A W L)

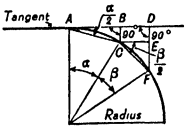
TANAIDACEA. Crustacea.

TANGENT OFFSET A method occasionally used by surveyors to reduce field notes or area or route surveys to map form is known as plotting by "tangent offsets" A small scale sketch of the **traverse** made with a protractor and scale, will greatly facilitate the plotting since it serves as a guide for locating the initial line so that the traverse will fall within the limits of the paper



Tangent Offset
Figure 1

The use of tangent offsets is illustrated in Figure 1 The initial line *ab* is located by means of the sketch mentioned above and prolonged a distance of 10 units to a point *x* where a perpendicular is erected The line *xy*, equal to the natural tangent of angle θ multiplied by 10 units, is then plotted on the perpendicular The angle θ may be obtained by direct measurement of the **deflection** angles in the field or by taking the difference of the **bearings** or **azimuths** of the two lines A line connecting *b* and *y* will give the direction of *bc* and serves as a base upon which to lay off the distance from *b* to *c* as measured in the field Each successive course may be plotted in relation to the preceding course by the method just described To avoid errors in plotting it is well to occasionally check the bearing of a particular line in relation to a fixed meridian by means of scaled distances.



Offsets from the Tangent
Figure 2

A method known as "offsets from the tangent" is frequently used for laying out **circular curves** in the field. The geometry of the method is illustrated in Figure 2. In order to lay out the curve it is necessary to locate points such as *C* and *F* in respect to the tangent through *A* which is the point where the curve begins. A transit is set up at *A*, sighted in the direction of the tangent *AD*, and points *B* and *D* located by taped distances The transit is then set up over *B*, sighted back on *A* and a 90 degree angle turned The tangent offset *BC* is taped which locates point *C* Point *F* may be located in a similar manner The coordinates used in the field operations are calculated from assumed **chord** lengths such as *AC* and *CF* which fix the value of the angles α and β respectively when the radius of the curve is given This method of locating a curve is of great advantage when accurate results are not needed In this case the right angles at *B* and *D* are estimated by eye resulting in a minimum use of the transit (C W C)

TANGENT PLANE TO A SURFACE. A straight line is said to be tangent to a surface at a given point *P* if it is the limiting position of a secant line through *P* and a neighboring point *P'* on the surface when *P'* is made to approach *P* along the surface

All tangent lines to a surface at a given point lie in a plane, which is called the tangent plane to the surface at the given point

If the equation of a surface in rectangular coordinates is $F(x,y,z) = 0$, the tangent plane at the point (x_1,y_1,z_1) has the equation

$$F_x(x_1, y_1, z_1)(x - x_1) + F_y(x_1, y_1, z_1)(y - y_1) + F_z(x_1, y_1, z_1)(z - z_1) = 0,$$

where $F_x(x_1, y_1, z_1)$ is the value of the **partial derivative** $\frac{\partial F}{\partial x}$ at the point (x_1, y_1, z_1), and similarly for the other coefficients The equation of the tangent plane is often written

$$\frac{\partial F}{\partial x}(x - x_1) + \frac{\partial F}{\partial y}(y - y_1) + \frac{\partial F}{\partial z}(z - z_1) = 0,$$

but it must be understood that the values of $\frac{\partial F}{\partial x}$, etc, must be taken at the point of tangency

If the equation of the surface in rectangular coordinates is of the form $z = f(x, y)$, the equation of the tangent plane at (x_1, y_1, z_1) is

$$f_x(x_1, y_1)(x - x_1) + f_y(x_1, y_1)(y - y_1) = z - z_1$$

A normal line to a surface at a point P_1 is the line through P_1 which is perpendicular to the tangent plane to the surface at P_1

If the equation of the surface in rectangular coordinates is of the form $F(x, y, z) = 0$ or of the form $z = f(x, y)$, the equation of the normal (line) at a point (x_1, y_1, z_1) is, respectively,

$$\frac{x - x_1}{F_x(x_1, y_1, z_1)} = \frac{y - y_1}{F_y(x_1, y_1, z_1)} = \frac{z - z_1}{F_z(x_1, y_1, z_1)},$$

or

$$\frac{x - x_1}{f_x(x_1, y_1)} = \frac{y - y_1}{f_y(x_1, y_1)} = \frac{z - z_1}{-1}. \qquad \text{(L L S)}$$

TANGENTS AND NORMALS TO PLANE CURVES. Consider a plane curve (Figure 1), take a point P_1 on the curve, also take a second point P_2 on the curve and draw the secant line P_1P_2 If as P_2 approaches P_1 along the curve, the secant P_1P_2 approaches a limiting position P_1T, this line P_1T is called the tangent to the curve at P_1.

Another form of definition of tangent to a curve, which can be shown to be equivalent to the preceding, is the following (Figure 2): Let a line *l* be drawn cutting the curve in two points *P* and *Q*, and let this line move parallel to itself so that *P* and *Q* move closer together; then if when *P* and *Q* approach coincidence, the

secant line PQ approaches a limiting position P_1T, this line P_1T is called the tangent to the curve at P_1

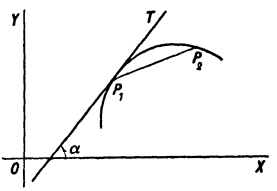


Figure 1.

The **slope** of the tangent to a curve at a point P_1 is often called the slope of the curve at P_1

If the equation of a curve in rectangular coordinates is $y=f(x)$, then the slope of the tangent to the curve at a point (x_1,y_1) is given by the value of the **derivative** $f'(x_1)$ at the value $x=x_1$. The equation of the tangent at (x_1,y_1) is then

$$y-y_1=f'(x_1)(x-x_1).$$

If the equation of a curve is given in **polar coordinates** as $r=f(\theta)$, the direction of the tangent at a point (r_1,θ_1) is determined by $\tan\psi_1=r_1/f'(\theta_1)$, where ψ_1 is the angle between the **radius vector** to the given point and the tangent at this point, the angle α, which the tangent makes with the X-axis (or polar axis) is then $\alpha_1=\theta_1+\psi_1$ (Figure 3)

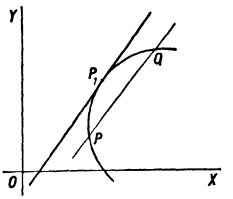


Figure 2

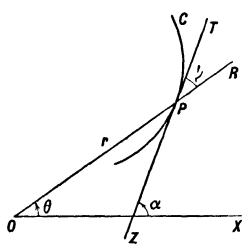


Figure 3

A normal to a curve is a straight line perpendicular to a tangent to the curve, its slope is the negative reciprocal of the slope of the tangent If the equation of the curve in rectangular coordinates is $y=f(x)$, then the equation of the normal at the point (x_1,y_1) is

$$y-y_1=-\frac{1}{f'(x_1)}(x-x_1)$$

If the tangent and normal at P_1 intersect the X-axis at T and N respectively, then we define $P_1T=$ length of tangent at P_1, and $P_1N=$ length of normal, at P_1 (Figure 4).

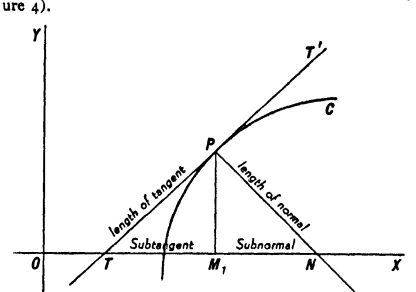


Figure 4.

The projections on the X-axis of the length of tangent P_1T and the length of the normal P_1N are called the subtangent and subnormal at P_1 Then subtangent $=TM_1$, subnormal $=M_1N$, where M_1 is the projection of P_1 on $X'X$

If m is the slope of the tangent at $P_1(x_1,y_1)$, then subtangent $=-y_1/m$, subnormal $=my_1$ (L L S)

TANGERINE. Citrus Fruits.

TANIPAN. Carapato.

TANK. A tank is a vessel constructed for the purpose of holding a liquid The principal materials from which tanks are made are wood, plate steel and reinforced concrete The ordinary shape employed is the cylinder, since that shape most naturally resists internal pressure The ends which are firmly connected to the cylindrical portion may be flat, conical or hemispherical Small tanks usually have flat ends, whereas large vertical tanks have hemispherical ends Conical ends are seldom used due to the difficulty in making a satisfactory connection to the cylinder Tanks lying in a horizontal position are supported on the cylindrical portion Large vertical tanks are connected to circular girders which are supported by columns Some fairly large vertical tanks are built with a flat bottom which rests on a platform

Many water storage tanks are built of wood Cypress and redwood due to their resistance to deterioration are most often used The wooden tank, if small, may be rectangular, but it is more frequently cylindrical in shape When the latter form is used it is constructed of staves supported and squeezed by adjustable iron or steel hoops until the joints are water-tight The bottom of the tank which is flat is wedged into the staves at the croze The latter is a groove cut in the stave near the lower end, and the tapered edge of the bottom is wedged into it The bottom of the tank is supported on level timbers known as dunnage strips, which run at right angles to the bottom boards The capacity of a cylindrical tank of this type is equal to πr^2h in which r is the inside diameter and h is the height Steel tanks are made of plates rolled to the proper curvature and drilled so that they may be fastened by rivets The riveted joint is caulked until it is water-tight Steel tanks are also **welded** (F T M)

TANNINS. Tannins are substances generally related to one of the **phenols**, pyrogallol or catechol, and they are found in many plants By their action on animal skins they cause changes which make the skins resistant to decomposition and at the same time leave them flexible and very strong, greatly improved in wearing qualities Skins so treated are said to be tanned, and are called leather Tanning is a very old art, having been practiced in China since long before the Christian era It was also known to the American Indian before the arrival of the white man

Tannins are found in various parts of the plant, appearing frequently in leaves, and in the cortical tissues of stems Tannins may be found in the walls of cells or in the **vacuoles**; often their presence causes the cell to appear dark-colored Many fruits, such as the persimmon, contain large amounts of tannin, especially before they are ripe Wound tissues, and especially the **hypertrophied** tissues known as **galls**, which result from the bites of certain insects, are particularly rich in tannins Tannins appear to be by-products of the **metabolism** of the plant When present in the epidermal cells they are seen as a deterrent to snails, which might injure the leaf by feeding on it, to parasitic fungi which might otherwise enter the leaf tissue, and as a protection against desiccation, since they form substances impervious to water

An important source of tannin is the bark of various trees, especially that of the hemlock, and several species of **oaks.** The bark is removed from the tree in sheets about four feet long Stripping from the tree is usually done in the spring, when the **cambial** cells are most active and the bark separates easily To remove the bark two rings are cut completely through the bark and

round the tree. A longitudinal slit is made through the bark from one ring to the other Using a blunt long-handled implement the bark is then pried loose from the tree and allowed to dry. By felling the tree, the entire trunk may be stripped of its bark in this way The dried bark is shipped to mills which extract the tannin. Tannins from these barks are used to tan leather for shoe-soles and other heavy leathers The wood of the chestnut tree yields a tannin similarly used The available supply of tannin from these sources does not meet the demand, so many foreign plants are now being used.

Of these the most important are small trees of the genus *Schinopsis*, natives of the southern part of South America, including southern Brazil, Bolivia and other southern countries These trees are known by the name "quebracho," which means "ax-breaker," because of their very hard, dense, heavy dark-red wood, which is cut with difficulty The heartwood of the tree contains 20–27% tannin, which is obtained by cutting the wood into small chips and extracting with water This tannin is often used in combination with tannins from other plants

The bark of many other trees yields large amounts of tannins Among these are the **mangrove**, and several species of *Acacia*, known as wattles, natives of Australia Fruits also may be a source of tannin The fruits of *Terminalia chebula*, called myrobalans, are an important tannin source. The tree is a native of tropical Asia Another fruit rich in tannin is divi-divi, the pods of a legume, *Caesalpinia coriaria*, which is native in tropical America and the West Indies Sumac leaves, especially those of *Rhus coriaria*, a shrub or small tree native in Mediterranean Europe, are rich in tannins To obtain the tannin, the plants are cut down, and spread out to dry The leaves are then removed from the stems, and packed into bags which are shipped to the mills. There the leaves are first cleaned, and then ground up The tannins from this source are used in manufacturing fine leathers, like glove leathers Leaves of other species of sumac, including the various American sumacs, also contain tannins which, however, are not so valuable and are little used Tannins are solids, soluble in water or alcohol, usually extracted by hot water, insoluble in **ether, chloroform, carbon** disulfide, **benzene,** soluble in alcohol-ether mixture, and in ethyl acetate, possessing a bitter astringent taste Tannins (1) yield precipitates with gelatin, proteins (connected with the property of making leather from hides), **alkaline,** salt solutions of many heavy metals, e g , **lead** acetate, **copper** acetate (precipitate brown), **antimonyl** tartrate, concentrated dichromate solution, also by **chromic** acid (1% CrO_3), (2) yield dark blue or green coloration with **ferric** salt solutions, (3) in alkaline solution, absorb **oxygen** and yield dark colored solution, (4) with **iodine** in potassium iodide plus small proportion of ammonium hydroxide, yield red color, (5) with dilute solution potassium **ferricyanide** in ammonium hydroxide, yield a red to brown coloration (care not to use excess reagent)

REACTIONS OF TANNINS

Reagent	Pyrogallol Tannins	Catechol Tannins	Phloroglucinol Tannins
	1 Oak wood 2 Chestnut wood 3 Galls 4 Sumac 5 Myrobalans 6 Divi-divi	1 Pine barks 2 Oak barks (but not oak wood, fruit or galls) 3 Acacia 4 Quebracho wood 5 Cassia bark 6 Mangrove bark 7 Cutch 8 Gambier	1 Gambier
With ferric salt solution	Dark blue color	Greenish-black color	
Bromine water	No precipitate	Yellowish to brownish precipitate (excess reagent)	
Sulfuric acid concentrated		Water extract yields dark red or crimson layer at the junction, on diluting turns pink	
On leather	Forms a bloom	No bloom formed	
Acid, boiled		Red insoluble phlobaphenes	
Moisten pine wood with water extract, add concentrated hydrochloric acid			Red to purple color

Tannins are used (1) in making hides and skins into leather, after preparation of the hide, e g , dehairing, (2) in the manufacture of inks, (3) in dyeing, as a mordant, (4) in the clarification of solutions, e g , wine, and (5) as a source of gallic, pyrogallic, and tannic acids. (R K S , R M W)

TANTALUM. Symbol Ta Atomic number· 73. Atomic weight 181 4 Density 16 6. Melting point· 2850°

Tantalum is a slightly bluish metal; ductile, malleable, and when polished resembles **platinum;** burns upon being heated in air, insoluble in **hydrochloric** or **nitric acid,** but soluble in hydrofluoric acid or a mixture of hydrofluoric and nitric acids Tantalum metal was used as a filament for the incandescent electric lamp, but has been superseded by **tungsten.** Ductile tantalum is used for chemical apparatus as a substitute for platinum, for surgical instruments, as a resistant **electrode;** in electric current rectifiers Discovered by Ekeberg in 1802

Tantalum occurs, usually with **columbium,** in **tantalite** ($Fe(TaO_3)_2$, 85% Ta_2O_5), **samarskite** (20% Ta_2O_5) chiefly found in Western Australia, and South Dakota Recovered along with columbium by fusion with **potassium** hydrogen sulfate in the residue after subsequent extraction with water Tantalum and columbium are

separated by fractional crystallization of the **potassium** fluorides, tantalum concentrating in the crystals and columbium in the mother liquor. Tantalum metal may be obtained by **electrolysis** of fused potassium tantalum fluoride, or by reduction of the pentoxide with **carbon** in the **electric furnace.** On heating, the metal absorbs large volumes of **nitrogen** and **hydrogen,** which are only removed by heating to fusion in a vacuum. Chemically related to **vanadium** and columbium.

Chloride: Tantalum pentachloride ($TaCl_5$), white crystals, melting point 221° C., boiling point 242° C.

Fluoride: Tantalum potassium fluoride (K_2TaF_7).

Oxide: Tantalum dioxide (TaO_2), brown solid; tantalum pentoxide (Ta_2O_5), white solid.

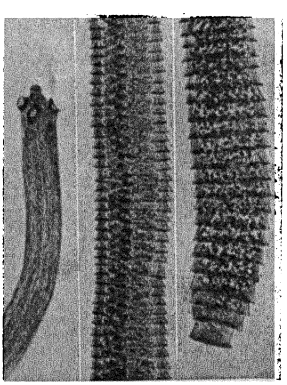
Tantalates: (tantalum of valence plus 5).

Tantalic acid: ($HTaO_3$), gelatinous precipitate by addition of water to tantalum pentachloride. (R.K.S.)

TAP. The tap is a tool for cutting internal threads. It is employed to cut threads on nuts, and to thread the inside of drilled holes into which studs or cap screws are to be screwed. The tap itself is a rod of steel properly hardened, and having external threads corresponding to the internal threads to be cut. It is fluted longitudinally so that cutting edges will be presented at the edge of the flute, and the open spaces will serve to clear the chips. It is tapered at the point so that it can be readily inserted in the hole which has been drilled to receive it. This permits getting the tap started in the hole, and once it is started it will advance itself. The tap is provided with a square shank so that it may be gripped with a tap wrench while being used. When tapping, the hole must be drilled just the right size to eliminate any unnecessary cutting, but leave enough metal to form the threads. The diameter of the drill used should equal the outside diameter of the stud minus the pitch of the thread. (F.T.M.)

TAPACULO. Aves, Passeriformes. *Pteroptochus.* A South American bird (**Aves**) superficially like the wrens. The several species are distributed over the entire continent. (A.W.L.)

TAPE WORM. Tape worms (**cestodes**) are parasitic flat worms, segmented in form, and having a head portion (**scolex**) which can continually give rise to new segments. As long as this head remains in the human intestine the worm has not been destroyed, for from this an entire new body can grow. These worms do not possess a digestive canal and are usually **hermaphrodites.** Nourishment is absorbed from the host through the surface of the worm's body. Fertilization is accomplished between segments of different worms or between different segments of the same worm.



Dwarf Tapeworm, head, middle segments, and terminal segments. From stained and mounted specimens (photographs × 30). (From Todd and Sanford, *Clinical Diagnosis by Laboratory Methods,* W. B. Saunders Co.)

Certain tape worms apparently do not greatly harm the host while others may produce marked symptoms such as grave anemia. Larval forms of the worm may invade the various tissue of man in certain forms of cestode infestation and cause serious trouble.

The kinds of tape worms commonly found in man are as follows: (1) The fish tape worm (*Diphyllobothrium*) is found throughout the world and infests humans when infected fish that has not been thoroughly cooked, is eaten. Serious symptoms may not develop for years, but often a condition resembling pernicious anemia develops. Recovery follows the expulsion of the worm. (2) The Dwarf tape worm (*Hymenolepididae*) is also found throughout the world and is the most common of tape worms occurring in the United States. It is of small size but when present in large numbers the worms cause diarrhea, loss of weight, appetite, and nervous manifestations. The symptoms disappear when the parasites are expelled. (3) The pork tape worm (*Taenia solium*) is large, measuring 9 to 12 feet in length, most of the symptoms and dangers of this worm are due to the invasion of the tissue by its larval forms. This form is rare in the United States. (4) The beef tape worm (*Taenia saginata*) is common in the world wherever infected beef is eaten. Cold storage will kill the parasite. The adult forms are extremely large worms, some having been found that measure 30 to 50 feet in length.

Colic and pain are seen in cases infected with this worm and spontaneous discharge of a long piece of worm may inform the patient of his guest.

Treatment is often difficult and to be successful the entire worm, especially the head, must be recovered. This last described worm is the most difficult to eradicate. (R.S.M.)

TAPIOCA. Spurge Family.

TAPIR. Mammalia, Perissodactyla. *Tapirus.* Moderately large animals found in the neighborhood of water in the forests and Central and South America and the Malayan region. They reach a length of eight feet and a height of a little over three and are stoutly built. Their most conspicuous characteristic is the short trunk into which the snout is prolonged. Only one of the five species occurs in the Old World.

The natives of the American tropics hunt tapirs for their flesh and hides, although the value of the latter for leather is limited. (A.W.L.)

TARANTULA. 1. Arachnida, Arancina. A name applied indiscriminately to many of the large hairy **spiders** of the warmer parts of the Americas, perhaps most commonly to the forms so often imported into temperate latitudes in bunches of bananas. The name comes from the generic name *Tarantula,* which has been applied to an entirely different group of spiders. 2. Arachnida, Pedipalpi. A genus of **whip scorpions.** The application of this name is dependent upon rules of nomenclature which have apparently received no authoritative interpretation. It will undoubtedly remain in popular usage as a name for many large spiders, whatever its scientific disposition. (A.W.L.)

TARDIGRADA. The bear animalcules, a group of minute animals with four pairs of short legs bearing claws. The mouth has piercing stylets and is formed for sucking. Neither respiratory nor circulatory organs are present. Bear animalcules occur in water and in moist places on land, and while they are evidently arthropods, their relations within this **phylum** are uncertain. They are commonly regarded as a separate class. (A.W.L.)

TARN. Cirque.

TARO. Aroids.

TARPAN. Mammalia, Perissodactyla. A wild horse of the steppes of central Asia This species has been regarded as feral rather than a natural species, but this interpretation has been disputed by other authorities It is in any case closely related to the domestic horse and may be the ancestral form. (A W L)

TARPON. Pisces, Teleostei *Tarpon* A large marine fish (**Pisces**) of silvery color, found in the waters of the West Indies, along the Gulf Coast, and northward to a limited extent along the Atlantic coast It reaches a length of six feet and is known for its very large scales, which may be three inches across Also known as the silver fish, silver king, savanilla, and sabalo

The tarpon is among the great game fishes but is not commonly regarded as desirable for food It is eaten in Central America (A W L)

TARRAGON. Artemisia.

TARSIER Mammalia, Primates *Tarsius* A peculiar animal found on some islands of the Oriental region It is about as large as a rat and has a very short muzzle and enormous eyes The hind legs, particularly the ankles, are long, and the tips of the digits are expanded into fleshy disks The tarsier moves about on its hind legs by springy leaps It is one of the extreme forms related to the lemurs (A W L)

TARSUS. 1 The terminal division of the leg of an **insect** It consists of five segments in the typical form, the terminal segment bearing a pair of claws Tarsi are modified in various species by the fusion or loss of segments, and in one genus, *Bittacus*, the terminal joint folds back on the next to form a grasping organ 2 The shank of the leg of a bird (**Aves**) 3 The proximal portion of the foot of **vertebrates**, containing several tarsal bones 4 The framework of connective tissue which gives shape to the eyelid (A W L)

TARTAR EMETIC. Tartaric Acid.

TARTARIC ACID AND TARTRATES. Tartaric acid (H_2 $C_4H_4O_6$ or COOH CHOH CHOH COOH) is a white solid, melting point of dextro or laevo 170° C (of racemic, dextrolaevo, about 205° C, of mesotartaric, inactive, 140° C.) (See **Isomerism**), soluble in water, slightly soluble in alcohol, insoluble in ether Tartrates (like **citrates**) in solution change silver of ammonio-**silver** nitrate into metallic silver **Potassium** hydrogen tartrate, and **calcium** tartrate, on account of their solubility characteristics, are of importance in the separation and recovery of tartaric acid The former salt is readily converted into the latter, and the resulting calcium tartrate plus dilute sulfuric acid yields tartaric acid plus calcium sulfate, and the latter may be separated by filtration Tartaric acid may be obtained by evaporation of the filtrate Ester Diethyl tartrate ($COOC_2H_5$ $(CHOH)_2COOC_2H_5$), melting point 17° C, boiling point 280° C Tartaric acid may be obtained (1) from some natural products, e g, in the juice of grapes and acid fruits, often in conjunction with citric or **malic acid**, potassium hydrogen tartrate "argol" in the residue of wine vats, (2) by synthesis Tartaric acid is a dibasic acid, that is, two series of salts and **esters** are known Tartaric acid is used (1) in **baking powders** as potassium hydrogen tartrate ("cream of tartar") with **sodium** hydrogen carbonate ("baking soda"), (2) in medicine, e g, potassium antimonyl tartrate ("tartar emetic"), (3) in effervescent medicinal salts, (4) in **blue printing** as ferric tartrate, (5) in silvering mirrors—ammonio-silver nitrate yielding smooth deposit of silver Sodium potassium tartrate ("Rochelle salt, $NaKC_4H_4O_6$ $4H_2O$) is used in medicine, and in the preparation of Fehling's solution, which is an alkaline cupric solution made by mixing **copper** sulfate solution, sodium potassium tartrate solution and **sodium** hydroxide solution, and is used as an oxidizing reagent in the case of many organic compounds, such as **glucose** and reducing sugars, and **aldehydes**, with which cuprous oxide, red to yellow precipitate, is formed (R K S)

TASMANIAN DEVIL. Mammalia, Marsupialia A Tasmanian animal, *Sarcophilus ursinus*, resembling the badger in its stout build and large head It is nocturnal in habits, hiding during the day in a burrow or in natural crevices It eats all kinds of living animals, even killing forms much larger than itself The species is grouped with the **dasyures** of Australia (A W L)

TASMANIAN WOLF. Mammalia, Marsupialia *Thylacinus* A pouched animal closely resembling the wolves and of similar habits It is related to the **dasyures.** Also called the thylacine

Like the wolves of the northern hemisphere, this species has been killed in large numbers for its attacks on domestic animals and is now restricted to the wilder mountainous parts of Tasmania (A W L)

TASTE BUD. A sensory organ of the **vertebrates**, sensitive to contact with substances in solution and those in a liquid state A taste bud consists of a spindle-shaped group of cells in the **epithelium** of the vertebrate tongue and in some species in the lining of the mouth and **pharynx.** Taste buds have been reported in the skin of some aquatic animals The bud includes supporting cells of thick spindle shape and slender taste cells ending with a short taste hair which projects into a minute pit at the free end of the bud The interpretation of these two types of cells is a subject of disagreement, it is possible that they represent stages in the development of a single form of cell

The action of taste buds results in four fundamental taste sensations sweet, sour or acid, salty, and bitter Perception of these chemical properties is localized in the tissues containing organs of taste, but differentiation of the organs accompanying this localization has not been demonstrated (A W L)

TATLER. Aves, Charadriiformes A North American **sandpiper** *Heteractitis incanus*, the wandering tatler, is found along the Pacific coast of North America, where it breeds in northern latitudes, and on some of the Pacific islands (A W L)

TATOUAY Mammalia, Edentata The broad-banded **armadillo** of South America, *Cabassous unicinctus.* It is similar to the six-banded armadillo in many ways The largest of the group with the exception of the giant armadillo of the same region. (A W L)

TAURUS (The bull) (Map page 306) Taurus, the second sign of the **zodiac**, is a constellation of very great antiquity, two of its open **clusters**, the **Pleiades** and the **Hyades**, being frequently referred to in the Bible, and **Aldebaran**, its brightest star, is mentioned by both Homer and Hesiod

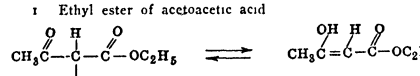
Aldebaran (Alpha Tauri) is the standard first **magnitude** star of the northern hemisphere The star is distinctly yellowish in appearance and has a measured diameter about 60 times that of the sun It is a **double** star, but difficult to resolve except with moderately large instruments

The two asterisms, the Pleiades and the Hyades, are both open clusters, i e, groups of stars moving through space together The Pleiades group is also noteworthy in that it is filled with diffuse **nebulous** material

There are a number of double stars available for observers with small telescopes With a wide field instrument, such as an opera glass, the two doubles Sigma and Theta can both be seen at once and, with the surrounding stars, make a very interesting spectacle (W K G)

TAUTOMERISM. This is a phenomenon observed in organic chemistry when a substance has one molecular formula but must be assigned two structural formulae (**Chemical formulae**) Two sets of reactions characteristic of two mutually incompatible groups in the molecule and two sets of derivatives can be produced by reactions depending on but slight variations of the experimental conditions Consequently a unique structural formula cannot be assigned to such a compound This difficulty is solved in theoretical organic chemistry by assuming the existence of two compounds with different structural formulae and also an existence of a dynamic **equilibrium** between these two forms The latter differ in their structural formulae in general by the position of a hydrogen **atom** and that of a double bond The following are the more important cases of tautomerism

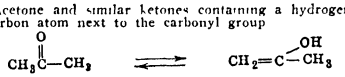
1 Ethyl ester of acetoacetic acid



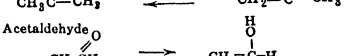
keto form enol form

The equilibrium mixture at room temperatures consists of 7% keto and 93% enol form The enol form can be obtained in the free state by treating the **sodium** derivative with dry **hydrogen chloride** and distilling The enol form can be preserved in the pure state at low temperatures but at room temperatures it is converted into the equilibrium mixture in two weeks The enol form gives characteristic reactions with **ferric** chloride The keto form can be obtained by **crystallization** at low temperatures of the **ester** from an **alcohol**, ether, or hexane solution It does not give the ferric chloride reaction and at room temperatures is gradually converted into the equilibrium mixture

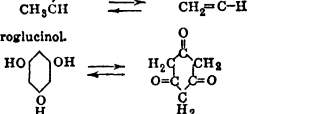
2 Acetone and similar ketones containing a hydrogen on the carbon atom next to the carbonyl group



3 Acetaldehyde



4 Phloroglucinol



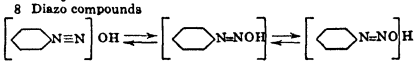
5 Nitro compounds. $R_2C-NO_2 \rightleftharpoons R_2C=N(=O)OH$

6 Nitrous acid $HONO \rightleftharpoons HNO_2$

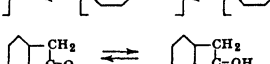
7 Hydrogen cyanide $HCN \rightleftharpoons HNC$

Two sets of derivatives can be formed CH_3CN methyl cyanide and CH_3NC methyl isonitrile.

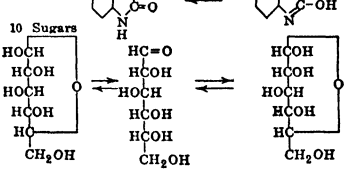
8 Diazo compounds



9 Isatin.



10 Sugars



The existence of this tautomerism is invoked to explain mutarotation (R K S)

TAXIS. **Tropism**, and also **Movement in plants.**

TAXONOMY. The science of **classification** In dealing with the many details involved in classifying the half-million known species of animals, it has been found necessary to adopt rules of procedure in order to secure approximate uniformity and stability of results The work of the earlier naturalists was without such restrictions, hence much of the confusion of modern taxonomy has arisen from the interpretation of these early contributions

Of the several codes of taxonomic procedure the International Rules of Zoological Nomenclature, drawn up by the International Commission on Zoological Nomenclature, is commonly regarded as authoritative These rules establish many principles relating to scientific names of all ranks Among them is the provision that all zoological nomenclature shall start with the tenth edition of Linnaeus' "Systema Naturae," published in 1758 All prior works are discarded A second important provision is the law of priority, which states that the valid name first applied to a group or species shall stand, all names subsequently applied to the same category becoming synonyms All names, to be accorded consideration, must be published by printing or by a similar permanent form of reproduction and distributed to other scientists either in a recognized periodical or by private enterprise

All scientific names are latinized, although the range of choice of names is not limited to the Latin, it is, in fact, practically unlimited The Rules make several specific provisions Restrictions are placed on the formation of names of superfamilies, families, and subfamilies, which are formed of the stem of the type genus plus the ending -oidea, -idae, or -inae, respectively The type genus is the included genus regarded by the author of the greater group as typical

The rules relating to genera have been the source of most confusion Once applied, a generic name is not to be used again in the animal kingdom, and if inadvertently used a second time, the later usage becomes a homonym of the name as first applied and is replaced by a new name In naming a genus the author is supposed to indicate a type species which shall be the embodiment of the characteristics of the genus Types were designated long before the formulation of these rules but many genera were erected without stated types before their value was appreciated To meet these cases rules for the citation of types of genera described without them are available The type species must be among those included in the original description of the genus, and the first designation of such a type takes precedence over all others As a result historical research has been necessary to fix the older generic names and some are still in a state of confusion Such cases may be submitted to the Commission for special ruling

In naming species the specimens available, or a selection of them, should be labeled as types and preserved, preferably in the permanent collections of a museum The species bears the name of the genus to which it belongs, followed by its own name, and for completeness the name of the author of the species should be appended The generic name is capitalized and both it and the specific name are underlined or in printing are italicized The use of two names for each species is the principle of binomial nomenclature

Many other details of taxonomic procedure, based on written and unwritten laws, are of interest only to specialists A minimum of knowledge in this field is essential to any well-rounded biological training (A W L)

TAYLOR'S THEOREM. **Expansion of Functions in Series.**

TAYRA. Mammalia, Carnivora *Galera* A South American animal of the weasel family. It is among the larger species, comparing with the otter in size, and has the characteristic long body and short legs of the

weasels, with a long and rather heavily furred tail. These animals range from white to black in color (A W L)

TEA. *Thea sinensis* Theaceae The tea plant is an evergreen shrub probably indigenous to China, where it has been cultivated since early times The plant possesses alternate elliptical leaves which when mature are tough, and vary in length from two to five inches The flowers are axillary (See **Axil**) and appear singly or in small groups They are white, slightly fragrant, and about an inch in diameter Each flower has numerous **stamens** and a single **pistil** composed of three **carpels.** The fruit is a woody **capsule** containing three large seeds

For successful growth tea must be planted in regions having abundant rainfall In China most of the tea plants are grown on small farms The plants are grown from seed or from nursery stock and begin to yield crops when three or four years old, continuing to do so thereafter for fifty years The young shoots appear in flushes, growing rapidly for a time From these flushes are picked the young leaves used for tea Several flushes occur each year Picking is done entirely by hand, necessitating an abundant supply of cheap labor

After picking the leaves are spread out and allowed to wilt for some time The limp leaves are then rolled and crushed in machines, so that the cells are bruised and certain enzymes freed The crushed leaves are again spread out and allowed to ferment, after which they are again rolled and dried until crisp They are then sorted and graded While still warm the leaves are packed in lead-lined chests partly to conserve the aroma of the leaf and partly to prevent absorption of any odor which might spoil the product This method of preparation produces black tea, which when brewed yields a rich orange-colored drink Black tea is principally obtained from China and Ceylon The best grade is known as Orange-Pekoe

The preparation of green tea differs in several particulars from that of black tea After picking, the leaves are at once steamed so that no oxidative **enzymes** remain Steaming tends to bring out the aroma After steaming, the leaves are rolled and dried, usually by machine They are then sifted, graded and packed Green teas are principally produced by Japan and largely exported to the United States

Oolong is a slightly fermented tea produced in Formosa, and is intermediate between green and black tea

In China tea is often delicately scented by exposing the leaves to the odors of flowers Large quantities of Jasmine flowers are used for this purpose, the product being known as Jasmine Tea

Tea is principally used as a beverage Great Britain and its dominions consume by far the greatest amount used outside the producing countries (R.M W)

TEAK. *Tectona grandis* Verbenaceae The teak tree is tall, with very rough-surfaced oblong leaves from 10–20 inches long and 8–15 inches broad, and small white or blue-tinted flowers borne in large panicles The tree is native in the tropics of Asia and is frequently grown in plantations in India, Java, and other Asian countries for its hard wood This wood is very durable and much used in shipbuilding and in the making of fine furniture The wood is very heavy and dries slowly Drying is hastened somewhat by girdling the tree at the base and leaving it standing for a year or more During this time it dies and dries out, after which it is felled and floated to the shipping port (R M W)

TEAL. Aves, Anseriformes A small **duck** whose beak has almost parallel sides The several species are beautifully marked Teals are found throughout Europe, Asia, and North America The common European species migrates into Africa and is sometimes found in northern and eastern North America, while other species have a much more limited range In North America the blue-winged teal (*Querquedula discors*) is common east of the Rockies, the green-winged teal (*Nettion carolinense*) throughout the continent, and the cinnamon teal *Q cyanoptera*) west of the Mississippi (A W L)

TECTIBRANCHIATA. Gasteropoda.

TECTONITE. A term proposed by Backland, for a variety of **mylonite** produced from **para**-schists (R M F)

TEGMEN. For the use of this term in botany, see **Seed** In zoology, it has two meanings 1 A thickened forewing of the kind found in the **grasshoppers** and related forms These wings are less thickened than the **elytra** of many beetles but they also serve as wing covers under which the hind wings are folded when at rest Most tegmina vary from scarcely thickened membranes to leathery appendages 2 The leathery top of the **calyx** of crinoids (A W L)

TEJU. Reptilia, Sauria *Tupinambis* A large **lizard** of the West Indies and South America Lives in the forests near water but is not aquatic Reaches a length of a yard, with long slender tail and heavy forequarters It is chiefly olive and black (A W L)

TELEGONY A supposed influence of a scrub sire on the offspring of a blooded dam by later mating with a blooded sire Many animal breeders suppose that the accidental mating of a choice female with a mongrel makes it impossible to be sure of securing pure-bred young at subsequent births There is nothing in the findings of geneticists to support this view Influence of the sire is limited to the hereditary potentialities of his **germ cells,** and once his own progeny have been born, the female carries no residual influence of the mismating (A W L)

TELEGRAPHY. Communication by telegraph, whether the older manual type or the more recent automatic or printing type, is done by a code of electrical pulses In the manual type the operator sends a certain combination of pulses for each letter of his message and the receiving operator then transcribes them into the characteristic letters In the more complicated automatic types the sending operator uses a keyboard similar to that of a typewriter, and the equipment transforms the striking of a key into the proper signals (not the same code as for manual operation) and a machine at the receiving end selects the proper letter and the message is typed

In its simplest form the telegraph consists of **battery,** key, and sounder, with connecting wire or wires The telegraph key is a type of switch designed for easy operation by hand The sounder is similar to a **relay,** the essential difference being that the sounder has no electrical contacts to close, but its armature strikes a stop at each end of its travel, giving a sound characteristic of the stop Thus a skilled operator can tell the position of the armature by the sound and can interpret the code message

A system commonly used in this country is the closed-circuit, so named because the electrical circuit is normally closed, current flowing when no message is being sent Several stations are usually connected in series, with two common batteries serving all A circuit is shown in Figure 1, (page 1106). Since the stations are all in series the keys must be short-circuited when not in use, hence a switch is attached to each key To operate, the switch is opened and the key is tapped in accordance with the code This sends pulses of current through

the wire and ground circuit, causing all sounders to operate These hit the stops on either side of the armature and give the message to the receiving operator

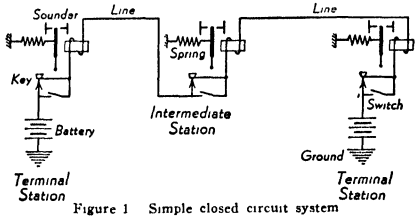


Figure 1 Simple closed circuit system

While the single-current system just described is older and somewhat simpler, a better arrangement is the double-current system of Figure 2 In this system current flows in one direction for a signal and in the

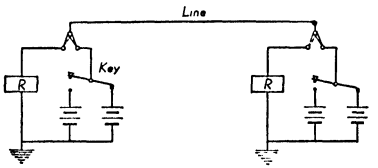


Figure 2 Double current system

opposite direction for a space The operation is more positive than with single current circuits These currents may be sent as illustrated with two batteries oppositely connected or a means may be provided for reversing the connections to a single battery The system requires a special relay, known as a polarized relay, between the line and the sounder A polarized relay is one so designed that current flowing in its windings in one direction will close the contacts in one direction, and current flowing in the opposite direction will close the contacts in the other direction The combination of relay and sounder is shown as *R* in Figure 2 The connections are set for transmission of signals from left to right, the operation of the key at the left station sending pulses of current to the receiver *R* at the right station There may be intermediate stations

Both circuits shown allow transmission in only one direction at a time, but there are several arrangements providing simultaneous transmission in both directions This is known as duplex service as opposed to the previously described simplex service. The differential duplex system is shown in Figure 3 The duplex operation depends upon a split winding relay and a balancing of the actual line with an artificial one An artificial line is a circuit designed so that its electrical characteristics are the same as those of the actual line. Therefore, when it is connected to the relay at one end and the line at the other, the two halves of the relay winding and associated connections are electrically identical Operation of the key at the left station causes the keying relay to send current in first one direction and then the other into the differential relay. Since the two sides of the relay are equal electrically, the current divides, half flowing upward and half downward. The **magnetic flux** of the windings oppose and cancel This prevents the relay picking up and operating the sounder However, current coming into the relay from the line all flows through the winding in the same direction, the flux is not neutralized, and the relay picks up, operating the sounder Thus both transmission and reception may occur at the station at the same time, and only the incoming signals operate the sounder The half of the transmitted current which flowed upward in the relay goes out over the line to the right station and operates its relay as just described (Especially prepared for this volume by L R Quarles) (See also **Wireless Telegraphy**) (F T M)

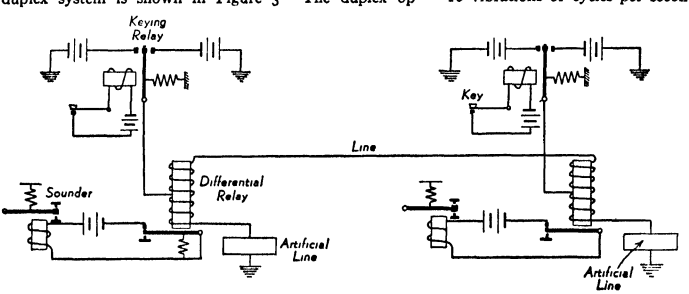


Figure 3 Differential duplex telegraph system.

TELEODESMACEA. Bivalve mollusks, including the soft-shelled **clam**, the **shipworms**, and many other marine species The group is included as an order in one of the classifications now widely used Equivalent to the order Eulamellibranchiata **Lamellibranchiata.** (A W L)

TELEOSTEI. Bony fishes of the vast majority of existing species The group is regarded in most classifications as a very large order of the class **Pisces**, divided into many suborders and families, but a tendency also exists to elevate it to a higher rank and to make its principal subdivisions orders The principal subdivisions are well established, whatever the rank accorded to them. In North America they number about a score, containing above three thousand species of fresh-water fishes The principal forms among these many species and the more important food and game species are treated under their vernacular names in this work, as **bass, eel, killifish, salmon, shad, trout,** etc (A W L)

TELEOSTOMI. The true fishes, a subclass of the class **Pisces** (A W L)

TELEPHONY. Telephony is the art of transmitting speech over distances by means of electric currents The basic requirements are (1) a **transmitter** which will produce a current which is a replica of the sound wave, (2) a transmission system to carry the current to the receiving point, (3) a **receiver** to convert the electric current into sound again

Audible sound covers the **frequency** range from about 16 vibrations or cycles per second up to 25,000 or more, some individuals being able to hear higher frequencies than others To transmit intelligible speech with a considerable degree of naturalness requires a range of from 200 to 2500 cycles. High-quality music requires a range of from 30 to 7000 cycles or higher. It is characteristic of all distributed constant circuits such as lines and cables that they do not transmit all frequencies with equal facility. While all frequencies are attenuated in transmission, some are attenuated more than others and the **phase** or position of one frequency with respect to another is shifted The current wave thus

arrives at the receiving point generally reduced in amplitude and distorted in shape Too much attenuation makes the received sound too feeble to be heard and too much distortion renders it unintelligible. It is the problem of the telephone engineer to arrange his circuits so as to hold distortion within certain limits or else to compensate for it General decreases in amplitude can be taken care of by special **amplifiers** called repeaters

The transmission system may consist of overhead wires, aerial or underground cable, or radio waves In the latter case the voice current is superimposed (**modulation**) on a high-frequency wave for transmission and after being received is picked off (demodulation or detection)

In order to improve the efficiency of transmission of lines and cables it is customary to "load" them by inserting units of inductance at specified intervals This practice was suggested by Heaviside and developed by Pupin It is very necessary to load cables since they possess naturally less inductance and more capacitance In fact, it would be impossible to transmit intelligible speech over more than a few miles of cable without loading For aerial lines and cable the loading inductances are placed in cases similar to transformer tanks, which may be seen along such lines at frequent intervals For underground construction the "loading pots," as they are called, are placed in vaults While loading increases the efficiency of transmission and helps to correct distortion within certain limits, it also tends to increase the attenuation of the higher frequencies This is not particularly objectionable where only speech is involved, but becomes a problem when it is necessary to transmit high-quality radio programs, to which the high frequencies are essential Loading may also be accomplished by wrapping the individual conductors with special steel tape, but, due to the cost, this method of loading is limited in its application to a few submarine cables.

In order to eliminate **cross talk** and interference between circuits it is necessary to "transpose" the lines or change their relative positions on the cross arms Where a large number of circuits is involved the working out of the transpositions becomes quite complicated The complexity of **transpositions** is further increased by the use of **phantom circuits** The special insulator supports, which may be seen bolted to the cross arms on open wire lines, are for the purpose of effecting the transpositions Where telephone circuits parallel power lines it is necessary to transpose both the power lines and telephone lines to prevent interference Even these precautions will not eliminate serious disturbances on the communication circuits at times when faults develop on the power lines The only satisfactory solution is to separate the two systems by a considerable distance, place the telephone circuits underground, or both

For very long distance transmission the attenuation is so great that the received speech is inaudible Some improvement can be effected by using larger conductors, but the cost is out of all proportion to the gain To overcome this fundamental difficulty various types of amplifiers or repeaters have been tried Briefly the function of a repeater is to take a weak current which has been received and amplify or strengthen it without changing its form so that it can be sent on its way again Repeaters of the mechanical type were not very successful, and it was not until the advent of the vacuum tube amplifier that telephone communication over great distances was put on a satisfactory basis The subject of repeaters is a complete study in itself, and only a brief discussion of the fundamental principles can be given here While the straight one-way amplifier is a simple device, the problems to be met in the design of telephone amplifiers are very difficult due principally to the fact that two-way action must be provided This generally means that two amplifiers must be installed, one to work in each direction The problem is to keep the output of one amplifier from feeding into the input of the other amplifier. If this should happen the amplifiers would oscillate or "sing" and become inoperative as repeaters. Figure 1 gives the simplified circuit of a standard two-element, two-way repeater. Use is made

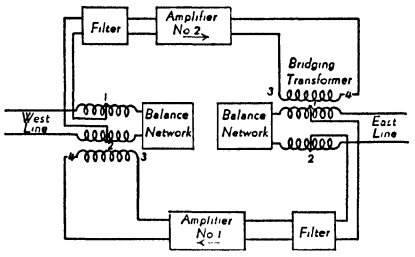


Figure 1 Repeater station

of bridging transformers and balancing networks to prevent singing

Let us suppose that the subscriber on the West line is talking The voice current reaches the West line bridging transformer Part of it enters the input circuit of the West-East amplifier (No 2), the rest being lost in the balancing network The filter serves to remove those frequencies not essential to intelligible speech The output of the amplifier enters the winding 3–4 of the East line transformer The current induced in the secondary of this transformer divides, part of it going out to the East line and the remainder going into the balancing network It will be obvious that if the network matches the line exactly it will consume half the output of the amplifier and no potential difference will be produced between points 1–2 of the input circuit of the East-West amplifier (No 1) If the balancing is not exact some impairment of quality or possibly singing will result The use of repeaters has not only made long-distance telephony possible but has also made it possible to use much smaller line or cable conductors Repeater stations are located at intervals of forty or fifty miles on many lines

Carrier-current transmission is similar to radio transmission in that the voice current is superimposed on a high-frequency wave or carrier Instead of radiating the energy from an antenna the current is actually conducted along wires For this "wired wireless" transmission it is necessary to use lower carrier frequencies than are used for radio In order to transmit speech it is necessary to transmit a **band of frequencies** ranging from 2500 cycles below the carrier to 2500 cycles above it Thus by using carrier frequencies which differ by more than 5000 cycles it is possible to transmit several conversations simultaneously Telegraph communication may also be carried out at the same time Suitable filters are used at the ends of the line to separate the different bands The characteristics of the transmission circuits and terminal apparatus limit the number of conversations which may be carried on at one time In regular telephone work the principal use for carrier current is to provide quickly additional channels when existing circuits prove inadequate to carry the volume of business. Such systems may be kept in operation until such time as additional lines or cables can be installed Power companies make extensive use of carrier current for communicating over their high-voltage lines The **carrier current** may be put on the lines by means of antennas paralleling the power lines, but this function is usually accomplished by the use of coupling condensers, the same means being used to take off the message at the receiving end The construction of separate telephone lines is thus avoided

The transmission of high-quality radio programs over telephone lines for chain broadcasting imposes exacting

requirements on both the circuits and the terminal equipment While a range of 200 to 2500 cycles is ample for intelligible speech and considerable distortion can be tolerated, high-class musical programs require a range of from 30 to 7000 cycles or more and distortion must be reduced to a minimum Non-loaded open wire lines are preferred. In order to overcome the natural selective action of the circuits it is necessary to resort to special compensating networks or equalizers. Attenuators or "pads" are used to reduce volume when necessary and amplifiers to increase it **Television** programs require such a wide band of frequencies that it is impossible to use conventional lines or cables One solution of the problem is to use the so-called coaxial cable Here the circuit consists of a tubular conductor with the return conductor in the form of a wire placed inside the tube and separated from it by means of insulators The transmission characteristics of such circuits are uniform over such wide ranges of frequencies that they are also well adapted to carrier current telephone systems As many as 250 simultaneous conversations may be handled over a single circuit

Central offices or exchanges are necessary to make the required interconnections between lines Exchanges may be either manual or automatic In the manual exchange

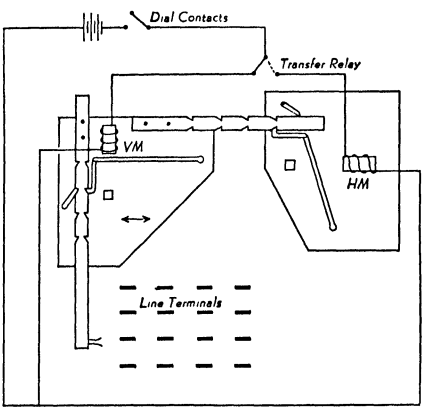


Figure 2 Principle of the automatic telephone exchange

the lines terminate in jacks on a "board" in front of the operator, who can reach as many as 10,000 lines The removal of a subscriber's receiver from the hook causes a line relay to operate and light a signal light in front of the operator, who plugs in a cord, asks for the number, and then makes the necessary interconnection In machine switching exchanges these functions are handled automatically by suitable combinations of relays and selectors The operation of such an exchange is extremely complicated, but the basic principles may be explained fairly simply The lines in groups of 100 terminate in contacts which are arranged 10 in a row and 10 rows high A connector may reach any of these contacts by suitable vertical and horizontal motion (rotation). The two motions of the connector are controlled by separate notching magnets Each time the circuit of a magnet is closed it moves the connector one notch, corresponding to one space or one row The operation of the subscriber's dial serves to make and break the circuit of the proper magnet a number of times corresponding to the digit being dialed When the first digit is dialed the vertical magnet operates to raise the connector the required number of rows During the delay before the second number is dialed a relay moves the vertical magnet from the circuit and substitutes the horizontal. As the second digit is dialed the connector advances to the proper terminal and makes connection Such a system is shown schematically in Figure 2, only four rows and four spaces in a row being shown for simplicity (Article prepared especially for this volume by J S Miller, Jr) (FTM)

TELESCOPE. The name telescope implies that it is a device for "seeing at a distance" There are two modern methods for accomplishing this purpose: (1) the refracting telescope which uses a lens for gathering light and forming a real image of a distant object, and (2) the reflecting telescope which employs a concave mirror for the same purpose. In both of these types an **eyepiece** is employed to "magnify" and study the image. In this article the development of the modern instrument will be briefly treated from the historical point of view

It is probable that experiments on the accomplishment of "seeing at a distance" were carried out from the time of introduction of lenses into Europe during the thirteenth century for the purpose of correcting defective vision However, it is not until 1608 that we find definite evidence of the discovery of telescopic vision, for in October of that year Jan Lippershey applied to the States-General of Holland for a patent to an instrument for seeing at a distance The States-General appreciated the importance of the instrument for military and naval purposes and refused to grant the patent, but did commission Lippershey to continue his experiments and purchased the rights to his instrument The news of Lippershey's discovery spread like wildfire over Europe, and by May, 1609, Galileo had heard of the discovery and set about to construct an instrument for himself based upon Lippershey's design Galileo immediately applied his instrument to astronomical observing, and before the middle of 1610 had made and announced a number of important discoveries.

The type of instrument first built by Galileo is shown diagrammatically in Figure 1 and is now known as the Galilean telescope A converging (convex) lens, *O*, known as the objective, forms at its principal focus a real inverted image of a distant object Before reaching the focal plane of the objective the converging rays are intercepted by a diverging (concave) lens, *E*, known as the eyepiece If the eye is placed behind *E* an enlarged virtual image of the distant object is observed This image is in the same orientation as the distant object (i e, it is an erect image), and the **magnifying**

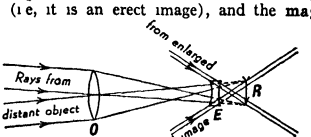


Figure 1.

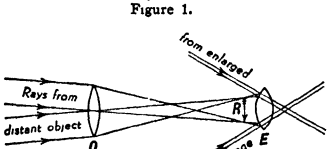


Figure 2

power of the instrument depends upon the relative focal lengths of *O* and *E*.

The Galilean type of telescope now survives only in the form of opera and field glasses, usually of from 2- to 5-power The principal advantages of this type are:

(1) the erect image, (2) the brilliant illumination of the field of view, (3) the diminished distance between *O* and *E* which gives a more compact instrument, and (4) the partial correction of **spherical** and **chromatic aberrations** by the combination of convex and concave lenses Set against these advantages there are the important difficulties that. (1) no **reticle** (cross hairs) can be used, and (2) the field of view with such an instrument is very limited In Galileo's instrument the field of view was only 7′ 15″, less than one-quarter of the diameter of the moon

To overcome the disadvantages of the Galilean form of telescope, Johann **Kepler** in 1611 described the type of instrument shown diagrammatically in Figure 2, which is now known as the Keplerian telescope, or, more commonly, as the astronomical telescope The real image *R* of a distant object is formed by the objective *O* as is the case with the Galilean telescope The difference between the two types of instruments is found in the eyepiece, *E*, which, in the original Keplerian instrument, was a relatively short focus convergent lens set in such a position that *R* is close to its principal focus The eye is placed behind *E* and an enlarged, inverted, virtual image of the distant object is observed This instrument overcomes the fundamental disadvantages of the Galilean instrument, for a reticle or a **filar micrometer** may be used, with the wires placed at *R*, and the field of view is large The chromatic and spherical aberrations are very severe when simple convex lenses are used, and the correction of these defects requires the construction of complicated objectives and eyepieces

In addition to its use in astronomical observing, the Keplerian form of telescope has a multitude of other uses such as fixing a line of sight (as in surveying instruments or in gunsights) and for reading scales on leveling rods, **galvanometers**, etc The inverted image is frequently a disadvantage for terrestrial observing, and erecting eyepieces of various designs have been invented These require the addition of extra lenses with consequent loss of light, both by reflection from the lens surfaces and also by absorption in the glass itself Such erecting systems are never used in astronomical observing The increased length of tube of the Keplerian form over the Galilean is compensated for in prism binoculars by reflecting the rays back and forth parallel to the tube The use of the prism system has the additional advantages of providing an erect image and also increasing depth perception by increasing the distance between the two objectives

For astronomical observing an object glass of large diameter is of fundamental importance both for the purpose of gathering more light, and hence increasing the brightness of faint objects, and also to diminish the size of the **diffraction** rings and thus increasing the resolving power Telescope builders of the seventeenth and eighteenth centuries were unable to obtain glass disks of sufficient clearness and homogeneity for the construction of large object glasses, and turned to the reflecting type of telescope In such instruments a concave mirror is used to form the real image to be examined with the eyepiece This image will be formed in the open end of the tube, and to examine it the observer would have to put his head directly in the path of the incoming rays and seriously reduce the light-gathering power of the instrument To avoid this difficulty a number of different schemes have been evolved **Newton** placed a small mirror in the path of the rays, slightly inside the focus and inclined at an angle of 45° so that the image would be formed at one side of the tube where the eyepiece was located Cassegrain, and others, adopted the scheme of reflecting the light from the objective mirror back through a hole cut out of the center of the mirror The relative advantages, in the Cassegrainian type, of using convex hyperbolic mirrors inside the focus of the objective, concave elliptical mirrors outside the focus, etc, are far too complex to be considered in a work of this character However, by the use of different types of secondary mirrors, the focal length and efficiency of a telescope using one objective mirror may be altered to suit the requirements of a particular problem at hand In general, it may be said that when the principal focus of the main mirror is used, either by placing a photographic plate at this point or reflecting the image out to one side, the instrument is being used in the Newtonian focus When the image is formed through a hole in the objective mirror the instrument is said to be used in the Cassegrainian focus

One fundamental disadvantage of the reflecting telescope is the spherical aberration of the concave mirror Even though this may be corrected along the axis by the use of a concave paraboloidal mirror instead of a spheroidal mirror, nevertheless, the field of good definition is limited Recognizing this difficulty, glass makers and lens designers continued their endeavors to produce large aperture refracting telescopes, culminating in 1897 with the dedication of the Yerkes Observatory telescope, with an objective diameter of 40 inches It seems highly improbable that any refractors will ever be made with lens diameters greater than this Not only are telescope builders faced with the difficulty of obtaining the large clear glass disks and grinding the four surfaces of the achromatic objective, but also there is the difficulty of maintaining the lens figure as the telescope is moved to different positions, since, of necessity, the glass must be supported at the edges For photographing large areas of the sky the refractor still has its place, and compound objectives are continually being designed and built for the purpose of improving definition over large angular fields

Another difficulty with reflecting telescopes has been the tarnishing of the reflecting surface In the original reflectors, in which the mirrors were built of metal, this tarnishing of the surface required the complete regrinding of the figure of the mirror at frequent intervals These metal mirrors were also subject to serious changes in figure due to expansion and contraction of the metal with changes of temperature Both of these difficulties have been overcome by making the mirror of glass and depositing a metallic coating on the figured concave surface The glass does not have to be clear or transparent, can be supported at the back, and has such a low temperature coefficient of expansion that the figure does not change seriously with temperature variation. Up to 10 years ago the mirrors were coated with silver, which was chemically deposited on the surface This could readily be dissolved off and replaced after it had tarnished The new 200-inch reflector, and probably all reflectors of the future, will be coated with **aluminum** deposited by evaporation and recondensation in a vacuum When such a surface is first exposed to the air a transparent oxide of aluminum is immediately formed which protects the surface from tarnishing for a considerable period of time (W K.G)

TELEVISION. Television is the art of transmitting images and scenes and reproducing them faithfully, including motion, at points distant from the source The medium used in existing methods of television is one wherein the transmitting agency is electrical in nature Although it is possible to transmit television over wires, it seems easier to develop it by using **radio** transmission, similar to the broadcasting of sound In this electrical system the following elements are necessary to the complete television process

a An apparatus to view the scene to be televised, and to convert the viewing into electrical pulses
b The radio transmitting station to load these pulses onto radio waves for transmission to the receiving station
c Receiving station for reception and detection of the radio waves
d **Amplification** of the relatively weak received signal

e. Transduction of the electrical pulses to light.
f. Recreation of the scene upon a suitable viewing screen.

When a camera is employed to record a scene upon a film, the entire scene is recorded simultaneously This is also true of the ordinary motion picture No means has yet been discovered for applying to television the complete impression of a scene, rather it has been found necessary to resort to a method known as scanning The scanning of a picture is illustrated by Figure 1,

Figure 1 Horizontal 30 line scanning (Lines show paths taken by scanning spot)

wherein the image is crossed by several horizontal lines Each line represents a path taken by a spot of light which flickers over the scene to be televised, beginning, for example, at the upper left-hand corner and proceeding to the right When the first line has been scanned, the second immediately follows The light and dark spots of the scene, as traced out by the scanning spot of light, can then be picked up, as reflected light by a photo-electric tube (See **Photo-electric Cell**) As the picture is thus completely scanned by a spot of light, there may be produced an electric current varying in accordance with the details of the original picture (in degree of light and dark) This varying electrical current is then put through the subsequent processes outlined in the preceding paragraph until it again appears as a variable beam of light in the transducer Now if this beam is caused to flicker back and forth over a screen in exact synchronism with the scanning spot of light, the image will be recreated That this is possible is due largely to a characteristic of the eye known as persistence of vision If the scanning spot moves so rapidly that it completes the traverse of the scene several times a second, persistence of vision will merge the succession of pictures so that the impression received is one of continuous motion This principle was not, of course, discovered by those working on television problems as the principle is fundamental to all methods of motion picture projection In motion pictures there is flashed on the screen a succession of individual pictures at a rate of from 16 to 24 per second, a rate sufficiently high so that the persistence of vision eliminates flicker. The same must be true of the television picture, which is often transmitted at the rate of eighteen pictures per second In the illustration mentioned, horizontal thirty-line scanning is shown, however, an inferior picture from the standpoint of clearness and detail will be had unless the number of lines into which the scene is divided greatly exceeds this Also, vertical line scanning could be employed Two hundred-line horizontal scanning is being used to a considerable extent

In the early days of television mechanical means of scanning were generally employed Among these the Nipkow disk was of importance because of its contributions to the early history of television. The principle is shown herewith by Figure 2 A rotating disk has bored in it a series of holes arranged spirally. In the

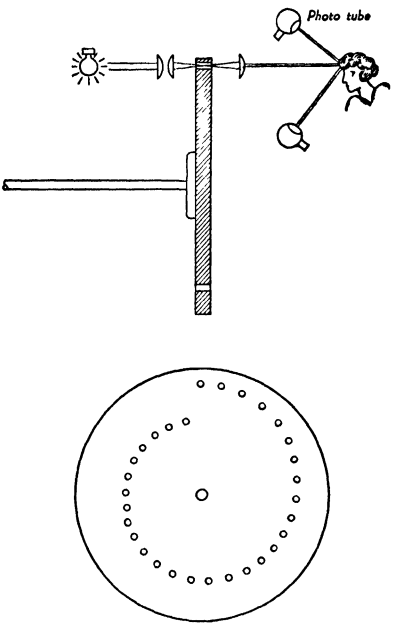


Figure 2 Scanning by the "Flying Spot"

illustration there are thirty holes, as would be necessary to produce thirty-line scanning The flying spot method of scanning is illustrated This is more suitable than the reflected image system, since the stage is not subjected to unpleasantly strong illumination The disk is mounted so that it can be rotated and a strong source of illumination provided where it can be focused on the disk As the disk rotates and a hole moves across the beam of light, it will cause a spot of light to be thrown across the scene being televised There will be as many of these light traces per revolution of the disk as there are holes The spiral arrangement causes each line to be a uniform distance below the preceding one, so that the scene will be completely scanned as many times per second as there are complete revolutions of the disk.

Suitably arranged banks of photo-electric tubes receive the varying light impulses reflected from the flying spot and transform them to a varying electric current This is then employed in the radio sending system in the manner similar to that which is employed for sound broadcasting. There are, however, important differences here, some of which are at the root of the difficulties of securing commercial television Principal among these are the wide bands of frequencies necessary for the transmission of television. In sound broadcasting each broadcast channel is arranged with a clear frequency band of about ten kilocycles to eliminate interference between stations. Even with Federal control in this matter, interference is troublesome, as any listener knows In television a much wider band of frequencies must be allowed because of the possible high frequency of the light impulse resulting from practical

scanning speeds For example, with two hundred-line scanning on a square frame having fifteen pictures per second, there will be 3000 lines per second Considerations of light impulse frequency show that one-half of two hundred lines can be considered as the number of complete light cycles per line, and therefore we have a maximum possible frequency of the light impulses of 300,000 per second This indicates that a wide broadcast channel is required for television It is obvious that the present already crowded broadcast band cannot be invaded by television, but there is available the short wave range, and it is to this that television turns for sufficient "elbow room" This, coupled with the fact that television apparently cannot be transmitted with fidelity over distances such as are common in sound broadcasting, will give room for much local television broadcasting

After transmission of the radio wave and its reception and **demodulation** into a uni-directional variable electric current, there arises the need for a transducer which will perform the service of varying the intensity of a beam of light in proportion to the received electric signal, and of reproducing the same on a screen, in lines and pictures which succeed each other at the same rate as that used in scanning The electric current might be fed to a **neon** lamp, as the quantity of light emitted is very sensitive to input voltage The neon lamp could thus transfer the electrical impulses to corresponding light pulses A second Nipkow disk running at a speed and position synchronized to the scanning disk might then build up on a screen a succession of pictures which to the eye reproduce the original scene

Although the system mentioned was employed in the earlier days of television, mechanical scanning and transducing methods are not able to obtain the number of lines considered necessary for commercially successful television For two-hundred-line scanning, the electrical methods of scanning and transducing, such as are illustrated by the **cathode ray** tube, are employed

The invention and development of the cathode-ray tube has been immensely important to the field of television. It has greatly improved the prospects of ultimate commercial success The cathode-ray tube was first applied to **oscillographic** uses, that is, the production of a visible image which in graphical form represented an otherwise invisible electric wave In its simplest form the cathode ray tube is composed of the filament, or **cathode**, which, when heated, emits **electrons** Nearby is an **anode**, generally of circular form, to which is applied a high voltage at positive potential The electrons leaving the cathode are attracted to the anode as in the common **vacuum tube**. Due to the ring shape of the latter, and the very high speed to which the electrons are accelerated by the anode voltage, there results a beam of electrons which continues at high velocity through the hole in the anode in a straight line along the axis of the tube However, should this beam of electrons come under the influence of an **electric field**, it will be deflected from its original course Now, referring to Figure 3, the electron emitting filament is seen at the left-hand end of the tube The electrons travel through a screen or shield and through the anode or accelerating ring The beam of electrons shooting through the hole then follows the path which is included between two sets of deflecting plates located at right angles so that the beam may be deflected either vertically or horizontally by suitably applied voltages Finally the beam of electrons strikes a fluorescent screen, where it creates a brilliant spot of light The reproduction of a scene upon the screen is accomplished as follows Assume that scanning was horizontal at the rate of two hundred lines per picture, eighteen pictures per second The received and amplified electrical impulse is applied to the modulating shield, and the electron beam strength is thereby caused to vary in accordance with the intensity of light reflected from the original scanning spot A voltage having a saw-toothed wave form and a frequency equal to the number of lines per second, is applied to the X deflecting plates, while to the Y deflecting plates a similar voltage, but with a frequency of eighteen cycles per second, is applied If these two frequencies are suitably locked to the original scanning system, they will cause the beam of electrons to be deflected over the screen in exact reproduction of the original scanning Since the beam strength is varied in accordance with the intensity of light received from the original scanning system, the illumination created by the impact of electrons upon the fluorescent screen reproduces the original scene

The description just given is intended to be illustrative of the basic idea, and does not convey a true picture of the equipment actually used Lack of space forbids an extended discussion of the problems which make a successful employment of the cathode ray tube complicated Problems of beam dispersion, intensity of illumination, and others, have given rise to modifications of the cathode ray tube as diagramed However, in the actual equipment one may see functioning the basic principle expounded Neither is there space adequate to the proper discussion of methods of creating the deflecting voltages and of locking them to the scanning system It is of interest, however, to survey one alternative type of transducer employing a rotating disk (Figure 4) A **Nicol prism**, which is of Iceland spar, polarizes light If the axes of two such prisms are turned at right angles in a beam of light, the beam will be extinguished The intensity of the beam therefore may be varied from full to extinction by rotation of the prism In television it is not practical to rotate the prism mechanically in an attempt to follow the received electrical impulses, rather, the beam of light leaving the first prism is transformed electrically before reaching the second prism, which is stationary This is accomplished by a Kerr cell The latter is a transparent dielectric (nitrobenzene) in a transparent container Two insulated plates are provided in the cell The dielectric has the property of converting the plane-polarized light from the first prism into elliptically polarized light of varying eccentricity (See **Electric and Magnetic Double Refraction**) The effect of this is to vary the intensity of the light that gets through the second Nicol in accordance with the potential differences across the plates, and if this potential difference corresponds to the intensity of light reflected by the scanning spot, there can be produced from a source of light of constant intensity, a beam of light of varying intensity duplicating the original When this beam is put through the holes of a synchronized Nipkow disk, there results a rebuilding of the original scene.

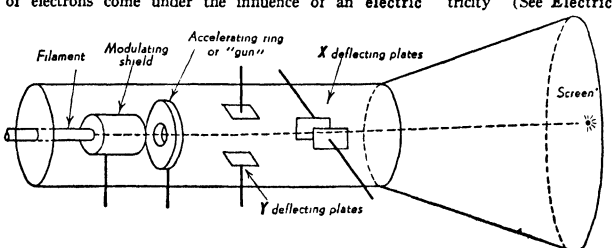


Figure 3. The cathode ray tube

It was only natural that the success of the cathode ray tube as a transducer should focus attention upon its possibilities as a scanner, especially as it would not

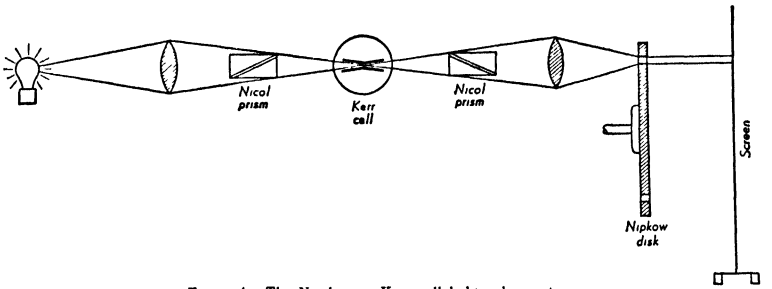


Figure 4 The Nicol prism Kerr cell light valve system

suffer from the principal defect of the mechanical system, namely, difficulty of scanning at such high speeds as 3600 lines per second The problem of scanning with a cathode-ray tube is somewhat different and more difficult than that on the receiving end, but it has been possible to scan with a cathode-ray tube having in place of the phosphorescent screen a plate which is coated with granular material of a photo-sensitive nature, in fact, each grain acts as a small photo-electric cell The scene to be televised is focused on the plate and a beam of electrons is caused to scan the plate by means of the two deflecting voltages The image of the scene sets up in each minute granular photo cell an electric charge, which is released as the beam of electrons passes it Upon release the charge created by the particular intensity of light in that photo cell passes through the external circuit to the transmitting system This apparatus is called an iconoscope

Television has attracted the attention and energies of many of the best of the world's scientific intellects, but, although it has received attention for many years, the severe problems which must be overcome have made progress in television necessarily slow The high state to which sound broadcasting has been developed in the United States has been a great incentive to the development of a corresponding system of television Some of the impediments to a rapid acceptance of television on the part of the present radio audience have been mentioned In addition to these, television receivers will of necessity be much more costly than sound receivers Add to this the higher cost of the broadcasting equipment, and the difficulty of national hook-ups for the broadcasting of programs originating at a central point, and the field becomes one in which widespread commercial acceptance will of necessity be slow At the same time, so attractive are the possibilities of successful commercial television that there is every likelihood that it will ultimately replace the present experimental status (F T M)

TELLURIUM. Symbol Te Atomic number· 52. Atomic weight: 127 61. Density· 6 25 Hardness· 2 3 Melting point: 452° C Boiling point 1390° C (Isotopes page 238)

Tellurium is a silver-white brittle semi-metal; stable in air, and in boiling water, when heated in air burns with a greenish flame to form the dioxide, insoluble in **hydrochloric acid**, but dissolved by nitric acid or **aqua regia** to form telluric acid, dissolved by **sodium** hydroxide solution; combines with chlorine upon heating to form tellurium tetrachloride. Discovered by Reichenstein in 1782

Tellurium occurs chiefly as telluride in **gold, silver, copper, lead,** and **nickel** ores in Colorado, California, Ontario, Mexico, and Germany, and infrequently as free tellurium and **tellurite** (tellurium dioxide, TeO_2). The **anode** mud from copper and lead refineries, or the flue dust from roasting telluride gold ores is treated by fusion with sodium nitrate and carbonate and the melt extracted with water The resulting solution is acidified carefully with **sulfuric acid**, whereupon tellurium dioxide is precipitated, and the dioxide reduced to free tellurium by heating with carbon Chemically related to **selenium**

Acids Tellurous acid (H_2TeO_3), white crystals, only slightly soluble in water, telluric acid (H_2TeO_4), white crystals, soluble in water, forms telluric oxide upon heating to a red heat

Chlorides Tellurium dichloride ($TeCl_2$), black solid, tellurium tetrachloride ($TeCl_4$), white solid, melting point 224° C, formed by reaction of tellurium and excess chlorine

Hydride Tellurium hydride, hydrogen telluride (H_2Te), by reaction of aluminum telluride with water or hydrochloric acid, gaseous, unstable, of unpleasant odor, chemically related to hydrogen selenide

Oxide Tellurium dioxide (TeO_2), white solid, sublimes at 450° C, only slightly soluble in water, soluble in acids, and in sodium hydroxide, tellurium trioxide (TeO_3), orange crystals, insoluble in water, in nitric acid, and in cold **hydrochloric acid**, soluble in hot concentrated sodium hydroxide solution

Tellurides Metallic tellurides are formed by combination of tellurium and the metal, or by precipitation of the metallic salt solutions with hydrogen telluride.

Numerous organic compounds of tellurium have been prepared (R K S)

TELOGONIA. Nematoda.

TELPHER. An electric **hoist** suspended from a wheel carriage which rolls on an overhead track is called a telpher The operator rides on a platform, also supported by the carriage, and controls the hoisting as well as the horizontal movement of the telpher The telpher can be employed to lift and transplant all material which can be suspended from a hook, and is suitable for a variety of service in industrial plants, being able to transport lumber, pipe, iron (usually with electromagnet), partially or completely manufactured parts, packages, and bulk material (with grab bucket) The carriage may roll on an I-beam suspended from an overhead structure In building interiors it may be suspended from the roof trusses Outside, of course, a special supporting structure must be built. (F T M)

TELSON. The hind part of the body of an **arthropod**, beyond the segmented abdomen. The **anus** opens in this structure, which is otherwise extremely varied In the **lobster** it is a flap associated with a pair of broadened appendages to form a powerful fanlike swimming organ and in the **scorpions** it is the sting. The telson of the **horseshoe crab** is the spinelike terminal appendage. (A W.L.)

TEMPER. The tempering of **hardened steel** is a reduction of its brittleness which, without any large reduc-

tion in hardness, toughens the metal and renders it suitable for service in which there might be some shock, and for cutting tools of all sorts To temper a piece of hardened iron, it is reheated to a temperature below the critical range, then quenched The desirable tempering temperature varies with the service to which the product is to be put. It is generally determined by noting the surface of the metal, which, before reheating, has been brightened The color attained just before quenching indicates the temperature approximately, and tempering as ordinarily carried out is a process of heating to a known desired color, followed by quenching. For example, twist drills should be tempered by heating to approximately 500° F, which means that they must be heated until the surface exhibits a deep purplish shade Springs which should be heated to approximately 550° must be brought to show a bluish color before quenching The tempering is obtained by the temperature to which the steel is heated, and not by the rate of cooling, quenching being merely a matter of convenience in bringing the piece down to a handling temperature Sharp-edged tools are often hardened and tempered in one operation They are heated to above the critical range, then the cutting edge only is quenched It is quickly rubbed bright, and as the heat creeps by conduction down the stem of the tool, the hardened cutting edge is reheated The temperer watches the change of color closely, and when the desired color is reached, he quickly quenches the whole tool (F T M)

TEMPERATURE. Fundamentally, temperature is a manifestation of the average translatory kinetic energy of the molecule of a substance due to heat agitation, and is measurable by any one of many physical effects due to changes or differences in this energy Thus, substances expand, their electrical resistivity changes, gases and vapors exert varying pressure, the viscosity of fluids alters etc, as the temperature varies, and the state of aggregation of any substance (whether solid, liquid, or gaseous), under a fixed pressure, depends primarily upon the temperature Very imperfectly, also, our special temperature sense is able to judge whether one body with which we come into contact is warmer or colder than another Heat energy always transfers itself spontaneously from the warmer to the cooler parts of any body or system of bodies, never in the reverse direction, and the transfer ceases when the temperatures become equalized The temperature of a vacuum may be defined as the temperature of a small body placed in it and in thermal equilibrium with it All measurements of temperature, upon whatever principle they are based, are comprised under **thermometry** (See also **Temperature Scales**) (L D W)

TEMPERATURE, HUMAN Temperature of the body Normal temperature is usually said to be 98 6° Fahrenheit Actually this normally varies in the course of twenty-four hours, so that the variation between maximal and minimal temperatures during this period is about 1 8° Fahrenheit The above figures are those obtained when the temperature is taken by mouth The rectal temperature is one degree Fahrenheit higher

The body temperature is determined by the relation of two factors· the amount of heat produced within the body, and the amount of heat eliminated The amount of heat produced depends on the basal **metabolism.** Additional heat is produced by muscular activity and eating Extra heat is eliminated by any increase in radiation, condensation, or evaporation on the skin surface, and by more rapid and deep breathing When insufficient heat is eliminated the temperature rises and fever is said to be present Normally the delicate adjustment in the body between heat production and heat elimination is under control of the temperature centers in the brain If the body temperature falls below 86° Fahrenheit, life is seriously threatened On the other hand, the highest temperature compatible with life is between 109° and 110° Fahrenheit, (R S M)

TEMPERATURE SCALES. Temperature is usually reckoned both ways from an arbitrarily chosen zero When it had become known that **heat** is a form of **energy** and that temperature is determined by the mean transitional energy of molecular agitation, the concept of an **absolute zero** of temperature became possible, but since such a condition is apparently unattainable and is inconveniently far removed from temperatures of everyday experience, a more practicable reference point, such as the melting point of ice, is preferable for ordinary purposes

Starting at such a zero, it would seem logical to base the temperature scale upon equal quantities of some selected effect caused by temperature change For example, a change of one Fahrenheit degree in· the temperature of ice-cold mercury increases its volume by almost exactly one ten-thousandth, so that each ten-thousandth might be taken as indicating one degree of temperature However, a different plan has been followed Instead of one fixed point, two are chosen, and the temperature interval between them divided into aliquot parts

Thus, for the Centigrade scale, the fixed points are the freezing and the boiling points of water, and the interval is divided into 100 parts, so that the freezing point is 0° C and the boiling point is 100° C. On the Fahrenheit scale, these points are marked 32° and 212° respectively, the zero point having no obvious physical significance The ratio of the Fahrenheit to the Centigrade degree is therefore 5 9, and if t_F and t_C are respectively the Fahrenheit and the Centigrade value of the same temperature, their relation is easily seen to be

$$t_F = \tfrac{9}{5} t_C + 32°, \text{ or } t_C = \tfrac{5}{9}(t_F - 32°)$$

The original of the Centigrade scale was the Celsius scale, on which the boiling point was zero and the freezing point 100° The Réaumur scale, with freezing as zero and boiling at 80°, is still used in parts of Central Europe Special limited scales have been adopted for certain purposes, for example, the Leyden low-temperature scale (or low-temperature range of the Centigrade scale), taking the boiling point of hydrogen at —252 74° and that of oxygen at —182 95° as its fixed points and using the Centigrade degree

Since the Centigrade value of absolute zero has been determined as —273 18°, it follows that if we wish to express an "absolute temperature" in Centigrade degrees, we have but to add 273 18° to the Centigrade temperature

$$T = t_C + 273\ 18°$$

It will be noted that nothing is here said as to the basis upon which equal subdivisions or "degrees" of a fixed temperature interval are established For this the reader is referred to **Thermometry** (L D W)

TEMPORAL. A bone of the vertebrate skull In the human skull it lies at the side, centering about the ear It forms the posterior part of the cheek bone with the articulation of the lower jaw, and bears the mastoid process behind the ear It includes the squamosal bone and the bones of the ear (A W L)

TENCH. Pisces, Teleostei A European fresh-water fish (**Pisces**), *Tinca tinca* It is found in ponds, lakes, and other quiet waters, particularly those with a muddy bottom The species is known to reach a weight of five pounds in some cases. (A W L)

TENDON. Connective tissue structures connecting muscles with their skeletal supports They are composed of parallel white fibers, closely bound into bundles between which the cells of the tendon are compressed The entire tendon is surrounded by a fibrous sheath known as the vagina fibrosa which is split in some cases to form a cavity containing a mucoid liquid Such a sheath is called a vagina mucosa. It develops where a wide range of movement is necessary.

Aponeuroses, ligaments, and fasciae are fibrous structures resembling tendons in structure The first are broadly expanded and usually bind down muscles The second connect bones The third are fibrous coverings of muscles and other organs When tendons are severed they must be sutured together again At least six weeks are required for union between the cut ends (A W L, R S M)

TENDRIL. A tendril is a slender elongated structure which either twines around any supporting object or is attached thereto by means of small disks. Tendrils may be modified **stems**, as in the grape, or **leaves**, as in various peas, or **stipules** (R M W)

TENOSYNOVITIS. An infection of the membranous sheath which envelops certain tendons in various parts of the body These sheaths usually surround tendons, especially those controlling movement of the fingers, wrist, and hand, and provide frictionless movements Normally there is a small amount of fluid within these sheaths to provide lubrication When infection takes place, more fluid accumulates with the production of pus The only treatment that will save the function of the tendon is very early surgical drainage

The symptoms of tenosynovitis are acute pain, swelling, and redness over the affected part (R S M)

TENREC. Mammalia, Insectivora *Centetes* An animal of Madagascar This species resembles the other members of the order in its compact body, short legs, and long sharp muzzle It is the largest of the group, attaining a length of sixteen inches, and is clothed with a mixture of spines, bristles, and hair Tenrecs are nocturnal burrowing animals (A W L)

TENSION. In structural engineering tension is used to denote the longitudinal force which causes the fibers of a member to elongate, thus giving rise to tensile **stress** (C W C.)

TENSORS. The tensor concept is a generalization of that of a **vector**, and requires for its specification more than three components

A tensor may be defined as a set of n^r components which are functions of the coordinates of any point in space of n dimensions, which is transformed linearly and homogeneously, according to certain rules, when a transformation of coordinates is made Tensors are called covariant, contravariant or mixed according to the law of transformation The number r is called the rank or order of the tensor. (L L S)

TENTACLE. A slender fleshy protuberance of the body wall, in the region of the mouth and usually arranged as a group surrounding the mouth Tentacles are well developed among the **coelenterates**, the marine **annelids**, and the **cephalopod** mollusks, and are present in all **Bryozoa, Brachiopoda,** and **Phoronidea.** In the coelenterates they contain stinging cells and are capable of wrapping around the prey to bring it to the mouth They also act to secure food by ciliary movement, in the Bryozoa the cilia covering them apparently carry a food-bearing current down the funnel that they form about the mouth Cephalopod tentacles also enfold the prey but in addition they are provided with cuplike suckers which enable them to grip even very smooth surfaces In this group and to a limited extent in the coelenterates they are used for locomotion

In the **echinoderms** a sensory appendage at the end of each radial water vessel is called a terminal tentacle and in the sea cucumbers tube feet in the region of the mouth are developed into tentacles of various forms, sometimes finely branched. (A W L.)

TENTACULOCYST. A sense organ of the jellyfishes and a few allied forms. It consists of a reduced tentacle at the margin of the body, hooded by a small projection of the margin The tentacle bears a pigment spot which may be a light-sensitive organ and is flanked by two pits regarded as olfactory organs Tentaculocysts lie at the ends of the interradial and perradial canals. (A W L)

TEOSINTE. Corn.

TEPHRITE. A term proposed by Cordier, in 1816, for a variety of **basalt** containing both **plagioclase feldspar** and **nepheline** or other soda-feldspathoids. Tephrite differs from **basanite** because of the absence of olivine. (R M F)

TERBIUM. Symbol Tb Atomic number: 65 Atomic weight 159 2 Type of compound Tb_2O_3 Color of salts: colorless Discovered by Mosander in 1842 A member of the **yttrium** sub-group of the rare earth metals. (R K S)

TERGITE. Skeletal system.

TERMINAL MORAINE (END MORAINE). When balance is maintained between the melting of a **glacier** and its forward advance, the debris carried on (superglacial), within (englacial), and dragged along the bottom (subglacial), is dumped at that point and builds up a heterogeneous mass of the transported material called the terminal moraine If a glacier is slowly retreating and makes successive halts farther and farther up the valley, a series of terminal moraines are formed which are spoken of as recessional moraines (R M F)

TERMITE. Isoptera.

TERMITOPHILE. An insect of another form living in the nest of **termites.** Both ant and termite colonies are inhabited by other insects, some apparently living as scavengers and profiting by the supply of food and by the protection afforded by the colony while others produce secretions used by their hosts and so live in a commensal relationship Even in the latter cases the termitophiles may eat the young of the termites, but since they render some return they are not to be regarded as parasitic on the colony Some, however, are nourished by food supplied by the termites in return for the desired secretion Insects of such habits are often very strangely formed, differing conspicuously from other members of the orders to which they belong

Among the known termitophiles are **flies, larvae** of **moths,** one species of **Homoptera,** and many **beetles.** (A W L)

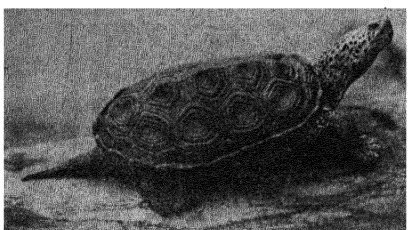
TERN. Aves, Charadriiformes A bird (**Aves**) resembling the gulls but with a more slender and tapering beak The tail is forked Terns are very like gulls in habits and are usually seen in flight over water, both on the coasts and near ponds and lakes About ten species are normally found in the United States (A W L)

TERRA COTTA. Terra cotta is the name given to a product made of burnt clay which has been fired at a high temperature It is employed in building construction as a decorative feature, and is to be found in copings, cornices, facades, and other trim It is used both on exteriors and interiors Terra cotta is one of the most permanent of building materials, and a great deal of distinctive individual ornamentation of buildings of present and past times has been achieved by liberal use of terra cotta A standard building material used to construct interior partitions, to back up exterior face brick in a masonry wall, or to form a complete exterior wall for an industrial building, is known as hollow building tile The aim in manufacturing this product, of course, is to produce a cheap fireproof building material, but not an especially decorative one

A great deal of terra cotta work is special, i.e., in its shape and surface decoration, as well as color and method of attachment. Models of the separate pieces are made and plaster casts taken. These casts are then used to

mold the clay body of the terra cotta. When the molded clay has dried it is removed from the mold and fired at high temperature until it has become hard and unaffected by moisture. It is known now as a bisque, and is ready for the application of liquid glazes, known as slips. The minerals which produce the color are incorporated in this slip. The bisque is either sprayed or dipped in the slip, and returned to the kiln for firing of the glaze. Terra cotta is set in mortar, with carefully pointed joints, and in some cases may be reinforced by metal ties or by shelves or caps. (F.T.M.)

TERRAPIN. Reptilia, Chelonia. Certain of the pond and land **turtles,** especially those of the genera *Malaclemmys* and *Pseudemys*. The related genus *Terrapene* includes the box turtles, and the common painted turtles are also closely connected forms. The species whose flesh **is so highly** esteemed is the diamond-backed terrapin or



Diamond back terrapin. (Courtesy of N. Y. Zool. Soc.)

salt-marsh turtle found in salt marshes along the Atlantic coast from Massachusetts to Florida. This and a related species of the Gulf coast make up the genus *Malaclemmys*. The species of *Pseudemys* are commonly called sliders or cooters, one species bearing the name red-bellied terrapin. They are edible but are less highly valued than the diamond-back. Terrapins are widely distributed in the northern hemisphere. Elsewhere they are limited to a few species in Central and South America. (A.W.L.)

TERRA ROSSA. A red **ferruginous,** residual earth derived from the surface alteration of limestones. A characteristic soil of the *Karst* lands surrounding the Adriatic Sea. (R.M.F.)

TERRESTRIAL COORDINATES. The position of a point on the surface of the earth may be defined to a high degree of precision by considering the earth as a sphere and establishing on that sphere a reference frame **for spherical coordinates.** The most common system is to consider the line joining the poles of rotation of the earth as a fundamental line. The plane perpendicular to this line, and passing through the center of the earth, is the plane of the **equator** and cuts out on the surface of the earth a great circle known as the terrestrial equator. Great circles on the earth perpendicular to the plane of the equator and passing through the poles of rotation are known as terrestrial **meridians.** The fundamental direction selected in the plane of the equator is the direction of the point of intersection of the meridian through Greenwich, England, with the equator.

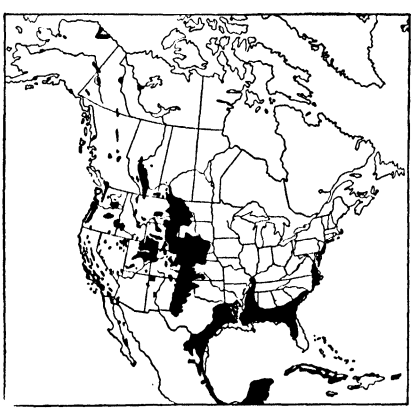
Terrestrial **longitude** of a point on the earth is the spherical coordinate measured in the plane of the equator either east or west from the point of intersection of the meridian through Greenwich to the point of intersection of the meridian through the point in question. **Latitude** is the spherical coordinate measured from the equator north or south along the meridian to the point in question.

Further details regarding the coordinates of terrestrial latitude and longitude, together with modifications produced by the shape of the earth, will be found elsewhere in this work. (W.K.G.)

TERRESTRIAL MAGNETISM. The outstanding facts of the earth's magnetism were investigated by William Gilbert about 1600. He recognized that the earth acts as a huge bipolar magnet, and anticipated by many years the actual discovery of its magnetic poles, which are located, respectively, north of Hudson's Bay and south of Australia. (The pole north of Hudson's Bay is, of course, one of the negative or south-seeking kind, since the positive poles of compasses point toward it.) Our direct knowledge of the terrestrial magnetic field is confined near the earth's surface, and is usually represented by maps showing lines of equal magnetic **declination** (departure from the true north), lines of equal **inclination** or dip (See **Dip Needle**), and lines of equal magnetic intensity (See **Magnetometer**). The inclination at middle latitudes approximates 70°, while the total intensity in this region is usually something like 0.6 **oersted,** with a horizontal component of about 0.2 oersted. There is a line of zero declination (agonic line) at all points of which the compass indicates the true north; this line passes down through the United States and traverses the globe in each hemisphere from northwest to southeast.

The terrestrial field has certain variations, chief among which are: (1) the diurnal variation, in which the compass swings back and forth through an angle of many minutes once a day; (2) the secular variation, a slow periodic movement of many degrees with a period of several centuries; (3) random variations, sometimes very great, when they are called "magnetic storms." These last are unquestionably associated in some way with those solar activities which result in **sun spots,** since their occurrence is almost simultaneous with the appearance of sun spots, and they have the same eleven-year cycle. The **aurora borealis** seems to be similarly involved. The mechanism behind terrestrial magnetic phenomena has not been satisfactorily explained; though the rotating earth's electrical condition (See **Lightning**), together with thermoelectric earth-currents, doubtless contribute to some of the effects. (L.D.W.)

TERTIARY. A major subdivision of the **Cenozoic,** or last geologic era. The periods of the Tertiary from



Map showing the surface distribution (areas of outcrops) of Tertiary strata in North America.

the oldest to the youngest are: **Paleocene, Eocene, Oligocene, Miocene, Pliocene.** (R.M.F.)

TESCHENITE. Theralite.

TESLA COIL. A type of **induction coil** in which the primary has a high-frequency spark gap instead of the usual interrupter, and whose secondary yields an intense high-frequency discharge A typical arrangement is shown in the figure A high-voltage transformer *T*, or sometimes an ordinary induction coil, sends sparks across the primary gap G_1, which is in circuit with a condenser C_1 and the primary air-core coil *P*, composed of a few turns of heavy copper wire or tubing Because of the oscillatory nature of the condenser discharges, this circuit is the seat of powerful high-frequency oscillations The secondary, *S*, consists of many turns of fine wire The secondary circuit may be "tuned" by means of a variable condenser C_2, and when it is in **resonance** with the primary, the oscillations in it are very intense A torrent of high-frequency sparks plays across the secondary gap G_2, or one terminal may be grounded and sparks drawn from the other (L D W)

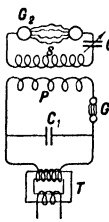


Diagram of Tesla-coil circuits

TEST. A noncellular structure enclosing the body of an animal and formed by the outer layers of cells A test is found in some one-celled animals, giving the name Testacea to one division of the phylum In these forms it is composed of various materials, including **chitin** and calcareous (See **Calcium**) deposits It may be either rigid or flexible Foreign particles such as grains of sand are incorporated into some of these tests

A tough enveloping test is also formed about the body of the **tunicates,** giving them their name through the synonymous term tunic In this group the structure is formed of a material closely related to cellulose, which is a common plant product (A W L)

TESTA. Seed

TESTACEA. Sarcodina.

TESTICARDINES. Brachiopoda.

TESTICLE Testis. One of two egg-shaped glandular organs in the male They are suspended from the groin by the spermatic cords and are supported and enclosed by the **scrotum** Each gland measures about one and a half inches in length, one inch in width and about three-quarters of an inch in thickness from side to side The testicle is joined to the spermatic cord by means of the epididymis which is a coiled duct lying at the upper portion of the testicle When uncoiled this duct measures twenty feet in length The function of the testicle is to produce **spermatozoa** and an internal secretion or **hormone** This hormone controls sex development and personality factors interacting with hormones of other glands, particularly the **pituitary gland**

If both testicles are removed before **puberty,** secondary sex characteristics fail to develop, and the skin remains smooth, voice is high pitched, fat develops around the breasts and buttocks, excessive growth occurs and the pubic hair is scanty Erections are feeble, and no ejaculation occurs The individual is timid, lacks ambition, and normal combativeness and aggressiveness (eunuch) In early fetal life both the ovaries and the testicles lie in front of and below the kidneys During fetal growth they descend The ovaries finally lodge on the side wall of the pelvic cavity The testicles normally continue downward and descend through and out of the abdomen in the region of the groin to the scrotum This descent may be arrested along any portion of this pathway At times one or both testicles remain in the abdominal cavity, in its wall or in the groin. To obtain normal function, an operation is performed and the undescended testicle is brought down to its normal scrotal position This operation is best done at or shortly after puberty In some cases glandular injections will cause the testicle to descend without operative interference. (R S M)

TESTIS. Gonad.

TESTUDINATA. The **turtles** and **tortoises,** constituting an order of the class **Reptilia,** also known as the order Chelonia These animals have a short broad body enclosed in a shell composed, in most species, of closely joined bony plates covered with thin plates of horn or tortoise shell The bony plates are flattened ribs and vertebrae, with supplementary dermal plates The upper part of the shell is the **carapace** and the plate below the body is the plastron, the two are firmly united along the sides in most species The skin is covered with scales and the jaws are without teeth, forming a horn-sheathed cutting beak.

Most species of the order are partially aquatic but some are strictly terrestrial The marine turtles are the most thoroughly aquatic species, but even they come to shore to lay their eggs. These species have all four limbs developed as paddlelike flippers while the other members of the group merely have webbed toes (A W L)

TETANUS (LOCK-JAW). An infectious disease caused by the **Bacillus tetani** which liberates a poison having a peculiar affinity for nerve tissue This results in spasms and convulsions of the body muscles

The disease has been known since ancient times, but no treatment was available until the discovery of antitoxin by Behring and Kitasato in 1890 In 1922 in the United States, 1,480 persons died from tetanus, but in the World War, when tetanus antitoxin was given to all wounded soldiers of the United States, among 224,089 wounded only 36 developed the disease

Tetanus usually follows an injury of the puncture or penetrating type Blank cartridge wounds are particularly dangerous in this respect The **toxin** produced by this organism is one of the most powerful known—1/300 of a grain being fatal to man

The time necessary for the disease to develop after injury is 5 to 7 days in acute cases and from 4 to 5 weeks in the chronic cases

The earliest symptoms are extreme restlessness and irritability, stiffness and tightening of various muscles The muscles first affected are usually the jaw muscles, which produce in the later stages the so-called lock-jaw Death is frequently caused by asphyxia following spasm of breathing muscles or cardiac failure during a convulsion

Tetanus bacilli are found normally in the excreta of animals and man The soil of certain geographical areas in the world favors the growth of the tetanus organisms more than other sections

All wounds of the dirty, deep lacerated type should be given immediate surgical care and a prophylactic injection of tetanus antitoxin After the disease once develops, the important factor in treatment is to give sufficient antitoxin to neutralize the effect of the poison produced by the tetanus organisms This is given in large doses by three routes· (1) in the tissues, (2) into the blood stream, and (3) into the spinal canal Before the use of antitoxin the mortality from tetanus was from 80–100% At present the mortality on those cases which do develop it is only about 25%

Recently a tetanus toxoid has been produced This is given to those who work in the soil, etc, and may also be given to children routinely, as it produces a permanent immunity to this disease (R S M)

TETRABRANCHIATA. Cephalopoda.

TETRADYMITE. The mineral tetradymite is a **bismuth tellurium sulfide** corresponding to the formula $Bi_2(TeS)_3$ It is **rhombohedral.** Occurs usually in gold **quartz** veins Found in Norway, Sweden, England, Bolivia, British Columbia, and in the United States in **Virginia,** North Carolina, Georgia, Montana, Colorado

and elsewhere It derives its name from the Greek word meaning *fourfold* in reference to the double twin crystals occasionally developed (E S C S)

TETRAGONAL SYSTEM. Crystallography.

TETRAHEDRITE. The mineral tetrahedrite is a **copper antimony sulfide,** the formula being $Cu_8Sb_2S_7$ The copper may be replaced in part by **iron, lead, zinc, mercury,** etc, and the antimony by **arsenic.** This mineral is **isometric** and the crystals are **tetrahedrons** often highly modified It is also found massive It has no **cleavage;** uneven fracture, brittle, hardness, 3–4, metallic luster, color, gray to black, streak, gray to black but may be brown or red, practically opaque There are many European localities for tetrahedrite among which might be mentioned Rumania, Czechoslovakia, France, and Cornwall, England It is found in Algeria and Bolivia, and in the United States in Colorado, Arizona and Utah While chiefly an ore of copper it may be also mined for **silver** or other replacing metals (E S C S)

TETRAPHYLLIDEA. Cestoda.

TETRAPLASY. A theory of the origin and **evolution** of living things formulated by Henry Fairfield Osborn According to this theory, also known as the tetrakinetic or tetraplastic theory, four complexes are the foundation of all that exists and occurs in the organic world These were designated as the inorganic environment, the organism, the Heredity-germ, and the life environment In more recent publications they have been discussed under the terms physical environment, internal environment, heritage, and organic environment The theory is distinctly mechanistic, since it postulates that vital phenomena are adequately explained as the results of interaction among these complexes (A W L)

TETRARHYNCHIDEA. Cestoda.

TETRATHIONIC ACID AND TETRATHIONATES Tetrathionic acid ($H_2S_4O_6$) is a colorless solution formed by reaction of **barium** tetrathionate and dilute **sulfuric acid,** and filtering off barium sulfate Dilute solution of tetrathionic acid may be boiled without decomposition but the concentrated solution decomposes yielding sulfuric acid, **sulfur** dioxide and **sulfur.**

Sodium tetrathionate ($Na_2S_4O_6$) is made (1) by reaction of sodium thiosulfate and **iodine** with accompanying formation of iodide, (2) by reaction of sodium thiosulfate and **ferric** salt solution, lead dioxide, barium peroxide, or sodium peroxide, (3) by **electrolysis** of sodium thiosulfate No visible reaction takes place when sodium tetrathionate is mixed with (1) ammoniacal **silver** nitrate, (2) **ammonium** sulfide, (3) sodium hydroxide (although thiosulfate, trithionate, sulfite and sulfide may be formed) (R K S)

TETRAXONIDA. A division of the sponges (**Porifera**) included in some classifications as an order characterized by the presence of spicules with four axes These sponges belong to the **Demospongiae** of this work. (A W L)

TEXTURE. This term, as used by **petrographers,** denotes, primarily the absolute and relative size, and shapes of the visible constituents of a rock In an igneous rock the texture of the mineral aggregate depends upon its crystallinity, **granularity,** and **fabric.** Texture, when applied to clastic sedimentary rocks should include the surface characteristics of the constituent particles, or **clasts.** (R M F)

THALAMUS. A great nuclear center in the **brain,** formed just behind the portion that gives rise to the cerebral hemispheres Communication between the centers of the cerebral cortex and the outlying parts of the body is established by the routing of nerve impulses through the thalamus, where the redistribution of impulses is accomplished Thus the center is important in the types of nervous control that are highly developed in man. (A.W L.)

THALIACEA. The salpians or salps A group of transparent marine animals related to the ascidians but drifting freely in the water in contrast with the sessile habits of that group They constitute a class of the subphylum Urochordata (**Chordata**)

This class is closely related in fundamental characters to the ascidians, showing a high specialization of structure with an enclosing test of material similar to cellulose It is divided into two orders.

Order Multistigmatea Barrel-shaped animals with muscle bands forming complete rings about the body

Order Astigmatea Body usually flattened Muscle bands incomplete (A W L)

THALLIUM. Symbol Tl Atomic number 81 Atomic weight: 204 39 Density· 11 86 Melting point 303 5° C Isotopes 203 (29 4%), 205 (70 6%)

Thallium metal is bluish-gray upon fresh exposure, changing to dark gray on standing, this oxidation increased with temperature above 25° C, soft, and may be easily cut with a knife, malleable but of low tenacity so that it must be extruded to form wire, **nitric acid** is the best solvent, forms alloys with many metals, e g, **mercury, cadmium, zinc, silver, copper, magnesium** Discovered by Crookes in 1861

Thallium occurs in small amounts in **pyrite, zinc blende,** and **hematite** of certain localities, and in a few rare minerals in Sweden and Macedonia For the recovery of thallium from flue dust of pyrite burners, the dust is boiled with water, allowed to stand some time, filtered, and **hydrochloric acid** added to the filtrate, whereupon crude thallous chloride is precipitated This is purified by further treatment, and thallium metal obtained (1) by **electrolysis** of the sulfate solution or (2) by fusion of the chloride with **sodium** cyanide and carbonate

Hydroxides Thallous hydroxide (TlOH), chemically similar to sodium hydroxide, reacts characteristically with traces of ozone to give brown coloration, when on filter paper, thallic hydroxide ($Th(OH)_3$), brown precipitate (possibly TlO OH) by reaction of **sodium** hydroxide and thallic salt solution, insoluble in excess sodium hydroxide

Oxides Thallous oxide (Tl_2O), black solid, melting point 300° C, when molten attacks glass and porcelain, thallic oxide (Tl_2O_3), brown to black solid

Salts Thallous Thallous sulfate (Tl_2SO_4), soluble, thallous carbonate (Tl_2CO_3), soluble, thallous **alum** (Tl_2SO_4 $Al_2(SO_4)_3$ $24H_2O$) These compounds are chemically similar to those of sodium Thallous chloride (TlCl), white resembling silver chloride in appearance and formation and used in an electrical **cell.** Thallous chromate (Tl_2CrO_4) yellow precipitate, thallous sulfide (Tl_2S) black precipitate in acetic acid, neutral or alkaline solution These compounds are chemically similar to those of lead Thallous chloroplatinate ($Tl_2Pt + Cl_6$), pale orange precipitate Thallous cobaltinitrite (Tl_6 $Co(NO_2)_6$), pale red precipitate These compounds are chemically similar to those of potassium

Thallic Thallic chloride ($TlCl_3$), nitrate ($Tl(NO_3)_3$), sulfate ($Tl_2(SO_4)_3$) all white to colorless soluble solids Volatile thallium salts, such as the chlorides, color the bunsen flame green Thallium compounds are poisonous, and as such used as rat poison, as insecticide, as a depilatory (R K S)

THALLOPHYTES. This division, the second largest of the plant kingdom (the seed plants being the largest) is considered to be the oldest and to contain the most primitive types of plants.

Plants of this division vary from minute forms composed of a single cell to seaweeds 200 feet or more in

length. These plants do not have any root, stem or leaves, though some have structures which resemble these parts in form. However, with a few exceptions in the brown **algae,** all these plants are composed of aggregations of **cells** which show very little differentiation A plant body thus not differentiated into true roots, stems and leaves is called a thallus

Several methods of reproduction are found in the Thallophytes The simplest is **cell division,** which occurs in the unicellular forms A second method is by spores These are single cells set apart for reproductive purposes Reproduction by spores is asexual Several kinds of spores are found in this division In many thallophytes, asexual reproduction is by means of zoospores, these are reproductive cells provided with one or more cilia, thread-like objects which by their beating propel the spore through the water

Another form of reproduction is sexual This occurs in many Thallophytes The cells which function in sexual reproduction are called **gametes.** As a rule gametes are incapable of developing until they unite in pairs, forming cells called zygotes From the latter new plants develop

There are two main groups of thallophytes, the **algae** and the **fungi.** Algae have **chlorophyll** in their cells and so are separated from fungi, which always lack chlorophyll In addition to these two groups, there is a third, composed of plants which are formed by an intimate union of an alga with a fungus These are the **lichens,** which in spite of their dual nature are usually described as separate plants, and classified as such (See also **Paleobotany.**) (R M W)

THALLUS. A thallus is a plant body having no differentiation into roots, stems or leaves (R M W)

THEBAINE. Alkaloids.

THECA. The outer ridge surrounding the depression in the hard deposit of a stony **coral** in which the **polyp** lives The deposit is formed by the basal disk of the polyp, first as a flat plate and later in a series of ridges as the ectoderm of the disk is thrown into folds The theca is a circular ridge in most species (A W L)

THEELIN. Sex Hormones.

THEOBROMA CACAO. Sterculiaceae A medium sized tree growing wild in the lowlands from Mexico to northern South America It has shining evergreen leaves about a foot long and small flowers, which grow from buds on the trunk or large branches of the tree The fruits are from 6 to 12 inches long and about four inches in diameter, and have a ribbed rough surface Each contains from 20 to 50 flattened seeds, or beans, embedded in a gelatinous pulp The tree is extensively cultivated in low humid climates in regions where there is a rich soil It has been introduced into various Old World countries, and is grown extensively in tropical Africa. The cultivated tree is somewhat smaller than the wild one and begins to bear in four or five years when grown from seed

The mature pods are cut from the tree and split open. The seeds are then scooped out and fermented for a week or so. During fermentation the color of the seeds darkens to a reddish tone and a rich aromatic odor develops The pulp surrounding the seeds liquefies and runs off. After fermentation the seeds are dried and shipped to the manufacturers, located chiefly in the United States and Europe

In the factories, the seeds are cleaned and then roasted for a short time (1–2 hours). After roasting, the seeds are cracked and the shell separated from the **cotyledons.** The shells may be ground up and used in the manufacture of cheap grades of cocoa, or they may be burned as fuel From the cotyledons is ground out by heated mills an oily liquid which hardens into the familiar chocolate If part of the oil is squeezed out and the residue ground to a powder, it is cocoa When chocolate is mixed with sugar and flavored with **vanilla,** it becomes sweet chocolate

The vegetable fat removed from the pressed beans is known as cocoa butter, and is used in the manufacture of various pharmaceutical preparations, and also in the preparation of confections (R M W.)

THEOBROMINE. Purines

THEODOLITE Altazimuth

THEOPHYLLINE. Alkaloids.

THEORY OF EQUATIONS The name "Theory of Equations" usually is applied to the study of the properties of **polynomial equations** and of methods for the numerical solution of such equations (L L S)

THERALITE Theralite is a granular intrusive **igneous rock** composed chiefly of **labradorite, nephelite** and **augite.** Duppau, Bohemia, is the type locality If **analcite** is present instead of nephelite the rock is called teschenite from Teschen, in Moravia The name theralite is derived from the Greek meaning eagerly sought for, because such a rock type was believed to exist and sought for before its actual discovery (E S C S)

THERIODONTIA Fossil Reptiles.

THERMAL CAPACITY. Specific Heat.

THERMAL CONDUCTION. Every substance is in some measure a conductor of heat, though liquids are generally poor conductors and gases almost non-conductors The best conductors are metals The flux of heat through a layer of many substance by conduction is proportional to the temperature gradient (fall of temperature per unit thickness), and to a factor called the "thermal conductivity" of the substance, defined as the quantity of heat transmitted per unit time per unit cross section per unit temperature gradient The thermal conductivities of a few solids are given below, in calories per centimeter per second per degree Centrigrade

Aluminum	0 480	Iron (cast)	0 161
Copper	918	Lead	083
Cork	0001	Paraffin	0006
Glass	002	Quartz	0 033 or 0 017
Ice	005	Silver	1 006

(It will be noted that quartz, a highly birefringent crystal, has different conductivities along and perpendicular to its optic axis, as do such crystals in general)

The mechanism of thermal **conduction** is probably at least three-fold Thermally agitated atoms and molecules doubtless actually jostle each other and thus mechanically pass along the heat energy Thermal radiation between neighboring atoms or molecules should have a similar result But neither of these explains the enormous difference in conductivity between, say, copper and glass, both of which are dense, fine-grained solids; or between silver and lead, both soft, crystalline metals of similar chemical properties If, however, we examine the electric conductivity of these substances (See **Electric Conduction** and **Resistance**), we discover that good thermal conductors are also good electrical conductors, and we are led to suspect that thermal as well as electrical conduction may depend upon the activity of electrons The relationship is brought out quantitatively by the **Wiedemann-Franz law.**

The speed with which a temperature wave progresses by thermal conduction depends upon the "thermal diffusivity" of the conductor, which is its thermal conductivity divided by its thermal capacity per unit volume (L D W)

THERMAL CONVECTION. This is a familiar phenomenon, consisting in the transfer of heat by the

automatic circulation of a fluid (liquid or gas) due to differences in temperature and density. While water and liquids generally are poor conductors, a kettle of water is quickly heated throughout by applying heat at the bottom. The warmer water, being less dense, is compelled to rise by the colder, which, sinking to the bottom is warmed in its turn. The process is more clear-cut when a definite circuit is provided, as in the heating coil attached to a hot-water tank or radiator system Gasoline engines are cooled by a similar circulation, either entirely automatic or augmented by a small rotary pump Gases likewise exhibit **convection.** A chimney "draws" when the air inside it is warmer than that outside, so that the greater pressure difference outside forces the air inward at the bottom (The term "draw" is manifestly misleading) The motion of the air in hot-air furnaces and in the winds of the atmosphere are good examples There is a type of pressure gauge which depends upon the cooling effect of convection currents in the gas upon a hot filament immersed in it, the rate of cooling being a function of the gas density. (L D W)

THERMAL DEGREE. The thermal degree is the measure on an arbitrarily arranged scale of the molecular activity which makes itself known as temperature The instrument for obtaining a measurement of thermal degree is the **thermometer.** The two scales most commonly used are the Fahrenheit and the Centigrade scales A thermal degree on the Fahrenheit scale is 1/180th of the change of temperature of pure water when it is heated from the temperature of melting ice to that of boiling water at standard atmospheric pressure The Centigrade thermal degree is similarly established, except that it is 1/100th of the same temperature range The temperature of melting ice is 0° on the Centigrade scale and 32° on the Fahrenheit, thus the temperature of boiling water is 100° on the Centigrade and 212° on the Fahrenheit scale (F T M)

THERMAL DIFFUSIVITY. **Thermal Conduction.**

THERMAL EFFICIENCY. Thermal efficiency is output in heat units divided by the heat supplied or chargeable Thermal efficiency may partially define the operating condition of both a machine and a static piece of equipment In the case of static equipment, if it is well insulated it may have very high thermal efficiencies. A machine which converts heat supplied into work output (the **steam engine, Diesel engine,** etc) is always characterized by low thermal efficiencies brought about by the fact that the conversion of the low grade type of heat energy into high grade energy of mechanical work is accomplished with considerable difficulty The thermal efficiencies of the best prime movers today rarely exceed 35%, and are not found higher than 40% even when the best conditions of loading, maintenance, and fuel employed, are present Thermal efficiency of a prime mover may be based on the output at the shaft per unit of heat supplied, or upon the electrical output in the case of a generator drive It may be based on cylinder horsepower in piston and cylinder prime movers. Heat supplied and chargeable to internal combustion engines is the heat in the fuel Heat supplied to steam prime movers is the heat in the **steam** at the throttle, the heat chargeable is the heat supplied after deducting the heat of condensate in the exhaust (F T M)

THERMAL METAMORPHISM. **Metamorphism.**

THERMAL RADIATION. All bodies that are not at absolute zero emit radiation excited by the thermal agitation of their molecules or atoms, whether there are other causes of excitation or not This thermal radiation ranges in wave length from the longest **infrared** to the shortest **ultraviolet** rays, its **spectral energy distribution,** however, depending upon the nature of the body and upon its temperature The total emissive power of a surface at any temperature is the rate at which it emits energy of all wave lengths and in all directions, per unit area of radiating surface The flux density (per unit solid angle) in various directions obeys the **cosine emission law** approximately, but strictly only in the case of a **black body.** Thermal radiation is observed and measured by means of different types of **radiometer,** by the **bolometer,** and by the **radiomicrometer;** also, in the shorter wave lengths, by its photographic and photoelectric effects.

In ordinary surroundings bodies not only emit but receive radiation. The net transfer of energy depends upon the relative rate of emission and absorption, and this, in turn, upon the temperature of the body and that of its surroundings. The dependence of this rate upon the two temperatures was investigated by Newton, by Doling and Petit, by Stefan, and by Boltzmann (See **Newton's Law of Cooling** and **Stefan-Boltzmann Law.**) **Wien's laws** have to do with the dependence of the spectral energy distribution of black-body radiation upon temperature, the last word upon which, however, seems to be **Planck's equation** developed through the **quantum theory.** Kirchhoff pointed out that the absorptivity of a surface (ratio of absorbed to incident radiation) and its emissivity (ratio of emissive power to that of a black body at the same temperature) are equal It follows that good radiators are good absorbers The reflectivity (ratio of reflected to incident radiation) is equal to one minus the absorptivity, hence good radiators and absorbers are poor reflectors.

Most surfaces exhibit "selective" emission, absorption, and reflection, that is, their emissivities, absorptivities, and reflectivities for different wave lengths are not proportional to those of a black body, and the proportion differs for different surfaces Thus copper has abnormally high reflectivity and low absorptivity in the red, silicon, in the ultraviolet

A substance transparent to thermal radiation is said to be "diathermanous" A material could be completely described in this respect by giving its **absorption coefficient** in the various parts of the spectrum Thus, rock salt is very diathermanous throughout the infrared and visible ranges, water and glass only in the visible, filtering out much of the infrared Well defined absorption bands often occur in different regions of the spectrum (See **Absorption Spectrum** and **Residual Radiation**) (L D W)

THERMEL. The well known Seebeck effect (See **Thermoelectric Phenomena**) is the principle underlying a large class of thermoelectric thermometers The essential feature is a circuit composed of two different metals, the two junctions of which are at different temperatures, and in which a net electromotive force develops as a result of this temperature difference Any device which uses this electromotive force, or the current due to it, as a measure of temperature is called a thermel.

The simplest form is a "thermocouple," composed of two pieces of metal, or wires, soldered or welded together at their ends, the other ends being connected to a **galvanometer** or a **potentiometer.** Various pairs of metals are used, for example, antimony and bismuth, copper and iron, or copper and constantan (an alloy of copper and nickel) High-temperature thermocouples are commonly of platinum, with some other refractory metal such as iridium or an alloy of platinum and iridium, rhodium or chromium. One of the junctions may be enclosed in a protecting tube, the other being kept at zero by means of melting ice In cases where a temperature difference only is desired, the two copper or platinum lead-wires may be attached to the opposite ends of a single wire of the other metal, and the two junctions placed at the two points to be compared.

A "thermopile" is composed of a number of thermocouples in series, the alternate junctions being assembled in two bunches which are used like the junctions of a single thermocouple This arrangement multiplies the

thermoelectromotive force and gives greater sensitivity. An exceedingly sensitive form of thermel is the **radiomicrometer.** The "thermoelement" utilizes a thermocouple to detect and measure very feeble currents by their heating effect on a fine wire (L D W)

THERMIONIC PHENOMENA. In view of the commotion among the atoms and electrons of a heated substance, it is not surprising that electric particles, both positive ions and electrons, should be projected from a highly heated body If the body is electrically charged, particles of the same sign as the charge, when once through the surface barrier (See **Work Function**), are repelled into the surrounding space, where they can be detected Electric particles thus emerging, either positive or negative, are called thermions The heated body may be a filament of pure metal, electrically heated, or a layer of some chemical substance spread over and heated by such a filament The usual experimental arrangement is to inclose the thermionic emitter as an electrode in a tube or bulb, along with another electrode of opposite sign, so that the field between the two will set up a stream of the released thermions, called a thermionic current With sufficient voltage, this current reaches a maximum or "saturation" value, the ions being then swept away as fast as they are released

In the early experiments of Becquerel, Guthrie, Edison, Elster and Geitel, and others, it was found that at lower temperatures (up to a red heat) the thermionic emission from metals is predominantly positive, but that at much higher temperatures (white heat) the negative or electronic emission rapidly surpasses the positive and becomes all-important The positive emission from a pure metal like platinum or tungsten appears to be due to impurities such as potassium, and falls off with prolonged heating, for metallic salts it consists of ions of the metal composing the salt Some metals emit electrons much more copiously than others, a notable example is **thorium,** an adsorbed film of which on tungsten gives very copious electron emission at high temperatures

The saturation current for any metal is an exponential function of the temperature, expressed by Richardson's equation

$$I = AT^n e^{-B/T},$$

in which T is the absolute temperature and A and B are constants dependent on the metal The exponent n appears in some cases to be ½, while in others the value 2 fits better B, and perhaps A, involves the thermionic work function The emission is not quite steady, being subject to the so-called **shot effect.** In the various forms of **triode,** the thermionic current is controlled by means of a grid, an arrangement of great practical importance in radio and elsewhere. (L D W)

THERMITE. Aluminum.

THERMOCHEMISTRY. Every chemical reaction is accompanied by a definite change in the heat content of the system. Most reactions evolve heat and are described as exothermic reactions, but some, such as the reaction of **nitrogen** plus **oxygen** to form **nitric oxide** absorb heat and are described as endothermic

The amount or quantity of heat change in a given reaction is measured in large or small **calories** (number of kilograms or grams, respectively, of water * multiplied by the temperature change in degrees Centigrade) or in British thermal units (number of pounds of water multiplied by the temperature change in degrees Fahrenheit). The amount of heat is calculated in various ways, for example, per 1 gram or per 1 pound of one reacting substance, as in the case of **solid** and **liquid fuels** and **foods,** per 1 cubic meter or per 1 cubic foot of gaseous fuels, per 1 equivalent in the neutralization of **acids** and **bases,** or per 1 mol in expressing heats of formation of compounds.

The intensity of heat is measured by the degrees of temperature on the Centigrade scale (melting point 0° C, boiling point 100° C of water), the Fahrenheit scale (melting point 32° F, boiling point 212° F of water) or the absolute scale + 273° C (which is also the Kelvin scale) and + 491° F As stated, 1° C equals 1 8° F It is estimated that the temperature of the **hydrogen**-oxygen flame may attain 2000° C, the **acetylene**-oxygen flame 2500° C, and the thermic reaction (**aluminum** plus **iron** oxide yielding aluminum oxids plus iron) even higher temperatures Coker and Scoble (1913) estimated the temperature attained in coal gas-air mixture in the ratio of 1 to 5 66, as 2250° C and the pressure observed 433 pounds per square inch

Changes of energy volume always accompany chemical reaction, and most common of these is heat energy, these have been stated to be "of hardly less importance to the modern chemist than the material changes themselves" (Huddeston)

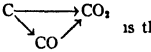
Thermochemical considerations may be classified as follows.

A When no change in composition is involved
- 1. No change of state takes place
  - Heat capacity or atomic heat of solid elements (Dulong and Petit, 1819)
  - Heat capacity or molecular heat of solid compounds (Kopp, 1864) (See **Chemical Composition**)
  - Heat of dilution of solutions
  - Heat of wetting and adsorption
- 2 A change of state takes place
  - Heat of fusion or solidification (melting point, freezing point)
  - Heat of vaporization or condensation (boiling point, condensing point)
  - Heat of sublimation (sublimation point)
  - Heat of transition (transition point of allotropic substances)
  - Heat of solution or crystallization of solids, liquids, gases

B. When a change in composition is involved
- 1. Temperature effects
  - (a) Temperature of reaction
    - Reactions at ordinary temperatures
    - Reactions at high temperatures
      - The temperature attained depends upon the rate of heat evolution in the system less the rate of heat loss from the system
      - High temperatures attained by combustion of fuels
        - Local, by use of hydrogen—or acetylene—oxygen flame
        - General, by use of fuel gas and pre-heated air, in metallurgical furnaces, ceramic, cement and glass kilns and furnaces, by product coke ovens
      - Very high temperatures attained in the electric furnace, producing such products as calcium carbide, silicon carbide, phosphorus, graphite, carbon disulfide, silicon, aluminum oxide fused, silicon oxide fused
  - (b) Temperature coefficient of reaction
    - About 2 for a rise in temperature of 10° C See **Chemical Changes.**
- 2. Heat effects
  - Heat of reaction, general.
  - Specific cases—heat of neutralization of acids and bases, heat of dissociation, heat of formation

* Temperature of water from 3 5 to 4 5° C, ordinary calorie; from 14 5 to 15 5°, normal calorie; from 0 to 100° C divided by 100, mean calorie

The initial and final conditions of a reaction or of a series of reactions determine the total heat effect without regard to the intermediate steps This is the formulation of Hess' Law of Constant Heat Summation Its usefulness is evident by a simple example The heat of reaction of carbon to carbon dioxide ($C + O_2 \rightarrow CO_2$) is 94,400 calories obtained by burning a weighed amount of carbon with excess oxygen in a bomb calorimeter The heat of reaction of carbon monoxide to carbon dioxide ($CO + 0.5\ O_2 \rightarrow CO_2$) is 68,000 calories obtained by burning a measured volume of carbon monoxide in a gas calorimeter It is not easy to ascertain the heat of reaction carbon to carbon monoxide ($C + 0.5\ O_2 \rightarrow CO$) directly, but since the heat evolved by the two routes



is the same, then the difference between the first and second reactions ascertained above is the desired result, namely, 26,400 calories.

The heat of formation of three grand groups of chemical substances follows

HEAT OF FORMATION OF OXIDES, CHLORIDES, SULFIDES

Element	Oxide	Calories per 16 Grams Oxygen	Chloride	Calorifs per 35 5 Grams Chlorine	Sulfide	Calories per 32 Grams Sulfur
Hydrogen	H_2O, gas	58	HCl, gas	22	H_2S, gas	5
Sodium	Na_2O	99	NaCl	98	Na_2S	90
Potassium	K_2O	86	KCl	104	K_2S	88
Magnesium	MgO	146	$MgCl_2$	77	MgS	82
Calcium	CaO	152	$CaCl_2$	95	CaS	114
Strontium	SrO	141	$SrCl_2$	99	SrS	113
Barium	BaO	133	$BaCl_2$	103	BaS	111
Boron	B_2O_3	93	BCl_3, liquid	31		
Aluminum	Al_2O_3	130	$AlCl_3$	56	Al_2S_3	115
Carbon	CO_2	94	CCl_4, liquid	8	CS_2, liquid	−11
	CO	26				
Silicon	SiO_2, fused	99	$SiCl_4$, liquid	37	SiS_2	16
Titanium	TiO_2	109	$TiCl_4$, liquid	46		
Nitrogen	NO, gas	−22				
Phosphorus	P_2O_5	73	PCl_3, liquid	26		
Oxygen					SO_2, gas	69
Sulfur	SO, gas	35	S_2Cl_2, liquid	7		
Vanadium	V_2O_5	87	VCl_4, liquid	40		
Chromium	Cr_2O_3	89	$CrCl_3$	47		
Manganese	MnO	91	$MnCl_2$	57	MnS, ppt.	47
Iron	Fe_2O_3	64	$FeCl_3$	32		
	Fe_3O_4	67				
	FeO	64	$FeCl_2$	41	FeS	23
Cobalt	CoO	57	$CoCl_2$	39	CoS, ppt.	20
Nickel	NiO	58	$NiCl_2$	37	NiS, ppt.	21
Copper	CuO	35	$CuCl_2$	26	CuS	12
	Cu_2O	40	CuCl	33	Cu_2S	19
Silver	Ag_2O	7	AgCl	31	Ag_2S	5
Gold			$AuCl_3$	9		
Zinc	ZnO, fused	84	$ZnCl_2$	50	ZnS	46
Cadmium	CdO	65	$CdCl_2$	46	CdS	34
Mercury	HgO	22	$HgCl_2$	27	HgS	11
	Hg_2O	22	HgCl, ppt	32		
Tin.	SnO_2	69	$SnCl_4$, liquid	32		
	SnO	70	$SnCl_2$	41		
Lead ..	Pb_3O_4	44				
	PbO	52	$PbCl_2$	43	PbS, ppt.	22
Arsenic	As_2O_3	49	$AsCl_3$, liquid	24	As_2S_3	10
Antimony	Sb_2O_3	55	$SbCl_3$, liquid	29	Sb_2S_3	12
Bismuth	Bi_2O_3	45	$BiCl_3$	30		

(R K S)

THERMOCOUPLE. Thermel.

THERMODYNAMIC POTENTIAL. Potential.

THERMODYNAMICS. This branch of physics had its origin in the classical discoveries of Rumford, Davy, Joule, and others early in the nineteenth century, which identified **heat** as a form of **energy** Gradually the mechanism of heat and the statistics of molecular motion were revealed by the researches of such men as Maxwell, Kelvin, Clausius, and Boltzmann, until now, with the added assistance of the **quantum theory**, we discuss the dynamics of **molecules** almost as confidently as that of visible bodies

The first law of thermodynamics is embodied in the fact of the **mechanical equivalent of heat**, and need be touched upon here only by expressing it in its customary algebraic form $W = JQ$, meaning that Q heat units are equivalent to JQ work units Our best present value of J is 41,852,000 ergs per calorie With increasing emphasis upon the fact that heat is kinetic energy, has grown the tendency to express heat directly in ergs and to do away with the **calorie** and the constant J; but the old notation still persists

The second law of thermodynamics is really a confession of our helplessness in making molecules do what we wish, because of their inconceivable numbers and their submicroscopic size It states, in effect, that the only way in which we can utilize any of the supply of heat energy in a body, and make it do mechanical work,

is to find another body whose molecules have less average heat energy (i e, a body at lower temperature), set up between them a mechanism (engine) through which the molecules of the warmer body can contribute some of their excess energy to those of its cooler neighbor, and capture part of this donated energy on the way (No such engine will run on heat energy given by a cooler to a warmer body, it would have to be run from outside as a refrigerating machine) It is shown that if the warmer and cooler bodies are at the respective absolute temperatures T_1 and T_2, the maximum fraction of the transferred energy that even an ideal engine could capture is $(T_1—T_2)/T_1$, which is thus the maximum ideal **thermal efficiency**

The variables commonly chosen in thermodynamic reasoning are temperature, pressure, and volume, and in terms of these we write the **characteristic equations** of the substances, such as air, steam, etc, used in engines The purely dynamic aspects are especially concerned with volume and pressure, and thermodynamic diagrams are often drawn with these as coord nates For example, if a gas expands and its pressure diminishes, this change may be represented by the curve AB, and the corresponding work by the area $AB\beta\alpha$ (Figure 1), while if, as in an engine, the change is a cyclic one, the net work de-

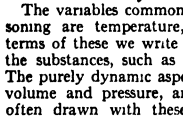


Figure 1

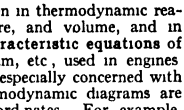


Figure 2

Representation of work during a unidirectional or a cyclic change in volume and pressure

rived from each cycle on one side of the piston is represented by the area w enclosed by the curve (Figure 2) A steam engine indicator, for example, automatically draws such a curve at each stroke of the engine, the efficiency of whose performance can thus be deduced See **Carnot cycle, Entropy, Joule-Thomson effect, Reversible Processes,** etc (L D W)

THERMOELECTRIC PHENOMENA. If two strips of different metals are closely joined at one end, and the junction kept at a different temperature from the rest of the strips, an electromotive force develops in the two-part conductor This thermoelectromotive force, sometimes called the Seebeck effect from its discoverer, depends upon the metals and the temperature distribution in them The pair of metals is called a thermocouple, and the change in the electromotive force per degree change in temperature at the junction is the thermoelectric power of the thermocouple

The thermoelectric power is a linear function of the junction temperature, while the thermoelectromotive force itself is a quadratic function, having a maximum value at some point (for iron and copper about 275° C)

Peltier discovered that when a feeble battery current is sent through a thermocouple, the junction is thereby either warmed or cooled, according as the direction of the current is from the — to the + or from the + to the — metal. (This is altogether apart from the ordinary resistance heating effect) Kelvin found that a potential difference develops even in a single metal (except in the case of lead) if one end is warmer than the other The thermoelectromotive force of a thermocouple appears to be a combination of a "Peltier electromotive force" at the junction and the Kelvin or "Thomson electromotive forces" in the two strips.

If several metals are joined to form a circuit of nonuniform temperature, the resultant thermoelectromotive force is the algebraic sum of the several Peltier and Thomson electromotive forces, and gives rise to a thermoelectric current, such as that utilized in any **thermel.**

Kelvin discovered that if a weak current is sent through a wire which is heated at one point, the current causes a flow of heat, sometimes one way and sometimes the other, depending upon the metal

None of these phenomena is fully understood, but they are believed to be due to the activity of **electrons** which are either free or related in some peculiar way to the **crystal structure** of the metals (L D W)

THERMOGRAPH. A recording thermometer. A common and very simple form employs a Breguet differential expansion spiral (See **Solid Expansion Thermometer**) One end of the spiral is securely fixed to a metal post, while to the other is attached a long rod bearing at its end a pen or pencil As the spiral coils and uncoils with changes of temperature, this marker moves up and down on a drum or disk covered with paper and slowly revolved by clockwork, thus leaving a graph of the temperature changes during a period of several hours or days Another arrangement is to use a **thermel** connected with a **galvanometer,** the mirror of which reflects a spot of light upon a slowly moving photographic film Thermographs are in extensive use at meteorological observing stations, for the exploration of the upper air, in deep sea soundings, etc (L D W)

THERMOLUMINESCENCE. Luminescence.

THERMOMETRY. The measurement of **temperature** and of changes in temperature has been based upon many different heat effects Among those which have been extensively developed are (1) the expansion of solids, liquids, and gases, illustrated by **solid expansion thermometers, liquid expansion thermometers,** and the constant pressure **gas thermometer,** (2) the change of pressure in a gas kept at constant volume (constant volume gas thermometer), or of the saturated vapor pressure of a liquid (See **Vapors**), (3) the change in resistivity of metals (metallic **resistance thermometer**), (4) the Seebeck thermo-electric effect (**thermel**), (5) the brightness of very hot bodies (optical **pyrometer**), and (6) the character of the **thermal radiation** from the heated body (**radiation pyrometer**)

With so many temperature indices, it is necessary to have a standard of temperature measure For various reasons, it was once found desirable to fix upon gas pressure at constant volume as the practical standard measure of temperature That is, equal changes of temperature were defined as those corresponding to equal changes of pressure in a selected gas (hydrogen) kept at constant volume The constant volume hydrogen thermometer thus became the reference instrument for the calibration of other types In 1927, however, the United States, Great Britain, and Germany proposed, and thirty-one nations represented at the Seventh General Conference of Weights and Measures unanimously adopted, what is now called the international temperature scale From —190° to +660° C, the measure of temperature is based upon the indications of a standard platinum resistance thermometer, specified and used in accordance with certain formulas From +660° C. to the melting point of **gold** a platinum-platinrhodium thermel is the reference instrument, and above the gold point, the optical pyrometer is used as standard The basic fixed points of this scale are the boiling point of **oxygen** (—182 97° C.), the freezing and the boiling points of water, the boiling point of **sulfur** (+444 60° C), the melting point of **silver** (+960 5° C.), and the melting point of gold (+1063° C).

Kelvin was long ago impressed with the dependence of such thermometric methods upon characteristic properties of certain arbitrarily chosen substances Even constant volume gas thermometers, using different gases, do not quite agree Kelvin therefore proposed an ideal absolute temperature scale on which changes of tem-

perature, whatever the substance concerned, are strictly proportional to the corresponding changes in internal energy This assumption would be true of a gas obeying the **ideal gas law**, if such existed The subsequent researches of Joule and Kelvin on the **Joule-Thomson effect** enabled them to calculate the corrections necessary to convert the hydrogen constant volume standard into the "thermodynamic scale" (more properly, a thermodynamic standard of temperature measure) proposed by Kelvin, which is commonly used in theoretical discussions. (L.D W)

THERMOPILE. Thermel.

THERMO SIPHON. The term thermo siphon refers to a method of circulation of a liquid arising from the slight difference of density of the hot and cool liquid At one time automobile engines were provided with thermo siphon action in the cooling water system Although the principal portion of circulation of modern automobile engines is achieved by a pump, there is some thermo siphon action aiding the pump Thermo siphon circulation is used to considerable extent on stationary gas engines which have an external radiator for cooling the jacket water When the water leaves the radiator and enters the engine jacket, it is heated and expands slightly Its decrease in density causes the column of hot water in the engine to weigh less than the equivalent column of cool water in the radiator, so there is a continuous displacement of heated water from the jacket by cool water flowing in from the radiator This system requires large hose, unobstructed hose connections from engine to radiator, and large radiators having considerable height (F T M)

THERMOSTAT. The thermostat is a device, the purpose of which is to regulate, automatically, the temperature of a body or of an enclosure, or to maintain the temperature at some predetermined value, or within a certain range Thermostats are employed widely in heating systems in order to adjust or regulate the temperature of the heating medium They also have a great many uses in industry, where fluids, chambers, or material must be maintained at predetermined temperatures in order to accomplish the industrial process satisfactorily There are other scattered uses of thermostats, many of which are very important, and among these might be cited the control of engine cooling water temperature in the modern automotive vehicle

Thermostats are actuated mainly either by the expansion of a fluid, or by expansion of a metallic element A very common example of the former is the wafer type thermostat, in which thin disk-shaped shells, called syphons, are filled with a gas, or partially filled with a liquid of suitable boiling temperature Actuated by the developed internal pressure, the expansion and contraction of these syphons, the cases of which are flexible, constitute a motion which can be mechanically transmitted to a regulating **valve** or **relay**. While the motion of any one disk is relatively small, a number of them may be made into a group, the motions of which are additive

Metallic element thermostats employ the well-known principle of differential with temperature The element is not always built as a straight rod, satisfactory thermostats are constructed of a bimetallic strip wound in spiral form, which tends to coil or uncoil with changes of temperature.

Thermostats are sometimes actuated by thermoelectric currents or by the varying resistance of conductors, the effects of which, suitably amplified, may be utilized to control heating elements (F T M)

THICK-KNEES, THICKNEES. Aves, Charadriiformes A long-legged European bird (**Aves**) whose habits are similar to those of our killdeer The same genus is represented by African, Indian, South American, and Australian species The European bird is also called the stone curlew, but there is some question about its inclusion in this order (A W L)

THIGMOTROPISM. Movement in Plants.

THIN SECTIONS. The term used by **petrographers** and **mineralogists** for slices of rocks or minerals which are cut and ground to the approximate thickness of a thousandth of an inch, and mounted on glass slides for use with the **petrographic microscope** The average practical thickness for normal petrographic or mechanical analysis is 0 03 millimeter (R M F)

THIOALCOHOLS AND RELATED COMPOUNDS Thioalcohols and thioethers are organic derivatives of **hydrogen sulfide** containing the groups —SH and =S respectively The thioalcohols (and thiophenols) may also be named as mercaptans, hydrosulfides, sulfhydrates, and thiols The last of these names (thiols) is given priority in the accompanying table Sulfinic and sulfonic acids are organic compounds containing the groups —SO_2H and —SO_3H respectively

TABLE SHOWING INTERRELATIONSHIP BETWEEN VARIOUS ORGANIC SULFUR COMPOUNDS

Thioalcohols	Sulfinic Acids	Sulfonic Acids
Boiling Point		
(Hydrogen sulfide HSH −62° C)		
Methanethiol CH_3SH 6° C (Methyl hydrosulfide, methyl mercaptan)	Methyl sulfinic acid CH_3SOOH	Methyl sulfonic acid CH_3SO_3OH 167° C dec
Ethanethiol C_2H_5SH 37° C (Ethyl hydrosulfide, ethyl mercaptan)	Ethyl sulfinic acid C_2H_5SOOH	Ethyl sulfonic acid $C_2H_5SO_2OH$
Propanethiol C_3H_7SH 67° C (Normal-propyl hydrosulfide, normal-propyl mercaptan)		
Phenylmethanethiol $C_6H_5CH_2SH$ (Benzyl hydrosulfide)		
Dithioglycol $C_2H_4(SH)_2$ (Ethylene mercaptan)		
Benzenethiol C_6H_5SH (Phenyl hydrosulfide, thiophenol)	Benzene sulfinic acid C_6H_5SOOH	Benzene sulfonic acid $C_6H_5SO_2OH$ Benzene disulfonic acid $C_6H_4(SO_2OH)_2(1,3)$ Benzene trisulfonic acid $C_6H_3(SO_2OH)_3(1,3,5)$

(Continued on next page)

TABLE SHOWING INTERRELATIONSHIP BETWEEN VARIOUS ORGANIC SULFUR COMPOUNDS—(*Continued*)

Naphthylamine Sulfonic Acids	Naphthol Sulfonic Acids	Sulfonic Acids
Naphthionic acid $C_{10}H_6(NH_2)(1)(SO_2OH)(4)$ Laurent's acid $C_{10}H_6(NH_2)(1)(SO_2OH)(5)$ Tobias' acid $C_{10}H_6(NH_2)(2)(SO_2OH)(1)$ Bronner's acid $C_{10}H_6(NH_2)(2)(SO_2OH)(6)$	Naphthol sulfonic acid (Alpha acid) $C_{10}H_6(OH)(1)(SO_2OH)(2)$ Naphthol sulfonic acid (Beta acid) $C_{10}H_6(OH)(2)(SO_2OH)(6)$ Naphthol disulfonic acid R-acid $C_{10}H_5(OH(2)(SO_2OH)_2(3,6)$ Naphthalmine disulfonic acid S-acid $C_{10}H_5(NH_2)(1)(SO_2OH)_2(4,8)$	Alpha-naphthalene sulfonic acid $C_{10}H_7SO_2OH(1)$ Beta-naphthalene sulfonic acid $C_{10}H_7SO_2OH(2)$ Naphthalene disulfonic acids $C_{10}H_6(SO_2OH)(2,6),(2,7),(1,5),(1,6)$ Methylene disulfonic acid $CH_2(SO_2OH)_2$ Ethylene disulfonic acid $C_2H_4(SO_2OH)_2(1,2)$
Sulfonyl Chlorides		
Methyl sulfonyl chloride CH_3SO_2Cl	Ethyl sulfonyl chloride $C_2H_5SO_2Cl$	Benzene sulfonyl chloride $C_6H_5SO_2Cl$
Thioethers Sulfides Methylene sulfide CH_2S (thiomethylene) Dimethyl sulfide $(CH_3)_2S$ (methylthiomethane) M P 38° C Diethyl sulfide $(C_2H_5)_2S$ (ethylthioethane) M P 92° C Divinyl sulfide $(CH_2 \cdot CH)_2S$ Diallyl sulfide $(CH_2 \cdot CHCH_2)_2S$ Dichloroethyl sulfide (beta, beta prime) (" mustard gas ") $(ClCH_2 \cdot CH_2)_2S$ Dibenzyl sulfide $(C_6H_5CH_2)_2S$ Diphenyl sulfide $(C_6H_5)_2S$ (phenylthiobenzene)	Sulfinyl-compounds Sulfoxides Methyl sulfinylmethane (dimethyl sulfoxide) $(CH_3)_2SO$ Ethylsulfinylethane (diethyl sulfoxide) $(C_2H_5)_2SO$ Benzylsulfinylphenylmethane (dibenzyl sulfoxide) $(C_6H_5CH_2)_2SO$ Phenylsulfinylbenzene (diphenyl sulfoxide) $(C_6H_5)_2SO$	Sulfonyl-compounds Sulfones Methylsulfonylmethane (dimethyl sulfone) $(CH_3)_2SO_2$ Ethylsulfonylethane (diethyl sulfone) $(C_2H_5)_2SO_2$ Benzylsulfonylphenylmethane (dibenzyl sulfone) $(C_6H_5CH_2)_2SO_2$ Phenylsulfonylbenzene (diphenyl sulfone) (phenyl sulfene) $(C_6H_5)_2SO_2$ Diethyl sulfone dimethylmethane (acetone diethyl sulfone, sulfonal) $(CH_3)_2C(SO_2C_2H_5)_2$ Trional $CH_3 \diagdown C_2H_5 \diagup C(SO_2C_2H_5)_2$ Tetronal $(C_2H_5)_2C(SO_2C_2H_5)_2$
Cyanogen sulfide $(CN)_2S$ M P 60° C Carbonyl sulfide COS B P. −48° C Acetyl disulfide $(CH_3CO)_2S_2$ Benzoyl disulfide $(C_6H_5CO)_2S_2$ Carbonyl disulfethyl $CO(SC_2H_5)_2$ Allyl trisulfide $(C_3H_5)_2S_3$	Carbon disulfide CS_2 B P 46° C Methyldithiomethane (dimethyl disulfide) $(CH_3)_2S_2$ Ethyldithioethane (diethyl disulfide) $(C_2H_5)_2S_2$ Benzyldithiophenylmethane (dibenzyldisulfide) $(C_6H_5CH_2)_2S_2$	Diethylene disulfide $C_2H_4S \cdot SC_2H_4$ Phenyldithiobenzene (diphenyl disulfide) $(C_6H_5)_2S_2$ Diphenylene disulfide (thianthrene) $C_6H_4(S)_2C_6H_4$
Sulfonium Compounds		
Trimethyl sulfonium iodide $((CH_3)_3S)I$	Trimethyl sulfonium hydroxide $((CH_3)_3S)OH$	(R K S)

THIOALDEHYDES AND THIOKETONES Thioaldehydes and thioketones are produced by the action of **hydrogen sulfide** on **aldehydes** and **ketones** They are ill-smelling liquids, but change on standing to odorless compounds, trithioaldehydes or trithioketones, e g, thio-acetaldehyde, ethanethial ($CH_3 \cdot CHS$) changes to trithio-acetaldehyde $(CH_3 \cdot CHS)_3$ Trithioacetone $(((CH_3)_2CS)_3)$, alpha, melts at 101° C , beta melts at 125° C , gamma melts at 81° C **Potassium** permanganate causes oxidation yielding sulfonyl compounds. (R K S)

THIOCARBONIC ACID AND THIOCARBONATES Thiocarbonic acid (H_2CS_3) is a yellow oily liquid, melting point 20° to 30°, with decomposition into **carbon disulfide** plus **hydrogen sulfide**, made by addition of acid, e g, **hydrochloric acid**, to sodium thiocarbonate

Sodium thiocarbonate (Na_2CS_3) is made by reaction of sodium hydrogen sulfide and carbon disulfide (similar to the reaction of sodium hydroxide and **carbon dioxide** to form **sodium** carbonate) (R K S)

THIOCYANIC ACID AND THIOCYANATES

Hydrogen thiocyanate (HCNS) is a gas, unstable, and upon cooling it solidifies to an odorous solid, melting point 5° C to a liquid that soon changes to a yellow solid Hydrogen thiocyanate is soluble in water, and the solution is thiocyanic acid, moderately stable when dilute and cold, but not otherwise

Thiocyanic acid is formed by reaction of **barium** thiocyanate solution and dilute **sulfuric acid**, and filtering off barium sulfate

Sodium, potassium, barium, or **calcium** thiocyanate may be made by reaction of **sulfur** and the corresponding **cyanide** upon heating to fusion Ammonium thiocyanate (plus ammonium sulfide) may be made by reaction of **ammonia** and **carbon disulfide**, a reaction which probably accounts for the presence of ammonium thiocyanate in the products of the destructive distillation of coal

Silver, lead, cuprous, and **thallous** sulfocyanates are insoluble, and **mercuric** and **stannous** sulfocyanates slightly soluble All of these are soluble in excess of soluble (e g , ammonium) thiocyanate forming complexes Ferric thiocyanate is a red solution, used in detecting either ferric or thiocyanate in solution, and is extracted from water by amyl alcohol

When thiocyanic acid is treated with oxidizing agents, e g , **nitric acid, sulfuric acid, hydrocyanic acid** is formed, when treated with reducing agents, e g , **aluminum** and dilute hydrochloric acid, hydrogen sulfide plus carbon plus ammonium chloride are formed

Esters Ethyl thiocyanate (C_2H_5 SCN), colorless liquid, boiling point 142° C Formed by reaction (1) of potassium thiocyanate and potassium ethyl sulfate, (2) of cyanogen chloride and ethanethiol Oxidizable with fuming nitric acid to ethyl sulfonic acid (C_2H_5 SO_2OH), and reducible with zinc and dilute sulfuric acid to ethane thiol (C_2H_5SH) Ethyl isothiocyanate (C_2H_5 NCS), colorless, odorous liquid, boiling point 132° C Formed by reaction of ethyl **amine** and carbon disulfide Reducible to ethyl amine ($C_2H_5NH_2$) plus methylene sulfide (CH_2S) Allyl isothiocyanate ("mustard oil," C_3H_5 NCS) liquid, boiling point 151° C , odor of mustard, and causes blisters in contact with the skin Thiocyanates give a characteristic red coloration with ferric salts (R K S)

THIOIC ACIDS. Sulfur

THIOLS Thioalcohols and Related Compounds

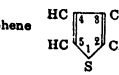
THIOPHENE AND RELATED COMPOUNDS.

Thiophene ($(CH)_4S$) is a liquid, boiling point 84° C , resembling **benzene** in odor and properties Thiophene is present in coal tar and is recovered in the benzene distillation fraction (up to about 0 5% of the benzene present) Its removal from benzene is accomplished by mixing with concentrated **sulfuric acid**, soluble thiophene sulfonic acid being formed Thiophene gives a characteristic blue coloration with isatin in concentrated sulfuric acid

Thiophene may be formed (1) by passing ethyl sulfide (diethyl sulfide) through a red hot tube, (2) by reaction of **sodium** succinate and **phosphorus** trisulfide **Chlorine** and **bromine** yield chloro- and bromo-substitution products, respectively, cold fuming **nitric acid** yields thiophene sulfonic acid Thiophene aldehyde (C_4H_3S CHO), liquid, boiling point 198° C , resembles **benzaldehyde** chemically rather than furfural The corresponding primary **alcohol**, and **carboxylic acid** are known Where sulfur of thiophene is occupied by oxygen, **furane** is the compound, and where by nitrogen (group —NH), **pyrrole**

Benzothiophene (C_8H_6 $(CH)_4S$), is a solid, melting point 31° C , boiling point 221° C , and resembles naphthalene Where sulfur of benzothiophene is occupied by oxygen, coumarone is the compound, and where by nitrogen (group —NH), indole

Thiophene

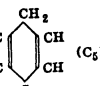


(C_4H_4S)

Benzothiophene (Thionaphthene)

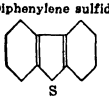
($C_8H_4(CH)_2S$)

Penthiophene



(C_5H_6S)

Diphenylene sulfide



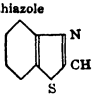
melting point 97°C.
boiling point 332°C

Nitrogen-sulfur ring compounds:
Thiazoles

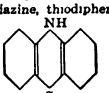
Thiazole

boiling point 117°C.

Benzothiazole

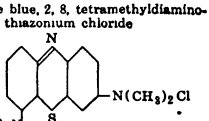


Thiazines
Phenthiazine, thiodiphenylamine



melting point 150°C.
boiling point 370°C.

Methylene blue, 2, 8, tetramethyldiamino-thiazonium chloride



(R K S)

THIOPHENOLS. Thioalcohols and Related Compounds.

THIOSULFURIC ACID AND THIOSULFATES.

Thiosulfuric acid ($H_2S_2O_3$) is possibly formed upon addition of an acid to **sodium** thiosulfate solution, but immediately decomposes into **sulfur** dioxide gas and sulfur, yellow precipitate, the latter appearing gradually (more rapidly with higher concentrations)

Sodium thiosulfate, "hypo" (misnamed hyposulfite) ($Na_2S_2O_3$ $5H_2O$), is used (1) to dissolve **silver** chloride,

bromide, iodide in the photographic "fixing" bath, soluble sodium silver thiosulfate being formed plus sodium chloride, bromide, iodide, (2) in reaction with **iodine** in solution, sodium tetrathionate and sodium iodide being simultaneously formed, or with **ferric** salt solution, sodium tetrathionate and ferrous being simultaneously formed, (3) in reaction with **chlorine** as an "antichlor" forming sulfate and chloride Sodium thiosulfate reacts with silver nitrate solutions yielding silver sulfide, brown precipitate, and with permanganate yielding **manganous. Sodium** amalgam changes sodium thiosulfate to sodium sulfide plus sodium sulfite

Sodium thiosulfate is formed (1) by reaction of sodium sulfite solution and sulfur upon warming, (2) by reaction of sodium sulfite solid and sulfur upon heating, (3) by complex reaction of sulfur and sodium hydroxide solution upon warming—sulfur yields sodium sulfide plus sodium sulfite and the latter reacts with excess sulfur forming sodium thiosulfate, and the sodium sulfide present may be converted into sodium thiosulfate by passing in sulfur dioxide until the solution changes from yellow to colorless

Thiosulfates are commonly identified as follows

1 Dilute acids precipitate sulfur from thiosulfates (difference from sulfides and sulfites)

2 Zinc sulfate and sodium nitroprusside give no color (difference from sulfites) (R K S)

THIOUREA. Thiourea, "thiocarbamide" ($(NH_2)_2CS$), is a white solid, melting point 172° C , easily hydrolyzed to **ammonia** plus **carbon dioxide** plus **hydrogen sulfide**, chemically analogous to urea, oxidized to **urea** by cold potassium permanganate solution

Thiourea is formed by heating ammonium **thiocyanate** at 170° C After about an hour 25% is converted With **hydrochloric acid** thiourea forms thiourea hydrochloride, with **mercuric** oxide thiourea forms a salt, and with **silver** chloride it forms a complex salt

Symmetrical diphenyl thiourea, "thiocarbanilide" ($(C_6H_5NH)_2CS$), is a solid, melting point 154° C , and when heated with concentrated **hydrochloric** acid yields **aniline** plus phenylisocyanate Formed by reaction of aniline and **carbon disulfide** Symmetrical-diethylthiourea ($(C_2H_5NH)_2CS$) is a solid, melting point 77° C (R K S)

THOMSON EFFECT. Thermoelectric Phenomena.

THOMSON E.M F. Thermoelectric Phenomena.

THONGALLEN. Types of **concretions** which occur in **loess** When these concretions simulate the forms of human figures they are called *Loessmanchen* (R M F)

THORACENTISIS. Removal of fluid or pus from the chest cavity by inserting a needle or trocar through the chest wall between the ribs (R S M)

THORACOPLASTY. Plastic surgery of the **thorax** The term is used commonly to describe the collapsing operation on the chest for the arresting of unilateral **tuberculosis** In this operation the lung affected by tuberculosis is put to rest, permanently, by removing the greater portion of the upper eleven ribs on that side, thus collapsing the chest wall The tubercular cavities in the lung are closed by this means, and tuberculosis is further arrested by rest of the lung, since it cannot expand with respiration The operation is very successful and is used in those cases not suitable for **pneumothorax** treatment (R S M)

THORAX. 1 The division of the **arthropod** body between the head and abdomen It consists of three or four metameric segments of the body, often closely united so that their boundaries are difficult to determine It bears a pair of jointed appendages on each segment, developed for walking or swimming, and in some species for grasping, and in the insects the two posterior segments may bear a pair of wings each The three segments of the insect thorax are known as the pro-, meso-, and metathorax 2 A division of the trunk of **vertebrates**, just behind the head and neck This region is supported by the ribs and contains the thoracic cavity, a division of the **coelom** In the **mammals** it is separated from the abdominal cavity by the diaphragm and is further subdivided into the pleural cavities containing the **lungs** and the pericardial cavity containing the **heart** It is a bony cage made of the sternum in front, the vertebral column behind, and the ribs connecting the two (A W L, R S M.)

THORIANITE. The mineral thorianite is chiefly composed of **thorium uranium oxide**, occurring in black nearly opaque cubic crystals in Ceylon and Madagascar It is radioactive, and as such is particularly valuable in helping to date the absolute, as well as the relative, ages of the rocks in which it occurs (See **Radioactive Minerals**, and **Chronology**) (R M F)

THORITE. The mineral thorite is a **silicate** of the rare element **thorium** and corresponds to the formula $ThSiO_4$ It is **tetragonal** and exhibits a prismatic **cleavage** The original thorite was black in color with a specific gravity of 4 4–4 8 A variety orangite, so called from its orange yellow color, has a specific gravity of 5 19–5 40 It has been found partly altered to thorite Uranothorite contains **uranium** oxide Thorite occurs in Norway in **augite syenites** Thorite and orangite occur in Sweden, and orangite and uranothorite are found in Madagascar Uranothorite is found in Ontario (E S C S)

THORIUM. Symbol: Th Atomic number 90 Atomic weight 232 12. Density 11 5 (11 3–11 7) Melting point 1845° C

Thorium metal is dark gray, dissolves in **hydrochloric acid**, is made passive in **nitric acid**, not affected by fusion with alkalis, at 450° C combines with **chlorine** and with **sulfur**, at 650° C combines with **hydrogen** and with **nitrogen** An outstanding property is the **radioactivity** of all thorium-containing substances Discovered by Berzelius in 1828

Thorium occurs in **monazite** sand in Brazil, India, North and South Carolina, which sand contains 3%–9% thorium oxide, and is the chief source, also found in thorite containing about 60% oxide and in thorianite, about 80% oxide When heated with concentrated **sulfuric acid** the minerals form thorium sulfate, from which, by a series of reactions, thorium nitrate, the chief commercial compound, is obtained Upon ignition the nitrate yields oxide which finds extensive use in the manufacture of gas mantles, where a mixture of 99% thorium oxide and 1% **cerium** oxide gives maximum luminosity at a comparatively low temperature The oxides are formed in place by ignition of the mantle fiber, which has been previously impregnated with the corresponding nitrates and dried

Hydroxide Thorium hydroxide ($Th(OH)_4$), white, gelatinous precipitate, by treating thorium salt solutions with sodium hydroxide solution

Nitrate Thorium nitrate ($Th(NO_3)_4$), crystallizes with 5, 6, and 12 molecules of water, and is the chief commercial salt

Oxide Thorium oxide (ThO_2), white solid, prepared by ignition of the nitrate, oxalate, or hydroxide. (R K S)

THORN APPLE. Potato Family.

THORNY-NOSE. Pisces, Teleostei A peculiar marine fish (**Pisces**) found near New Zealand It has very long serrate dorsal and ventral fins and the nose bears two strong spines (A W L)

THORON. Symbol: Tn A radioactive element of the thorium series (See **Radioactive Changes**) (R K S)

THOULET SOLUTION. An aqueous solution of **potassium mercuric** oxide the specific gravity of which is 3.19. Used by petrologists to separate mineral particles according to their specific gravities. Synonym, Sonstadt Solution. (R.M.F.)

THRASHER. Aves, Passeriformes. Moderately large North American birds (**Aves**) related to the wrens, the mockingbird, and the catbird. They have a long curved beak. Several of the species are among our finest singers.

The brown thrasher, *Toxostoma rufum*, is a familiar bird east of the Rockies. Our six other species are western and southwestern. (A.W.L.)

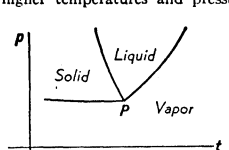
THREE-BODY PROBLEM. If we assume that three or more objects exist in the universe, each of them attracting every other in accordance with the law of **gravitation**, the problem of predicting subsequent positions and motions is commonly referred to as the three-body problem, or the *n*-body problem.

The **two-body problem** has been completely solved and the full solution may be expressed in comparatively few words and symbols. However, if we add two or more other bodies the solution becomes one of exceeding complexity and has never been accomplished in any form which is at all suitable for computational purposes. In fact, only one complete solution has ever been made, in spite of the labors of practically all of the great mathematicians of the past three centuries.

Even though no general solution of the problem is available, nevertheless, there are several practical computational methods for determining the positions of **planets** and other members of the **solar system**, taking into account the gravitational attraction of all effective members. Such solutions are all made by successive approximations and various methods of computing **perturbations**, rather than by the application of any general solution.

A number of particular solutions of the three body problem have been made by mathematicians, notable among them being the solution by Lagrange. He showed that it is possible for an **asteroid** to be stable in a position such that it is equidistant from both the sun and **Jupiter**. In this case the three objects would be on the vertices of an equilateral triangle and the asteroid **orbit** would have the same period as that of Jupiter. This case is illustrated in nature by the members of the so-called **Trojan group**. (W.K.G.)

THREE-PHASE EQUILIBRIUM. For every pure, chemically stable substance there is a certain temperature and pressure at which it can exist in all three states or phases, solid, liquid, and vapor, each phase being in equilibrium with each of the others. At higher temperatures and pressures the liquid and vapor states may attain equilibrium; solid-vapor equilibrium (See **Siblimation**) is possible at lower temperatures and pressures; while solid-liquid equilibrium can be obtained at high pressures and at lower or higher temperatures according as the substance contracts or expands upon melting (See **Fusion**). These three equilibria may be represented by three temperature-pressure graphs which converge at one point, the "triple point," corresponding to the unique condition of three-phase equilibrium. The figure illustrates the case of water, which contracts on melting, and for which the triple point is at $+0.072^\circ$ C. and 4.6 millimeters of mercury. (L.D.W.)



Triple point (*P*) on temperature-pressure diagram.

THRIPS. **Thysanoptera.**

THROAT. Internally, the pharynx: the cavity behind the mouth into which the nasal passages open and from which the esophagus and trachea lead. Externally, the ventral part of the neck. (A.W.L.)

THROMBOPHLEBITIS. **Thrombosis** associated with inflammation or **phlebitis** of a vein. (R.S.M.)

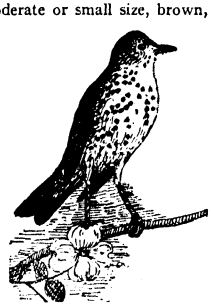
THROMBOSIS. The forming of a clot in a vessel, thereby shutting off the circulation beyond the point of thrombosis. This usually results from infection, injury to the vessel, or almost complete **stasis** in the vessel. (R.S.M.)

THROMBUS. A clot or plug forming in a blood vessel and attached to the vessel wall. When the thrombus becomes dislodged and is carried by the blood current to some other part of the circulation, it is called an embolus. (R.S.M.)

THROTTLING. Throttling is the reduction of pressure of a fluid passing a restriction or **orifice.** During a throttling expansion of a fluid there must be no work done, i.e., the heat contained in the fluid after throttling must be unchanged from the original. Throttling as a thermodynamic process may be used to advantage as in the control of a **steam engine**, where the weight of steam drawn into the engine per cycle is varied by varying the pressure with a throttle valve. The automobile engine is governed in speed by variable throttling of the intake, so that the cylinders receive more or less charge, depending on the extent to which the pressure of the incoming gas is reduced by throttling. (F.T.M.)

THROW. For the use of this term in geology, see **Fault.**

THRUSH. (In zoology) Aves, Passeriformes. In the broad sense a bird (**Aves**) of the family Turdidae, but the term is most widely applied to the members of this family that retain a spotted breast as adults, while other species which lose the spots as their adult plumage develops receive other names. Among the latter are the **robin** and **bluebirds** of North America. The North American thrushes are of moderate or small size, brown, gray, or olive above and white below, with spots similar to the back. The wood thrush, *Hylocichla mustelina*, is widely distributed in the eastern half of the United States, and the hermit thrush, *H. guttata*, is even more widely distributed, though less commonly known.


Wood thrush, *Hylocichla mustelina*. Bright brown above, white below, with large round spots on the breast and sides.

The family includes the European fieldfare, **redwing,** and **blackbird,** the ringouzel, and the Old World chats. In North America it is also represented by the Townsend solitaire and the **wheatear,** in addition to the robin and the several species of bluebirds.

The song-thrush of Europe, *Turdus philomelus*, is also called the mavis, and in America the term thrush is misapplied to the Louisiana water thrush, which is a warbler, because of its similar color and pattern.

In medicine, thrush is a parasitic infection of the mouth due to a **fungus** called *Oidium albicans*. It infects the mouth of debilitated infants and may occur in adults when the oral hygiene has been neglected, where the gums have been injured by too violent cleansing, and in those who have been confined to bed with long-drawn-out illnesses.

The disease is treated by adopting the proper methods of oral hygiene. (A.W.L., R.S.M.)

THULIUM. Symbol: Tm. Atomic number: 69. Atomic weight: 169.4. Type of compound: Tm_2O_3. Color of salts: green. Discovered by Cleve in 1879. A member of the **yttrium** sub-group of the rare earth metals. (R.K.S.)

THUMBLESS MONKEY. Mammalia, Primates. A group of African **monkeys** constituting the genus *Colobus*. They are named from the reduction of the thumb, which is either entirely absent or reduced to a small projection, with or without a vestigial nail. Some of the included species are called colobs, one is a guereza, and one is the king monkey. (A.W.L.)

THYLACINE. Tasmanian wolf.

THYME. Mint Family.

THYMUS. A ductless gland situated in the upper anterior portion of the chest cavity. It reaches its maximum activity during **puberty** and thereafter it diminishes in size and activity in most individuals. Its function in the body is not known. It is known, however, that certain individuals who have an enlarged thymus are subject to sudden attacks of unconsciousness, convulsions, sometimes sudden death. This has occurred following the administration of an anesthetic and a large thymus has been found on autopsy. The condition is described as *status thymicolymphaticus* and is characterized by low blood pressure, weak flabby muscles, and lack of resistance to fatigue and infectious processes. Certain behavioristic and mental peculiarities are frequently present.

Enlargement of the thymus when discovered in an infant is treated by exposure to **x-rays** and glandular treatment, particularly with **pituitary** and **adrenal** glandular preparations. (See **Hormones** and **Endocrine Glands.**) (R.S.M.)

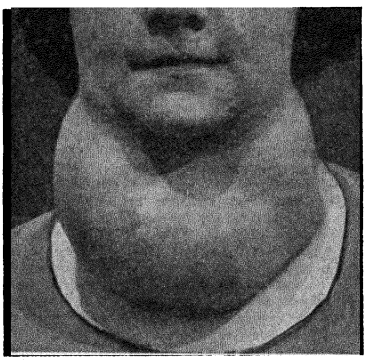
THYROID GLAND. This important gland of internal secretion is made up of two flattened lobes lying beneath the superficial muscles of the lower anterior part of the neck on either side of the **trachea.** The two portions of the gland are connected by a small bridge of thyroid tissue lying across the part of the trachea. Other masses of thyroid tissue may sometimes be present along the length of the trachea. They are accessory thyroid tissue. During pregnancy and menstruation the thyroid may temporarily increase in size. Complete removal and abnormal secretion of the gland causes grave systemic disturbances. The gland is also subject to **tumor** formation, which may be **benign,** causing enlargement only (adenoma), or be **toxic** (toxic adenoma), or be **malignant.**

The function of the thyroid is to serve as a storehouse for **iodine** and to secrete into the blood stream thyroxine, which has a stimulating effect on growth and metabolism. By means of **hormones** that are not well understood, the thyroid affects other ductless glands and the sympathetic **nervous system.** In a reverse manner, other endocrine glands in turn influence the thyroid—this is particularly true of the **pituitary gland,** which has a multiplicity of influences on all the endocrine glands. The interglandular relationship of the thyroid as well as other endocrine glands is not well understood at present.

Diseases of the thyroid gland are most frequent where iodine content of the soil and water is low, although cases appear where the iodine content is normal. Apparently another factor is involved. Disorders that develop in this gland may be characterized by exhaustion of the gland—as hypothyroidism and myxedema—by increased or disordered function of the gland—as hyperthyroidism, Graves' disease, thyrotoxicosis, exophthalmic goiter, and toxic adenoma—or by mere enlargement of the gland—as simple goiter.

The degree of activity of the thyroid gland is best measured by means of the basal **metabolism** test.

Cretinism is a condition appearing in fetal life, or soon after birth, due to a more or less complete lack of thyroid secretion. There is a marked hereditary ten-



Large simple goiter in girl seventeen years old. (From the *Nelson Loose-Leaf Surgery,* Thomas Nelson & Sons.)

dency. A marked condition of cretinism, untreated, is not compatible with long life. The condition is not common in the United States. It is most common in iodine deficient districts, where there is a lack of iodine in the maternal organism.

Often the disease is not recognized until the child has reached the age of one year. A pig-like expression is common. Soon it is noticed that the child is stunted in size, intelligence, and bodily activity. This type never achieves more intelligence than that of early childhood.

The most important treatment is prophylactic and consists of proper treatment of pregnant women with iodine compounds in goiter districts. Cretins must be treated early in life with thyroid gland substance if complete relief of symptoms is to be obtained.

Myxedema is a constitutional disorder due to lack of secretions of the thyroid gland (thyroxin). It may be due to exhaustion or removal of too much gland substance. Mild cases of myxedema (hypothyroidism) are exceedingly common and may follow many illnesses, as chronic diseases or repeated pregnancies. It occurs four to five times more frequently in women than in men. A goiter of simple type may be present although this is not usually the case.

The onset is usually gradual and occurs most frequently after twenty-five years of age. There is slowing of mental and bodily activities, an increase in weight, decreased appetite, and feeling of well-being. Cold is frequently complained of. Blood pressure is lowered and the pulse is slowed. Mental sluggishness, forgetfulness, and lack of ambition may be marked. The skin is thinned, coarsened, dry, and scaly, and the nails and hair may be brittle. Anemia is a frequent finding. There is a tendency to increased sleep and drowsiness. The basal metabolism varies from minus 5 to minus 40. **Arthritis** is common in these patients.

Brilliant and dramatic results are obtained by administration of thyroid gland substance or thyroxin. The symptoms entirely disappear as long as substitution of thyroid substance is maintained to counteract the deficiency. The basal metabolism rises to normal limits and this test provides a means of estimating the proper maintenance dose of thyroid.

Simple goiter (colloid goiter, struma) is a diffuse symmetrical enlargement of the thyroid gland appearing soon after puberty. There are no symptoms due to this condition other than enlargement of the neck and pressure symptoms secondary to it. There are certain districts in the world where this condition is common. These districts in general are in mountainous regions and the sites of glacial ice fields—in other words, districts deficient in iodine. Near the seacoast, where sea water iodine is present, this disorder is relatively uncommon. In the United States, goiter districts are found around the Great Lakes district, Mississippi Valley, and in the Northwest. In goiter districts preventive treatment to make up iodine deficiency is important to correct this disorder and prevent cretinism in offspring.

The symptoms are those of a diffuse enlargement of the neck. If there is pressure on the **trachea** there may be difficulty in breathing at times. The basal metabolism is not disturbed.

Treatment should be preventative in goiter districts. Preventative treatment with iodine, if given carelessly, may stir up hyperthyroidism in certain individuals.

Many simple goiters gradually decrease after puberty. Others respond to medical treatment and still others require surgery.

Myxedema and exophthalmic goiter do not commonly develop with simple goiter.

Adenoma of the thyroid seldom causes constitutional symptoms unless the adenoma becomes toxic and then hyperthyroidism develops. These adenomatous growths develop from fetal rests of thyroid tissue. Surgery is the only treatment for both the simple and toxic varieties of adenoma and gives excellent results.

Thyroid adenoma with severe hyperthyroidism and unequal exophthalmos. (Crile, G. W., and Dinsmore, R. S.: Surgery of the thyroid gland, *Nelson's Loose-Leaf Surgery*, Volume 2)

Exophthalmic goiter (Graves' disease, Basedow's disease, Thyrotoxicosis) is a constitutional disease due to an excessive and abnormal secretion of the thyroid gland. The cause of this condition is not known. It is a disease of civilized countries and is most common where conditions tend toward mental activity and strain. More women than men are subject to this disease. Frequently a nervous shock or strain or some infection seems to start the process. Exophthalmus is usually present with this disease and is characterized by large protruding eyeballs giving a peculiar staring expression to the eyes. The causes of the eye disturbances are not known. The disease begins insidiously—early symptoms of fatigue, loss of weight, marked nervousness. The patient's disposition may change, with irritability and inability to get along with other people. The basal metabolism is greatly increased and may be 40% to 75% above normal.

The symptoms of this disorder are due to excessive thyroid secretion. Thyroxin increases the oxidation rate in the body with increased production of activity and heat production. Because of this there is an increased appetite although the individual loses weight. The patient complains of feeling warm and of excessive perspiration. Gastrointestinal symptoms are common.

In this disease the **heart**, sooner or later in the severe forms, shows the effect of the increased metabolism. Rapid heart, **myocarditis**, auriolar fibrillation, and cardiac enlargement are common.

The thyroid is usually enlarged but this does not always occur.

Any complication such as nervous shock or an acute illness increases all the symptoms and produces a toxic state that leads to exhaustion and possible death.

The best treatment is combined medical and surgical care. The patient is first treated medically with the emphasis on bed-rest and mental rest. Iodine is used for several weeks before the operation. Cardiac failure must be treated. After several weeks the patient improves greatly, the basal metabolism becomes lower, and the patient may then be safely operated upon.

Thyroiditis is infection of the thyroid gland. This condition is not common.

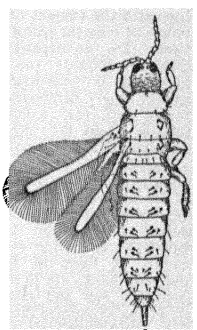
The thyroid is less commonly involved as a site of malignancy than many other organs of the body. Operation, x-ray, and radium give little hope of cure when the thyroid is involved. (R.S.M.)

THYROIDITIS. Thyroid Gland.

THYROXINE. Hormones.

THYSANOPTERA. The thrips, an order of minute **insects**, with or without wings. Their mouths are formed for sucking, the tarsi have an expanded tip, and the metamorphosis is gradual. When wings are present there are two pairs, both formed of slender membranes with very long fringes.

In spite of their minute size a number of species of thrips are serious pests, attacking cultivated plants. One of these is the onion thrips, introduced from Europe over sixty years ago. It attacks onions, cabbage, melons, and other plants and is sometimes troublesome in greenhouses, although it is not the common greenhouse thrips. Spraying with nicotine sulfate is an effective check, although onions are difficult to spray because the insects cannot easily be reached between the leaves. In greenhouses fumigation is desirable.



Thrips.

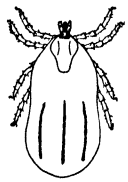
Some thrips live on other small insects, eggs, and mites, and so are of some value in checking other pests. (A.W.L.)

THYSANURA. Small to moderately large insects of the primitive wingless group, commonly called bristletails. The more common forms are the **silverfish** and the **fire-brat**, both grayish with silvery luster. The body is about a third of an inch long in both species, bearing long slender antennae and at the opposite end a pair of similar cerci and a slender median filament. The order also includes some species with forceps-like appendages at the tip of the body in place of the slender cerci. (A.W.L.)

TIC. A recurrent spasmodic involuntary muscular reaction taking place in a group of muscles. This condition is apt to develop in nervous people and frequently accompanies psychoneurotic disorders. It often develops in youth and the tendency may be hereditary. It is a more severe form of the so-called "habit-spasm," such as twitching of a part of the face. (R.S.M.)

TICK. Arachnida, Acarina. A blood-sucking parasite related to the spiders and mites. Its body is leathery and sacklike, with piercing mouth parts forming a small protuberance called the capitulum and a shield or scutum marking the dorsal surface in most species. The ticks are larger than their relatives, the mites, ranging from three to six millimeters in length. When filled with

blood the female sometimes reaches a length of one-half inch

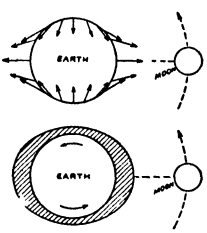


Tick

The common dog or wood tick of the eastern and central states, *Dermacentor variabilis,* often attaches itself to human beings in the woods and is a common pest of domestic animals, especially dogs, during the warm months A closely related species in the western states, *D andersoni,* transmits the dangerous disease, **Rocky Mountain spotted fever.** The Texas cattle tick, *Margaropus annulatus,* transmits Texas fever of cattle, also a destructive disease (A W L)

TIDES. The periodic rise and fall of the oceans, or other large bodies of water, relative to the surrounding land is commonly known as the tides Since the earth itself is not a perfectly rigid body, there are tides in the earth itself, and observations of the land tides have provided useful information regarding the rigidity of the interior of the earth

Tides are produced by the combination of a number of external forces, with the principal force being the **gravitational** attraction of the **moon** Owing to the differences of distance of the moon from various portions of the earth the amount of the attractive force will be different in different places and tend to produce a deformation The accompanying diagrams indicate (on a very much exaggerated scale) the deformation forces, and the resultant tides in a very deep ocean surrounding a rigid earth



Tides in a very deep ocean If the whole earth were covered by very deep water, and if the earth's rotation were slower, high tides would occur under and opposite the moon The upper figure, after Darwin, shows the tide-raising force of the moon at different places

The tidal force due to the gravitational attraction of the sun ranks second in importance to the tide-raising forces from the moon Twice during each month, at times of full and new moon, the forces from the sun and moon are acting in parallel directions and produce the maximum tide range known as "spring tides" At times of quarter moon the forces are acting at right angles to each other and the resultant minimum range of tides is known as "neap tides" Other tidal forces due to the rotation of the earth, the revolution of the earth-moon system, and the revolution of the sun-earth system, make the problem of tide prediction one of great complexity Detailed **harmonic analysis** of the observed tides have indicated the presence of tidal forces due to the attractions of several of the major **planets.** In the open ocean, from observations taken on isolated islands, the average range of ocean tides relative to the land is about two and one-half feet. Configuration of shore line and contour of the ocean floor greatly increase this range for most stations along the coasts of the continents The maximum range of tides in the land is about nine inches

If no other forces than lunar attraction were effective in producing the tides, the time of high water (the crest of the tidal bulge) would occur at a given point when the moon is on the local **meridian** (either at upper or lower culmination) Due to the other effective tidal forces the actual time of high tide differs from the instant of meridian passage of the moon by an amount known as the "lunar interval" The effect of lunar interval will average zero in the course of a long period of time, and the average interval between successive high tides is found to be 12 hours 25 5 minutes, which is one-half the average interval between successive upper culminations of the moon

The difference between the actually observed time of high tide and the time calculated from the instant of transit of the moon across the meridian, combined with the lunar interval, is known as the "establishment of the port" The values of the "establishment" are obtained observationally for various ports and are tabulated in tide tables The values obtained for two ports, which may be separated by only a few miles, may be very different owing to the configuration of the coast line between the ports.

The tides represent expenditure of energy, and a large part of this must come from the **kinetic energy** of rotation of the earth This should tend to check the earth's rotation and thus increase the length of the day, but the effect is too small to have been observed Considerable effort has been directed towards utilizing tidal energy for useful purposes to man, but so far the success has been very limited Tidal forces also play an important part in the evolutionary processes of the various astronomical bodies (W K G)

TIE. The rails of a **railway** are supported by cross ties, which maintain the gage between rails and transmit the wheel load to the **ballast** in which the ties are embedded Some limited use has been made of concrete and steel substitutes for wooden ties, but the wooden tie is standard practice in the United States The low cost, combined with certain advantages that wooden ties possess, such as the method of fastening rails by spikes, ease of disposal, freedom from corrosion, electrical insulating property, give the wood tie a very pronounced advantage over substitutes In countries where suitable timber is scarce and expensive, the substitute tie will be more economical Most cross ties in this country are made of oak or Southern pine Locust, hickory, and beech are also accepted The size of a class A tie is $7'' \times 9'' \times 8'\ 6''$ The ties must be made from sound live timbers, free from soft or decayed spots, shakes, worm holes, or other imperfections which would impair the usefulness Ties may be made from a log by sawing or hewing slabs from the surface, or by sawing or splitting larger logs The ties are barked before use Ties are spaced about 21 inches on centers, and are embedded nearly to their upper surface, with rock or gravel thoroughly tamped around them

At the present time, practically all wooden ties are creosoted before use, as it has been amply proved that creosote extends the life of the tie sufficiently to more than pay for the cost of creosoting This fact is not likely to be altered with time, because of the increasing cost of ties, and the improvements of creosoting processes In a treating plant, the tie is first seasoned and steamed, then placed in a cylindrical retort which is filled with hot creosote oil A pressure is then applied, and this drives the oil into the pores of the wood Then the pressure is released, and the excess oil is drained from the retort, after which a quick vacuum is applied to complete the extraction of the excess creosote. (F T M)

TIEDEMANN'S VESICLES. Water vascular system.

TIE ROD. A tie rod is a slender structural rod capable of carrying tensile loads only Since the ratio of its length to the **radius of gyration** of its cross-section is usually very large, it would buckle (bend) under the action of compressive forces Tie rods are used for airplane structures and in steel structures such as bridges, industrial buildings, tanks, towers, and cranes Tie rods known as sag rods are sometimes used in connection with purlins (See **Bent**) to take the component of the loads which is parallel to the **roof.** The strength of a

tie rod is the product of the allowable working stress and the minimum cross-sectional area In a rod which is threaded at the end and not **upset** to allow for the reduction of area caused by the thread, the minimum area will be that which occurs at the root of the thread T.e rods are connected at the ends in various ways, but the strength of the connection should be, at least, equal to the strength of the rod The ends may be threaded and passed through dr.lled holes or *shackles* and retained by nuts screwed on the ends If the ends are threaded right- and left-hand the length between points of loading may be altered This furnishes a method for pre-stressing the rod at will by turning it in the nuts so that the length will be changed A turnbuckle will accomplish the same purpose The ends may also be swaged to receive a fitting which is connected to the supports. Another way of making end connections is to forge an eye or hook on the rod (C W C)

TIGER. Mammalia, Carnivora One of the largest of the **cats**, *Fel.s tigris*, ranking with the l.on in size and strength. The fur normally varies from redd.sh to brownish yellow, with transverse black stripes and a black-ringed tail The total length of adult males, including the tail, is nine to ten feet The tiger is an Asiatic animal, found chiefly in the warm southern countries, but also northward into Turkestan and southern Siberia It is by no means a tropical species

Tigers have been hunted extensively for sport, but they have also had to be destroyed in India, Java, and Sumatra because of their destruction of domestic animals Occasionally also tigers have become man-eaters Tales of the killing of these great beasts are numerous in the records of big game hunting (A W L)

TIGER BEETLE. Insecta, Coleoptera A small long-legged **beetle** of predacious habits They are usually found on exposed earth or sand in the glare of the sun, where they both run and fly very rapidly The numerous species are blue or green, reddish, or white, with or without a characteristic pattern of spots and dashes on the elytra The **larvae** live in burrows in the ground, lying with the head at the entrance to the burrow ready to seize any victim that comes near. (A W L)

TIGER-CAT. Ocelot.

TILE FISH. Pisces, Teleostei A marine fish (**Pisces**), *Lopholatilus chamaeleonticeps*, found in the warmer seas These fishes are covered with small scales and are brightly colored They are chiefly remarkable for the discovery of a new species off the Massachusetts coast in the seventies which promised to be a valuable food fish The fishes were taken for a time in the same way as cod, but they disappeared abruptly (A W L)

TILL. A general term for coarsely graded and extremely heterogeneous sediments of glacial origin Till is generally classified as unstratified drift which may vary from clays to mixtures of clay, sand, and boulders A particularly sticky form of clay till is called gumbo (R M.F)

TILLERING. Grass Family.

TILLITE. Conglomerate.

TIMARAU. Tamarao.

TIMBER. Wood.

TIME. In the purely physical sense of the term, time may be defined as a measured duration In accordance with this definition two intervals of time are said to be equal when a body moving in **equilibrium** passes over equal distances in the two intervals The moving object may be said to be the clock and may be any one of a great number of different varieties.

From the earliest recorded history the apparently moving sun has been used as the fundamental clock The apparent solar day is the interval between successive passages of the true sun across any particular **hour circle.** For definiteness the apparent solar day is said to begin when the true sun is at upper culmination on the **meridian,** or has hour angle zero The apparent solar time at any instant is the hour angle of the true sun

The various hour angles of the true sun were originally marked by the shadow of a rod passing over a graduated plane known as a **sun dial** Since this instrument is only usable during the time that the sun is actually shining, the need for man-made clocks became apparent As these man-made clocks progressed from burning candles, water clocks, sand glasses, and other similar contr.vances down to the modern mechanical and electrical clocks, it became apparent that the true solar day is not constant in length throughout the year The variations in the length of the solar day through the year can be traced to the fact that the earth is not only rotating on an ax.s, but is also revolving about the sun in an orbit The plane of this orbit is not perpendicular to the axis of rotation of the earth, and furthermore the motion in the orbit plane is not uniform, because of the fact that the orbit is an ell pse and the velocity in the ell.pse varies in accordance with **Kepler's Law of Areas.**

In order that a time-keeping system could be employed which would be con.tant throughout the year, the **mean sun** was introduced The mean solar day is the interval between successive passages of the mean sun across any hour circle, and begins, by definition, when the hour angle of the mean sun is zero, and the mean solar time at any part'cular instant is the hour angle of the mean sun The difference between the hour angle of the true sun and the hour angle of the mean sun is known as the **equation of time** and is algebraically expressed in the sense apparent time minus mean time

Mean solar time has certain inconveniences for daily living on account of the fact that the date changes at the beginning of the mean solar day, and this comes very nearly at the middle of the daylight period To avoid this inconvenience the civil day has been introduced The civil day begins when the hour angle of the mean sun is twelve hours and civil time is the hour angle of the mean sun plus twelve hours

All three of the different kinds of time thus far discussed are measured from the local meridian Accordingly only those people living in the same terrestrial **longitude** would have synchronous clock readings To avoid this confusion the surface of the earth has been divided into a series of **standard time** zones The different sorts of standard time will be d scussed elsewhere, but standard time is defined as the civil time of some standard meridian

While the sun provides the most convenient reference point for measuring t me for everyday life, nevertheless it is not convenient for stellar astronomy because of the fact that the sun is continually moving eastward through the stars Sidereal time is defined as the hour angle of the **vernal equinox** Since the sun is apparently moving to the eastward throu:h the stars, due to the revolution of the earth about the sun, there is one more sidereal day than solar day in the course of a **year.** A clock keeping sidereal time gains approximately four minutes each day on a mean solar clock, the sidereal clock agreeing with the civ l time clock on approximately September 21 The **right ascension** of a star is measured from the vernal equinox in a direction contrary to the direction of apparent rotation of the **celestial sphere** and the sidereal time is the hour angle of the vernal equinox, and hence measured in the direction of apparent rotation of the celestial sphere. Therefore, sidereal time minus right ascension is equal to the hour angle of a star.

The standard unit of time for the physical sciences is the mean solar day as defined above The practical unit is 1/86,400 part of the mean solar day and is known as the mean solar second This is one of the three basic units of the so-called **c.g.s. system**. It should be carefully noted that the mean solar day is based upon a purely fictitious object known as the mean sun Hence the unit of time is just as arbitrary in character as are the other two units of the c g s. system (W K G)

TIN. Symbol Sn (stannum). Atomic number; 50. Atomic weight 118 70 Density white, 7 31 at 20° C, gray, 5 75 at 20° C Hardness 1 5–1 8 (white) Melting point 231 85° C Boiling point, 2260° C (**Isotopes**: page 238)

Tin is a silver-white metal with a bluish tinge, softer than zinc and harder than lead, malleable, ductile at 100° C, can be powdered at 200° C, and upon exposure to temperatures below 18° C crumbles to a grayish powder due to the "tin pest," which is caused by the transformation of white to gray tin (the reverse transformation may be brought about by heating gray tin to about 100° C), when a bar of tin is bent a marked creaking sound is emitted due to the friction of the crystals, not oxidized on exposure to air at ordinary temperatures, burns to stannic oxide when heated to high temperatures in air or oxygen, soluble in **hydrochloric acid** to form stannous chloride, converted by **nitric acid** into insoluble beta-stannic acid, soluble in **aqua regia** to form stannic chloride, soluble in **sodium** hydroxide solution slowly to form sodium stannite and **hydrogen** gas, reacts with **chlorine** to form volatile stannic chloride Discovery prehistoric

Tin is used (1) as a protective coating on iron and steel and on copper, largely used for "tin can" containers, (2) in **alloys**, such as solder, bronze, pewter, and bearing metals

Tin occurs as oxide (**cassiterite**, tin stone, stannic oxide, SnO_2), obtained commercially in Federated Malay States, Dutch East Indies, and Bolivia The ore is concentrated and then roasted to oxide (83%–88% stannic oxide) The product is treated in a **blast furnace** and crude tin recovered Refining is conducted by **electrolysis**, or by fractional fusion

Chlorides stannous chloride ($SnCl_2\ 2H_2O$), white solid, soluble, formed by reaction of tin metal and **hydrochloric acid** and then crystallizing, used as a mordant and reducing agent in dyeing and printing textiles, stannic chloride ($SnCl_4\ 5H_2O$), (1) white crystals, soluble by reaction of stannous chloride with **chlorine** and then crystallizing, (2) colorless liquid, soluble, boiling point 114° C, formed by heating tin metal in chlorine and condensing the distillate

Hydroxide stannous hydroxide ($Sn(OH)_2$), white gelatinous precipitate, by reaction of stannous chloride solution and alkalis, soluble in acids and in **sodium** hydroxide, insoluble in ammonium hydroxide

Nitrate stannous nitrate ($Sn(NO_3)_2$), white solid, by reaction of tin metal and dilute **nitric acid** and crystallization, soluble in water with slight excess of nitric acid

Oxalate stannous oxalate (SnC_2O_4), white precipitate, by reaction of stannous chloride solution and **oxalic acid** or ammonium oxalate solution, upon heating yields stannous oxide

Oxides stannous oxide (SnO), black solid, insoluble, (1) by heating stannous chloride solution and **sodium** carbonate solution several hours, (2) by ignition of stannous oxalate out of contact with air, stannic oxide (SnO_2), white solid, insoluble, (1) by heating tin metal to a high temperature in air or oxygen, (2) by reaction of tin metal and concentrated nitric acid and ignition of the precipitate, (3) by reaction of stannic salt solution with **alkalis**, and ignition of the precipitate

Stannates· sodium stannate (Na_2SnO_3) and potassium stannate (K_2SnO_3), colorless solutions, by reaction of stannic salt solutions with excess of **sodium** or **potassium** hydroxide, respectively

Stannic acids· stannic acid (H_2SnO_3), white solid, insoluble (1) alpha, by reaction of stannic salt solution and alkalis, or by reaction of stannate solutions with **acids**, (2) beta, by reaction of tin metal and **nitric acid**.

Stannites· sodium stannite (Na_2SnO_2) and potassium stannite (K_2SnO_2), colorless solutions, by reaction of stannous salt solutions with excess of sodium or potassium hydroxide, respectively Powerful reducing agents

Sulfates stannous sulfate ($SnSO_4$), white solid, soluble, stannic sulfate ($Sn(SO_4)_2$), white solid, soluble.

Sulfides· stannous sulfide (SnS), dark brown precipitate, by reaction of stannous salt solution and hydrogen sulfide, insoluble in sodium sulfide solution but soluble in sodium polysulfide solution, forming sodium thiostannate, stannic sulfide (SnS_2), yellow precipitate, by reaction of stannic salt solution and **hydrogen sulfide**, soluble in sodium sulfide solution, forming sodium thiostannate

Stannous chloride solution, when treated with **mercuric** chloride solution, yields a precipitate white to gray, depending upon the relative amounts of mercurous chloride (white) and mercury metal (black) formed (R K S)

TIN STONE. Cassiterite.

TINAMOU, TINAMU. Aves, Crypturiformes A bird (**Aves**) resembling the partridges superficially Characterized by the vestigial tail and by details of anatomy resembling the ostriches The several species live only in South America They are like game birds in many respects

Tinamous are remarkable for their courting habits The females court the males and the males fill the usual role of mother in the care of eggs and young The nest is a scantily lined depression in the ground and the eggs are unusually smooth and glossy, resembling porcelain of a bluish green or wine red color Some species have been reported as singers of exceptional ability (A W L)

TINCTURE. An alcoholic (**ethyl alcohol**), or water and alcohol, extract of a **drug** whose strength is weaker than that of the original drug (R S M)

TINGUAITE. A term proposed by Rosenbusch, in 1887, for a usually **porphyritic dike** rock chemically related to **aegirine-phonolite** Similar to solvsbergite but containing **nepheline** (R M F)

TISSUE. An aggregation of **cells** of characteristic form, specialized for the performance of some limited function or functions All cells of the multicellular animal body take part in the formation of tissues, and tissues in turn are to a great extent incorporated in organs. The cells in a tissue may be all alike, or several kinds may be present, and in some tissues the cells are supplemented by a conspicuous bulk of intercellular materials

Tissues are divided into five classes **epithelial, muscular, nervous, connective**, and **vascular** (A W L)

TISSUE CULTURE. A method for the study of the behavior of single **cells** and isolated bits of tissues of the multicellular body independent of their usual surroundings Minute pieces of tissue are separated from a growing mass, as in an **embryo** or a **tumor**, and are placed under aseptic conditions in a nutrient medium in small glass cells, where they can be observed microscopically Tissues taken from birds or mammals must be kept at the body temperature of the species from which they are derived Under proper conditions the cells of these isolated fragments continue to grow and divide, behaving to some degree as in the normal organism Cells in cultures, however, do not grow old

but persist at a uniform level of metabolism, apparently indefinitely.

This method of study has been especially important in cancer research, in studies of the physiology of senility, and in the observation of cellular phenomena in the living units. (A.W.L.)

TIT. Aves, Passeriformes. A small insect-eating bird (**Aves**) of agile habits and friendly nature, exemplified by the **chickadees** (*Penthestes*) and titmice (*Baeolophus*) of North America. They are chiefly birds of the northern hemisphere, but the group is represented in the Australian region. The colors of most species are quiet, ranging from white to black through bluish grays, relieved by a limited amount of buff or chestnut. The blue tit and the azure tit of the Old World, however, are much more brightly colored, as their names imply.

In North America some species of chickadee is to be found in almost every locality, while titmice occur in the far west and in the states east of the Mississippi.

These species are unusually fearless, and although they have no reputation as singers their cheery calls are always welcome. In the winter they visit feed boxes readily and soon become accustomed to close observation if the observer avoids sudden movements. (A.W.L.)

TITANIUM. Symbol: Ti. Atomic number: 22. Atomic weight: 47.90. Density: 4.5. Melting point: 1800° C. (**Isotopes:** page 237).

Compact titanium is a white metal, when cold it is brittle and may be powdered, but at a red heat may be forged and drawn into wire. At 610° C. titanium reacts with **oxygen** to form titanium dioxide; at 800° C. with **nitrogen** to form titanium nitride; and upon heating with **chlorine** to form titanium tetrachloride. Cold, dilute **sulfuric acid** readily dissolves titanium metal to form titanous sulfate, and the hot, concentrated acid yields titanic sulfate. Discovered by Gregor in 1791.

Ferrotitanium is used as a "scavenger" for the removal of oxygen and nitrogen from molten iron and steel, and copper-titanium and manganese-titanium similarly for brass and bronze.

Titanium occurs in practically all rocks, estimated by Clarke as ninth in abundance of the elements of the earth's crust (0.58% Ti), and in two important ores, **rutile** (titanium dioxide, TiO_2), and **ilmenite** (ferrous titanate, $FeTiO_3$). Ilmenite is a usual component of monazite sand of India, Brazil, and southeastern United States. The **magnetites** (ferroferric oxide, Fe_3O_4) of New York State contain titanium oxide.

Titanium metal is obtained by reduction of the oxide (1) with **carbon** in the **electric furnace**, or (2) with **aluminum** powder upon ignition.

Chlorides: Titanium dichloride ($TiCl_2$), black, deliquescent crystals; titanium trichloride ($TiCl_3$), violet crystals; titanium tetrachloride ($TiCl_4$), liquid, boiling point 136° C., which fumes in moist air, and used for producing white smoke screens in air.

Hydroxides: Titanous hydroxide ($Ti(OH)_3$), dark color; titanic hydroxide ($Ti(OH)_4$), white precipitate, soluble in acids, soluble in bases to form titanates.

Oxalate: Titanium potassium oxalate ($TiO \cdot C_2O_4 \cdot K_2C_2O_4 \cdot 2H_2O$), greenish-white crystals, used as a mordant in textile and leather dyeing.

Oxides: Titanium monoxide (TiO) of slight importance; titanium sesquioxide (Ti_2O_3), black, lustrous crystals by heating the dioxide in hydrogen; titanium dioxide (TiO_2), white powder, used as a paint pigment of high covering power and stability, and in glass and ceramic ware; titanium peroxide (TiO_3), formed in solution as a yellow to red color upon the addition of **hydrogen peroxide** to titanic salt solution and an important test for titanic.

Sulfates: Titanous sulfate ($Ti_2(SO_4)_3$), violet solution by reduction of titanic solutions with **zinc** metal; titanic sulfate ($Ti(SO_4)_2$), colorless solution used as a textile mordant. (R.K.S.)

TITEL. Mammalia, Artiodactyla. An African **antelope** related to the hartebeest. Also called the bubaline antelope. It is smaller than the hartebeest and has relatively short thick horns, ringed and black in color. (A.W.L.)

TITI. Mammalia, Primates. An American **monkey** of the genus *Callithrix*. They are small animals closely related to the squirrel monkeys but differing in their more rounded heads, smaller eyes, and in the longer hair of the tail. The several species are found chiefly in Brazil but to some extent in other parts of the Amazon valley. (A.W.L.)

TITMOUSE. Tit.

TITRATION. Reactions Involving Recombination of Ions; and **Analysis.**

TOAD. Amphibia, Anura. An animal related to the frogs and of similar form. The term is not a scientific one and its application lacks precision. As a rule the toads are better adapted for life away from the water and are found in merely moist situations, such as woods and gardens. The arboreal species are called both tree toads and tree frogs. The skin of the toads is glandular and more or less warty, a circumstance that is no doubt responsible for the false idea that handling toads will produce warts. Like the frogs, most toads have an aquatic larval stage.

The Surinam toad, *Pipa pipa*, is probably the most famous member of the group because of the peculiar habits of reproduction. During the breeding season the skin of the female's back becomes thick and soft. The male imbeds each egg, as it is laid, in this soft skin, and development proceeds to completion in a resulting pouch. The young issue as small toads.

Anderson's tree toad. (Courtesy of American Museum of Natural History.) (Photo by Mary C. Dickerson).

The common toads belong to the family Bufonidae. These species contrast strikingly with frogs in their warty skin and shorter and weaker hind legs. They are largely insectivorous and are of some slight value in the garden. Unlike the frogs, they deposit their eggs in long strings of jelly. (A.W.L.)

TOAD BUG. Insecta, Hemiptera. A small broad **bug** found on the muddy shores of ponds and streams. It is peculiarly like a toad in appearance and habits, capturing insects as prey and burrowing at times. Only a few species are known. (A.W.L.)

TOADSTONE. An old English term for **amygdaloidal basalts** interbedded with **carboniferous limestones** of Derbyshire, England. The rock probably takes its name from the resemblance of the amygdales to the warts or spots on the skin of a toad. (R.M.F.)

TOADSTOOLS. **Agarics** and **Basidiomycetes.**

TOBACCO. Potato **Family.**

TOBACCO WORM. Insecta, Lepidoptera. The **caterpillar** of a large **sphinx moth**, *Protoparce sexta*, which eats the leaves of tobacco, tomato, and other plants. The moth is gray with a row of six orange spots on each side of the abdomen and the larva is green, about three inches long, with a stout horn near the caudal end of the body. Its sides are marked with oblique whitish lines.

Crop rotation as prescribed for the region involved, and dusting with lead arsenate (See **Lead**), are effective

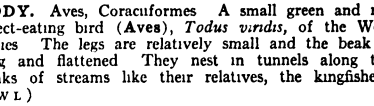
methods of control on large fields. The larvae are so easily seen when they become large enough to cause severe damage that hand picking is effective on truck crops of smaller extent

Tobacco is attacked by other caterpillars, hence the term tobacco worm is not always restricted to this form (A W L)

TODY. Aves, Coraciiformes A small green and red insect-eating bird (**Aves**), *Todus viridis*, of the West Indies The legs are relatively small and the beak is long and flattened They nest in tunnels along the banks of streams like their relatives, the kingfishers (A W L)

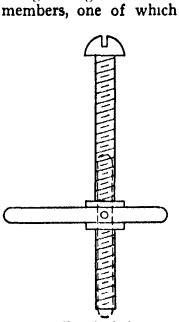
TOEPLER-HOLTZ MACHINE. Static Machines.

TOGGLE The toggle is the particular class of **mechanism** commonly used to apply heavy pressure The toggle effect which will be described is incorporated in



Toggle mechanism

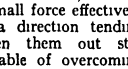
mechanisms known variously as toggle mechanisms, toggle joints, etc The principle of the toggle is the straightening out of a flat angle between two joined members, one of which is affixed at its outer end, the other connected at its outer end to an anvil, jaw, hammer, die, or whatever is used at the pressure face The diagram shows how two links, one pivoted and the other connected to a sliding lock, have a common joint at which pressure is applied Due to the flat angle between the two links, a comparatively small force effectively applied in a direction tending to straighten them out still more is capable of overcoming a large resistance at the moving end The force is applied at the joint by means of a threaded screw, a cam, a crank and connecting rod, or any other suitable means Examples of the use of the toggle are found in stamping machines, presses, crushers, etc


Toggle bolt

A toggle bolt is one having a short bar pivoted to the nut so that the bolt, with nut attached, can be pushed through a hole in a wall, then reversed The bar, which is laid parallel to the bolt when entering the hole, swings to a perpendicular position, thus retaining the bolt in the hole (F T M)

TOGGLE JOINT. Machines; toggle.

TOLLEN'S SOLUTION. Formaldehyde.

TOLUENE. Toluene, "toluol," methyl **benzene**, phenyl methane ($C_6H_5\ CH_3$ or) is a colorless, odorous **hydrocarbon**, boiling point 110 5° C , insoluble in water, miscible in all proportions with alcohols, ether, chloroform, and many organic liquids, dissolves **iodine, sulfur, oils, fats, resins, phosgene**, burns when ignited with a smoky flame Toluene reacts (1) with **chlorine, to form substitution products (one-half of the chlorine forms hydrogen chloride)**, such as (a) ortho- and para-chlorotoluenes ((1)$CH_3\ C_6H_4\ Cl(2)$ and (1) $CH_3 \cdot C_6H_4 \cdot Cl(4)$) at ordinary temperatures, moist, and in the presence of a catalyzer (e g , **iodine, phosphorus, iron**). Both products are colorless, pleasant-smelling liquids, heavier than and insoluble in water, unchanged by sodium hydroxide solution, and (b) benzyl chloride ($C_6H_5CH_2Cl$), benzal chloride ($C_6H_5CHCl_2$), benzotrichloride ($C_6H_5CCl_3$), at boiling temperature, dry, and in the absence of a catalyzer All three products are colorless, heavy liquids separable by fractional distillation, of pungent and irritating odors, insoluble in water, reactive with sodium hydroxide solution to form benzyl alcohol ($C_6H_5CH_2OH$), benzaldehyde (C_6H_5CHO), sodium benzoate (C_6H_5COONa), respectively, (2) with oxidizing agents, e g , **sodium** dichromate plus **sulfuric acid**, to form benzoic acid (C_6H_5COOH) Toluene, benzyl chloride, benzotrichloride, benzyl alcohol, benzaldehyde form benzoic acid upon oxidation, (3) with concentrated **nitric acid**, to form ortho- and para-nitrotoluene ((1)$CH_3\ C_6H_4\ NO_2(2)$ and (1)$CH_3\ C_6H_4\ NO_2(4)$), dinitrotoluene ((1)$CH_3\ C_6H_3(NO_2)_2(2,4)$, trinitrotoluene ("T N T") ((1)$CH_3\ C_6H_2(NO_2)_3(2,4,6)$), (4) with concentrated **sulfuric acid**, to form ortho- and para-toluene sulfonic acids ((1)$CH_3\ C_6H_4\ SO\,H(2)$ and (1)$CH_3\ C_6H_4\ SO_3H(4)$). From the former, **saccharin**  , which is some 500 times sweeter than sucrose and not a sugar, is made, and from the latter, chloramine T ((1)$CH_3\ C_6H_4\ SO_2\ NClNa(4)$), an important antiseptic Toluene is obtained from coal tar and coal gas, as described under **benzene** Toluene is used (1) as a solvent for various substances, (2) in the manufacture of nitrotoluenes for toluidines and explosives such as T N T , of sulfonic acids for saccharin and chloramine T, of benzoic acid, and of other organic chemicals, especially dyes and perfumes. (R K S)

TOLUIDINE. Aniline.

TOMATO. Potato Family.

TOMATO WORM. Insecta, Lepidoptera A large **caterpillar**, *Protoparce quinquemaculata*, similar to the tobacco worm in appearance and habits and belonging to a closely related species The moths of the two species are similar but are easily distinguished by comparison (A W L)

TOMBOLO. A type of sand bar which connects one island with another, or an island to the mainland (R M P)

TONALITE. Diorite.

TONGUE. For the use of this term in geology, see **Apophysis.** In anatomy an organ associated with the floor of the oral cavity, usually projecting or protrusible The true tongue is a vertebrate structure, occurring in all classes above the fishes It is made up largely of voluntary muscle fibers, so distributed that it can be protruded and withdrawn and swung in every possible direction It arises embryonically from the floor of the anterior part of the pharynx, extending forward into the oral cavity

The tongue is used in man and other species for the manipulation of foods in chewing, and in some of the amphibians, reptiles and birds it aids in capturing food, usually by adhesion In man it is an important organ of speech, aiding in the modulation of sounds produced by the larynx

The word is sometimes applied to the **radula** of the snails and to parts of the insect mouth, but only from superficial similarity with the true tongue of the vertebrates (A W L)

TONGUE SHELL. A common name for animals of the phylum **Brachiopoda**, also called lamp shells. (A.W.L.)

TONKA. **Bean.**

TONSILLITIS. An acute infection of the **tonsils** and surrounding throat tissues, usually caused by the *Streptococcus*. Two forms are usually seen: (1) the simple uncomplicated form, and (2) the severe or virulent epidemic form which may often lead to such complications as acute **rheumatic fever**, **endocarditis**, **pericarditis**, **peritonitis**, **pneumonia**, or middle ear infection. Other diseases may involve the throat, particularly at their onset, such as scarlet fever, measles, etc. Acute tonsillitis must always be differentiated from **diphtheria**. (R.S.M.)

TOOL. A tool is an appliance which is used by a worker in pursuing his handicraft. The worker handles the tool or operates a machine constituting the tool or containing the tool, so that the work is shaped or fabricated either in accordance with a predetermined design or with one evolved by the worker while employing the tool. Tools include also those which are employed to set the work up, to gauge it, and to test it during the job or at its completion. Thus the subject of this article will include not only such instruments as chisels, hammers, and the like, which can be used actually to alter the shape and remove the material from the work, but also wrenches, spanners, screw drivers, gauge blocks, surface gauges, scale calipers, and the like.

A salient feature of the "machine age" is the employment of large numbers of **machine tools**, some of which replace hand tools, while others perform operations never before accomplished by hand tooling. Although machine tools may be developed and extended in use, they can never be expected to eliminate the extensive use of hand tools. The latter might be divided for purposes of classification into those which (a) cut, (b) shear, (c) scrape, (d) mold, (e) detrude, and (f) strike, as by percussion. Examples of these are (a) chisels, (b) shears; (c) files; (d) trowels, (e) punches, (f) hammers. (F.T.M.)

TOOTH. 1. A hard structure projecting from the wall of the mouth or the anterior part of the alimentary tract (**Digestive system**) and used for grasping and breaking up food. Teeth vary from the chitinous projections on the radula of **mollusks** to the complex structures of the vertebrates. Chitinous teeth of **annelid** worms, located on the walls of the **pharynx**, are also known as jaws.

Vertebrate teeth are formed of two layers of hard materials over a living papilla, the pulp, which contains blood vessels and nerves. They form in the **embryo** from ingrowths of the outermost layer of the body, the ectoderm, associated with masses differentiated in the middle layer, the mesoderm. The mesoderm forms the dental papilla and around its outer surface, except at the end that is to remain connected with the body, lays down a layer of dentine. This material is similar to bone in composition but not in minute structure. It is harder, contains less organic matter than bone, and is the ivory of commerce. The ectodermal cap over the dental papilla develops into an enamel organ and deposits a layer of enamel on the dentine. Enamel is made up of minute prisms and is the hardest substance produced by the animal body, containing only 2% to 4% of organic matter. When the tooth takes its place in the jaw in the process of eruption the enamel organ is destroyed, hence no more of this substance can be produced. Dentine may be deposited later in life, however, encroaching on the pulp cavity.

The teeth of sharks are the most primitive vertebrate teeth. They are formed like the placoid scales of the body, with a principal point and sometimes smaller supplementary points, and are superficially attached in rows on the jaws. Both scales and teeth contain dentine covered with enamel.

In other fishes (**Pisces**) and **amphibians** teeth are distributed in various parts of the oral cavity and are associated with the bones of the jaws and skull. In **reptiles** and **mammals** they are limited to the jaws and are seated in sockets (alveoli) in the bones by means of a third hard substance, cementum, deposited between the dentine of the roots and the bone of the jaw.

Primitive teeth are simple conical structures. In mammals this type persists only in the canines. The other teeth are sharp-edged incisors, broad molars with projecting cusps on the apposed surfaces, and premolars of intermediate form. The premolars of man are also called bicuspids. An assemblage of teeth of these kinds, variously specialized for cutting, tearing and holding, and grinding and crushing, is known as a heterodont dentition, and is the fundamental plan of **dentition** in the mammals. The various forms of teeth are the basis of specialization in different groups of mammals for the use of limited types of food. Thus species that depend on plant tissues have greater need of crushing teeth while carnivorous forms need cutting teeth for their tougher food. The molars of the former are broad and are so folded that the worn apposed (occlusal) surfaces show alternating bands of dentine, enamel, and cementum in patterns characteristic of the kind of animal. In the elephants these materials form transverse ridges. The incisors of grazing animals are also flattened, forming clipping, rather than cutting, teeth. The canines are reduced or lacking. In carnivores the incisors are greatly reduced, the canines are highly developed, and the molars are sharp-edged. Molars of the two jaws work together like the blades of shears. Some mammals, notably certain **anteaters**, have lost all trace of teeth.

The tusks of various animals are greatly elongated teeth projecting from the jaws for use in fighting and digging. They are usually devoid of enamel. Those of the elephants are upper incisors and in early growth are provided with enamel tips. Those of **walruses** and **swine** are canines. Single tusks of **elephants** weighing almost two hundred pounds have been recorded but the average is less than one hundred. These tusks provide the finest ivory.

Some teeth grow constantly as they are worn away, while others attain a fixed form within a short period and still others undergo a partial compensation for wear. The incisors of **rodents** are of the first type. These chisel-like teeth wear away in gnawing but are constantly renewed by growth at their bases to preserve a uniform length. The molars and premolars of horses are elevated in the jaws by lengthening of the roots, but the amount available for use during the life of the animal is regulated by the height of the crown at the initial formation of the tooth. Human teeth assume a fixed form. The only compensation for wear is the partial filling in of the pulp cavity by the deposition of dentine.

A compensation for breakage and wear is also found in the replacements that occur in lower vertebrates. Mammals normally have no more than two sets, milk and permanent, and when once the permanent teeth of adult life have assumed their functional positions in the jaws, loss through accident is permanent. Rarely a third set of teeth develops.

The word tooth also denotes:

2. The interlocking projections at the hinged edges of the valves of the bivalve molluscan shell.

3. Toothlike projections on a hard structure or on the surface of the body of an animal. (A.W.L.)

TOPAZ. The mineral topaz is a **silicate** of **aluminum** and **fluorine** corresponding to the formula $(AlF)_2SiO_4$. It is **orthorhombic** and its crystals are mostly prismatic terminated by pyramidal and other faces, the **basal pinacoid** being often present. Massive varieties are

known It has an easy and perfect basal **cleavage** hence for this reason gems or fine specimens should be handled with care to avoid developing cleavage flaws. The fracture is conchoidal to uneven, hardness 8 , specific gravity 3 4–3 6 , luster, vitreous, color, of typical topaz, wine or straw yellow but may be colorless, white, gray, green, blue or reddish yellow, transparent to translucent When heated, yellow topaz often becomes a reddish pink Topaz is found associated with the more **acid rocks** of the **granite** and **rhyolite** type and may occur with **fluorite** and **cassiterite**. Topaz comes from many foreign localities, a few of which are Russia in the Urals and the Ilmen Mountains, Czechoslovakia, Saxony, Norway, Sweden, Japan, Brazil and Mexico In the United States topaz has been found in Oxford County, Maine, Carroll County, New Hampshire, Fairfield County, Connecticut, El Paso and Chaffee Counties, Colorado, and in Texas, Utah and California The name topaz is derived from the Greek meaning to seek, which was the name of an island in the Red Sea that was difficult to find from which a yellowstone, now believed to be a yellowish-olivine, was obtained in ancient times In the Middle Ages any yellow stone was called topaz, but now the name is properly applied only to the species here described (E S C S)

TOPAZOLITE. Garnet.

TOPE Pisces, Elasmobranchii *Galeus* A small **shark** found in all temperate and tropical seas More commonly called the dog shark or dogfish in North America, and sometimes the hound shark It attains a length of six feet but is usually much smaller It is used as food to some extent (A W L)

TOP MINNOW. Pisces, Teleostei Any small fish (**Pisces**) of several species, belonging to several genera, which live in quiet water of streams and in pools, swamps, and ditches, feeding on mosquito larvae and other small insects Some are also called mosquito fish and one species is known as the rain-water fish These fishes vary from less than one inch to three inches in length They are most abundant in the southern states and southward into Central America, living in fresh and brackish water

For introduction into lily pools to keep down mosquitoes these fishes are the most desirable (A W L)

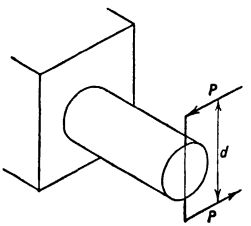
TOPOGRAPHICAL MAPPING Topographical mapping consists of representing on a map the physical features of a given section of land, by showing thereon **contours** or hachures representing the elevation, and noting various other physical features by conventionalized signs Thus trees, streams, marshes, and roads may be part of a topographic survey The method of topographic surveying and mapping of large areas consists of establishing points for horizontal and vertical control, and surveying the adjacent area from these points by the use of direct leveling of **stadia.** (F T M)

TOPOGRAPHY. Topography is a term used in a broad sense to include all details, both natural and artificial, which are required for a topographic map The details cover such points as the disposition of the parts of the earth's surface, namely, hills, valleys, plains, plateaus, etc , and the location of waterways, bridges, highways, railroads, cultivated fields, forests, buildings, etc The delineation of these features is also known as topography. (C W C)

TOPOLOGY. Topology may be described as a study of those properties of a geometrical figure unaffected by any deformation not involving tearing or joining (L L S)

TOPSOIL. Soil.

TORQUE. A torque, often called a torsional or twisting moment, is a **moment** which tends to twist **a body** about an axis of rotation In the accompanying illustration a **shaft** of diameter d is connected to a rigid support The forces P tend to rotate the shaft in a counter clockwise direction causing a torque $(T) = Pd$.



For a body in free rotation the torque $= I\alpha$, in which I is the **moment of inertia** of the mass of the body and α is the angular acceleration (See **Statics.**) (C W C)

TORSION. Elasticity.

TORSION BALANCE The torsion balance is an instrument for measuring very feeble forces of attract on or repulsion It has played an important rôle in the demonstration of **Coulomb's laws** and in measuring the **gravitation constant** and **radiation pressure.** It consists essentially of a light horizontal rod suspended by a slender elastic wire or fiber and carrying at each end a small ball, vane, or other object upon which the unknown force is to act tangentially The resulting torsional deflection is measured by an **optical lever,** the small mirror of which is attached at the base of the suspension To calculate the corresponding torque (and hence the force), the "torsion coefficient" of the suspension must have been previously determined This is the torque required to twist the suspension through an angle of 1 radian, and is conveniently obtained by using the same suspension as the support for a **torsion pendulum** of known **moment of inertia,** and measuring the period In the Cavendish method for determining the gravitation constant, small balls of gold or platinum are used and the torque applied by the attractions of much more massive balls or cylinders of lead in the same horizontal plane (L D W)

TORSION PENDULUM The torsion pendulum consists of a body suspended by a fine wire or elastic fiber in such a manner that it will execute rotational oscillations as the suspension twists and untwists If I is the **moment** of inertia of the body with respect to the axis of oscillation, and if K is the torsion coefficient of the fiber (torque required to twist it through an angle of one radian), the period of oscillation is given by the simple formula

$$T = 2\pi\sqrt{\frac{I}{K}} \qquad (1)$$

Both I and K may have to be determined by experiment in actual laboratory practice This is easily done by measuring the period T and then adding to the suspended body another of known moment of inertia I', giving a new period of oscillation T', which is also measured From (1),

$$T' = 2\pi\sqrt{\frac{I + I'}{K}}; \qquad (2)$$

and the solution of the two equations now gives $K = 4\pi^2 I'/(T'^2 - T'^2)$, $I = T^2 I'/(T'^2 - T^2)$

The oscillating balance wheel of a watch is, in effect, a torsion pendulum, with the suspending fiber replaced by hairspring and pivots The watch is regulated, first roughly by adjusting I (for which purpose screws are set radially into the rim of the wheel), then accurately by varying the free length of the hairspring, and hence its torsion coefficient K (L D W)

TORSK. Pisces, Teleostei A marine fish (**Pisces**), *Brosme brosme*, found in northern waters. Reported as abundant near the Shetland and Orkney islands. It is related to the cod (A W.L.)

TORTOISE. Reptilia, Chelonia. **A turtle.** There is no accurate scientific distinction between the two terms, although some species are called turtles and some tortoises This is true even of members of the same family

In North America the term turtle is commonly used, although a few species, including the gopher turtle of the south, belong to the genus of land tortoises This group is known especially for the giant land tortoises once so abundant on the Galapagos Islands These animals attain a weight of 500 pounds and live a century or more

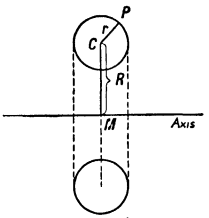
One species of northeastern South America is noteworthy for the angular prominences on the shell and head and for peculiar projections fringing the long neck It is called the matamata (A W L)

TORTOISE SHELL. The mottled horny plates of the shell of a marine **turtle,** *Eretmochelys imbricata* This species is found in warm seas, extending as far north as Massachusetts occasionally It is known as the hawksbill or tortoise-shell turtle

Tortoise shell was once highly valued for ornamental use, as in toilet articles and the handles of pocket knives, but it has been largely replaced by synthetic materials (A W L.)

TORTOISES Fossil Reptiles.

TORUS In mathematics, a torus (or anchor ring) is the figure generated by revolving a circle about an axis in its plane but not intersecting it.



Generation of torus

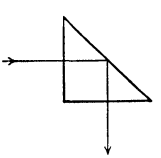
The volume of a torus is $2\pi^2Rr^2$ and the area of its surface is $4\pi^2Rr$, where r is the radius of the generating circle and R is the distance of the center of the generating circle from the axis of revolution

In zoology, a torus is a pad at the tip of a **digit** of the **vertebrates.** These structures form the tough resilient bearing surfaces of the appendages of most vertebrates, and are nicely illustrated by the pads on which the dog and cat walk. (L L S, A W L)

TOTAL DERIVATIVE. Partial Derivatives.

TOTAL DIFFERENTIAL. Differentials.

TOTAL REFLECTION. Total reflection occurs when light is reflected in the more refractive of two media from the interface between them, at any angle of incidence exceeding the so-called "critical angle" This is the angle whose sine is equal to the relative refractive index for light attempting to pass from the more to the less refractive medium (See **Refraction.**) Thus, for water against air, for which the index is 0 75, the critical angle is 48° 35′, so that if light is incident in the water at an angle of 50°, it will be totally reflected This phenomenon may be easily observed by holding a glass of water with the surface slightly above the eye and inserting the finger or a matchstick into the water The underside of the surface is then seen to reflect this object like a perfect mirror, and gives the impression of a mercury surface inverted The principle is often utilized in reflecting prisms such as those used in the prism **binocular.** Here the refractive index is about 0 6 and the critical angle, therefore, only 36° 52′, while the angle of incidence is commonly 45° (See figure). **Refractometers** utilize this principle For some metals whose external refractive index for light is less than unity, total reflection occurs on the outside of the surface The same is true of glass for x-rays (See **Mirage**) (L D W)


Total reflection in a right angled prism.

TOUCAN. Aves, Coraciiformes A bird (**Aves**) of South and Central America, characterized by the enormous beak Most species are brilliantly colored and of large size The beak, several times as large as the head, is of very light structure, with serrated edges used in cutting up fruit It is covered with a thin horny shell and contains a fine bony reticulum Toucans are also remarkable for their peculiar habit of tossing bits of food into the air and catching them in the mouth to be swallowed (A W L)

TOUCH. A special sense that responds to contacts The **tactile organs** through which the stimuli of contact are received are sensitive to varying pressures, sometimes of exceedingly slight degree They are related to other sense organs which respond to pressure, including internal receptors, chordotonal organs of insects, lateral line organs of fishes, and organs of hearing, but differ in responding to simple pressures from the outside of the body, while the other external receptors are stimulated only by vibratory pressures of varying frequency, usually in the surrounding air or water

The perception of degrees of simple pressure by organs of touch permits the formation of mental images of conformation of objects and characteristics of surfaces through the varied stimuli arising from contact with high and low points, yielding and rigid projections, adhesive materials, and other factors capable of carrying the pressure transmitted to the sensory endings (A W L)

TOURACO. Plantain-eater.

TOURMALINE The mineral tourmaline is a complex **silicate** of **aluminum** and **boron,** but because of **isomorphous** replacements this mineral varies widely in chemical composition, **iron, magnesium,** and **lithium** entering into combination to a greater or less extent with the aluminum and boron Tourmaline belongs to the **hexagonal** system, its crystals are usually prismatic, tending to be long and slender, often acicular The crystals are ordinarily terminated with three faces of a **rhombohedron** and usually **hemimorphic** The smaller crystals are frequently found in radial arrangement, and columnar masses are common The prisms are usually three, six, or nine sided with heavy vertical striations producing a rounded effect Tourmaline is essentially without **cleavage;** fracture, conchoidal to uneven, brittle, hardness, 7–7 5, specific gravity, 2 9–3 2, luster, vitreous inclining to resinous, color, in common tourmaline black, bluish black, brown, blue, green, red or pink, and in the transparent varieties colorless (rare), various shades of rose and pink, greens, blues and browns The color arrangement in tourmaline is of considerable interest, bi-colored crystals are common and may be green at one end and pink at the other, or green on the outside, and pink within, which, in the case of transparent or translucent crystals, is very attractive The opaque black tourmaline is called schorl, which term was applied to all tourmaline until 1703 when tourmaline was introduced, it being a corruption of the Ceylonese word, *turamali* The origin of the word schorl is not known, but is perhaps Scandinavian The rose or pink tourmalines are called rubellite (from ruby), the dark blue, indicolite (from Indigo), the lighter, Brazilian sapphire, the green, Brazilian emerald, the brown, dravite (from the Drave district of Carinthia), and the colorless, achroit from the Greek meaning without color Small tourmalines are found in **granites** and some **gneisses.** Due, no doubt, to the mineralizing action of **magmatic** vapors, tourmaline is found particularly well developed in **pegmatites,** and as a contact **metamorphic** mineral A few of the im-

portant foreign localities are· The Ural Mountains, Bohemia, Saxony, the Island of Elba, Norway, Devonshire and Cornwall, England, Greenland, Madagascar, and Brazil In the United States in Oxford and Androscoggin Counties, Maine, Grafton and Sullivan Counties, New Hampshire, Hampshire County, Massachusetts, Haddam and Fairfield Counties, Connecticut, St Lawrence County, New York, Sussex County, New Jersey, Delaware County, Pennsylvania, and San Diego County, California (E S C S)

TOWHEE. Aves, Passeriformes A North American bird (**Aves**) related to the finches and sparrows The common eastern species, *Pipilo erythrophthalmus,* is a black and white bird with red-brown sides. It is seen chiefly on the ground and nests chiefly beneath tangled thickets From its call this bird is also known as the chewink Four other species are found in the west, three congeneric with the eastern towhee and a fourth, the green-tailed towhee, *Oberholseria chlorura,* is placed in a related genus (A W L)

TOXEMIA. A general poisoning of the body by (1) absorption of toxins liberated by bacteria active at some infected portion of the body, (2) accumulation of toxic substances in the body by failure of certain organs whose purpose is to free the body of these poisons Such organs are the liver, intestines, kidneys and lungs (R S M)

TOXIN. The poison that is given off by **bacteria.** Toxins are usually **protein** substances which may be destroyed by heat, are easily soluble, and their degree of virulence varies for different bacteria When injected into animals, certain toxins cause antitoxins to be formed in the blood serum The antitoxins thus formed will neutralize the action of the toxin These antitoxins can be extracted from the blood serum of the animal purified, concentrated, and given to patients ill with the same disease with curative results Those best known are the antitoxins of **diphtheria, botulism, tetanus** and **scarlet fever** (R S M)

TRACHEA. 1 An air tube of the **arthropod** respiratory system These tubes open at the surface of the body through **spiracles** and lead inward, branching extensively and in some species expanding to form air sacs At their inner extremities they connect with very fine tubules called tracheoles, of independent origin Tracheae are ingrowths of the outer layer of the body and are lined with a continuation of the cuticula, which forms spiral rods in their walls Near the spiracle they are often provided with a muscular closing device by which air can be excluded if it contains harmful materials The tracheoles form within cells of the lining of tracheae, later breaking out and assuming their connection with the larger tubes They have no spiral supporting rods (taenidia)

2 The principal air tube of the vertebrate **respiratory system,** also called the wind pipe It leads from the **pharynx** to the major branches (bronchi) connecting it with the **lungs,** and its wall is supported by rings of cartilage At the pharyngeal end in **amphibians** and **mammals** it forms an expanded larynx containing vocal cords, and at the point where it forks to form the bronchi in birds the remarkable vocal organ called the syrinx is developed (A W L)

TRACHEIDS. A tracheid is an elongate xylem cell (angular in transverse section) with tapering ends, when mature it contains no **protoplasm.** In the thickened, lignified walls of a tracheid there are many bordered **pits.** Functionally a tracheid serves both for conduction of water and for support

For their development, see **cambium.** (R.M W.)

TRACHEOPHYTES. All plants with true **vascular** system composed of **xylem** and **phloem** are known as tracheophytes **Pteridophytes** and **spermatophytes** are included in the tracheophytes The other group is the atracheata, which lack special modified conducting cells. (R M.W)

TRACHOMEDUSAE. Hydrozoa.

TRACHYTE. The name of an **extrusive, igneous,** fine grained or **porphyritic rock,** the surface equivalent of **syenite** Trachyte is predominant in alkali **feldspar** and usually contains **biotite** and **augite.** Trachyte is an old name, proposed by Brongiart in 1813, and has never been altered or supplanted It is derived from the Greek, meaning rough (R M F.)

TRACTION. In a narrow sense, traction refers to the **friction** developed between a powered surface and one in contact with it The most common example of traction is the resistance to slipping developed at the point of contact of a driven wheel with the surface on which it rolls The locomotive driver on its rail, the pneumatic tire on the highway, or the traction engine wheel on earth, illustrate this case But traction is not confined to wheels, as may be proved by citing another example of traction The traction sheave of an elevator is a grooved pulley, power driven, over which passes a rope which is driven by the sheave The friction between the rope and pulley constitutes the traction

In a larger sense, traction includes the act of pulling a load over a surface by overcoming the resistance to motion, and the word may also be used descriptively of any vehicle which by its excess of power over its own tractive needs is able to pull other vehicles In the case of an automobile rolling on a highway, traction is applied through the rear wheels by means of a live axle which delivers a torque to the wheel The load on the wheel presses it against the road surface enough to develop sufficient friction so that the resistance to motion will be overcome before the wheel slips on the road If the roadbed be covered with a surface of low frictional power, for example, wet clay, there will be little traction developed because of the low coefficient of friction The traction of an automobile must overcome wind resistance, wheel bearing friction, rolling resistance, and grade

The railway train is drawn by a steam locomotive by means of traction developed between the drivers and the rail The weight on the drivers, multiplied by the coefficient of friction of steel on steel is equal to the traction In winter sand is sprinkled on icy rails in order to increase the coefficient of friction and so get more tractive power The train resistance which traction must overcome is composed of the rolling resistance of wheels on rails, journal friction (static), air resistance, grade, and friction of wheel flanges on rails The tractive efforts needed for starting a train are much higher than those required to keep it moving While standing, oil is squeezed out of the bearing surfaces at the wheels, and metal to metal contact exists for the first few revolutions when the train has started After the journal has revolved, oil is drawn into the surface between the journal and bearing, and a lower coefficient of friction results Rolling resistance would be zero if the rail and wheels were perfectly inelastic, but rails deform slightly ahead of the wheels, making the reaction of the rail on the wheel inclined somewhat from the vertical in the direction of increased drag (F T M)

TRADE WINDS. Winds.

TRAGOPAN. Aves, Galliformes. A large game bird (**Aves**) found in wooded country at high altitudes in China and northern India. These birds are related to the pheasants and are known as horned pheasants and, improperly, as Argus pheasants. The last name belongs to a different group The head bears a pair of fleshy projections, the horns, and the plumage of all of the several species is beautifully colored. (A W.L.)

TRANSCENDENTAL EQUATIONS. A transcendental equation is an equation which is not an **algebraic equation**; it contains one or more **transcendental functions.**

Transcendental equations include as special types **trigonometric equations, exponential equations, logarithmic equations,** etc (L L S)

TRANSCENDENTAL EQUATIONS, SOLUTION OF. **Transcendental equations** may be solved approximately by graphical methods, or by **Newton's method**

One graphical method is to write the equation in the form of a single **function** equated to zero, plot the **graph** of this function and find the **abscissas** of the point or points of intersection of this graph with the X-axis, this gives only the real roots of the equation

Another graphical method is to write the equation in the form of an equality of two appropriately chosen functions, construct the graphs of the two functions on the same diagram, and find the abscissas of their intersection points (L L S)

TRANSCENDENTAL FUNCTION. A transcendental function is a **function** which is not an **algebraic function.**

Among the transcendental functions are the following types **trigonometric functions, inverse trigonometric functions, exponential functions, hyperbolic functions, logarithmic functions, gamma functions, beta functions, elliptic functions, Bessel functions,** etc (L L S.)

TRANSCENDENTAL NUMBERS. A transcendental number is a **number** which is not an **algebraic number,** i e, is not a root of a **polynomial equation** in one unknown with integral coefficients

Two well-known transcendental numbers are $e \approx 2\ 71828$ and $\pi \approx 3\ 14159$ (L.L.S.)

TRANSFORMATION OF COORDINATES. In **rectangular coordinates in the plane,** the transformations of coordinates are translation of axes and rotation of axes

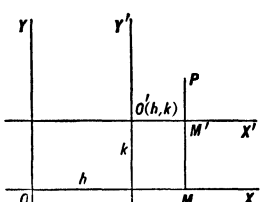


Figure 1

If a set of rectangular axes are moved from a first position OX, OY to a new position $O'X'$ and $O'Y'$ such that $O'X'$ and $O'Y'$ are respectively parallel to OX and OY, the axes are said to be translated from the first to the second position

If the axes are translated to a new origin $O'(h,k)$, then (Figure 1) the old coordinates are given in terms of the new by the formulas

$$x = x' + h,\ y = y' + k$$

If a set of rectangular axes are rotated about the origin through an angle θ, the old coordinates in terms of the new are given by (Figure 2)

$$\begin{cases} x = x' \cos\theta - y' \sin\theta, \\ y = x' \sin\theta + y' \cos\theta \end{cases}$$

In rectangular coordinates in space, we have also translation of axes and rotation of axes

If the origin is translated to a new origin $O'(h,k,l)$, **the equations for the old coordinates in terms of the new are:**

$$x = x' + h,\ y = y' + k,\ z = z' + l$$

If $(\alpha_1, \beta_1, \gamma_1)$, $(\alpha_2, \beta_2, \gamma_2)$, $(\alpha_3, \beta_3, \gamma_3)$ are respectively the **direction angles** of three mutually perpendicular axes OX', OY', OZ' with respect to a given set of perpendicular

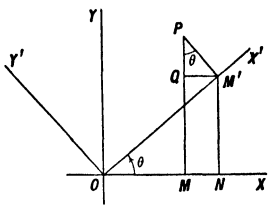


Figure 2

axes OX, OY, OZ, then the equations for rotating the old axes into the new position $O - X'Y'Z'$ are

$$x = x' \cos\alpha_1 + y' \cos\alpha_2 + z' \cos\alpha_3,$$
$$y = x' \cos\beta_1 + y' \cos\beta_2 + z' \cos\beta_3,$$
$$z = x' \cos\gamma_1 + y' \cos\gamma_2 + z' \cos\gamma_3$$

These nine **direction cosines** satisfy the following six equations

$$\cos^2\alpha_1 + \cos^2\beta_1 + \cos^2\gamma_1 = 1,$$
$$\cos\alpha_1\cos\alpha_2 + \cos\beta_1\cos\beta_2 + \cos\gamma_1\cos\gamma_2 = 0,$$
$$\cos^2\alpha_2 + \cos^2\beta_2 + \cos^2\gamma_2 = 1,$$
$$\cos\alpha_2\cos\alpha_3 + \cos\beta_2\cos\beta_3 + \cos\gamma_2\cos\gamma_3 = 0,$$
$$\cos^2\alpha_3 + \cos^2\beta_3 + \cos^2\gamma_3 = 1,$$
$$\cos\alpha_3\cos\alpha_1 + \cos\beta_3\cos\beta_1 + \cos\gamma_3\cos\gamma_1 = 0$$

(L L S)

TRANSFORMATIONS OF POLYNOMIAL EQUATIONS To transform a **polynomial equation** of the n^{th} degree into an equation each of whose **roots** is m times the corresponding root of the original equation, we multiply the successive coefficients of the equation, beginning with that of the next to the highest degree term, by m, m^2, , m^n If the given equation is

$$a_0x^n + a_1x^{n-1} + \quad + a_{n-1}x + a_n = 0,$$

the new equation will be

$$a_0x^n + ma_1x^{n-1} + m^2a_2x^{n-2} + \cdots + m^{n-1}a_{n-1}x + m^na_n = 0$$

If any power of the variable below the highest is missing, it must be written with a zero coefficient

To transform a polynomial equation into one whose roots are changed in sign from those of the original, we change the signs of the coefficients of the odd powers of the variable in the equation

To transform a polynomial equation of the n^{th} degree

$$P(x) \equiv a_0x^n + a_1x^{n-1} + \quad + a_{n-1}x + a_n = 0$$

into an equation each of whose roots is less by h than a corresponding root of the given equation, we proceed as follows Divide the polynomial $P(x)$ by $x-h$ synthetically and denote the remainder by R_n, divide the quotient by $x-h$ and denote the remainder by R_{n-1}, etc, continuing this process n times, obtaining a_0 as the last quotient and R_1 as the last remainder Then the coefficient a_0 and the remainders R_1, R_2, , R_n, in order, are the coefficients of the transformed equation, which is therefore

$$a_0x^n + R_1x^{n-1} + R_2x^{n-2} + \cdots + R_{n-1}x + R_n = 0$$

The divisions should be performed synthetically. (L L S)

TRANSFORMER. Without doubt, adoption of alternating current in favor of direct current by the growing electric industry was due as much to the ease and efficiency with which power could be transferred from low to high potential, and vice versa, as to the ad-

vantages of **alternators** over direct current **generators.** The power transformer is used to increase alternator voltage to economical transmission voltage or to decrease alternator or line voltage for station power service It can be defined as a device for transferring electric energy from a circuit at one voltage to one at another There are no moving parts, nor is there any electrical connection of the two circuits (except in the case of the **autotransformer**), the energy is transferred through magnetic linkage Regardless of the voltage, the energy supply circuit is termed the primary, and the energy receiving circuit the secondary

Transformers may be classed as follows

A According to purpose
- 1 Constant voltage ratio
- 2 Constant current
- 3 Feeder voltage regulation

B According to use
- 1 Heavy duty Power type as used in substations
- 2 Distribution At customer end of the distribution system
- 3 Instrument Potential and current transformers of small capacity and light weight, but having accurate ratios

C According to arrangement of magnetic circuit
- 1 Shell type Large, low-voltage units
- 2 Core type Small, high-voltage units

D According to arrangement of electric circuit
- 1 Single or three phase Small transformers are often three phase, but large capacity is met by the three-phase connection of three single-phase transformers
- 2 Connection of three-phase windings Δ to Δ, Δ to Y, Y to Y, open Δ

E According to cooling
- 1 Air insulated
- 2 Oil insulated Oil cooled by direct radiation or by heat transfer to separate water cooling system

The ordinary single-phase transformer consists of the magnetic circuit, the windings, the leads, the insulating bushings (solid dielectric, condenser, or oil filled types),

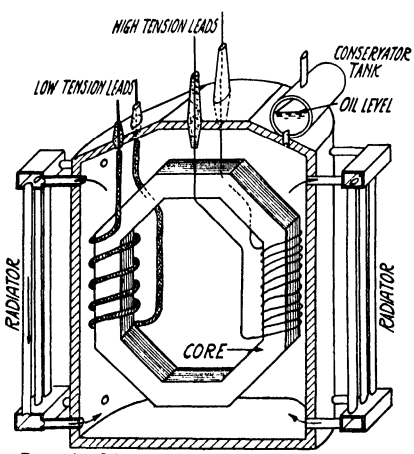


Figure 1 Schematic sectional view of a single-phase, self cooled transformer

the insulating oil and its cooling system, and the tank to contain the oil and provide support for the other components.

In an ideal transformer the voltage ratio is the same as the turn ratio Except for transformer losses, $N_1I_1 = N_2I_2$, in which N is number of turns and I is effective current Due to the excellent efficiency of transformers, especially in the larger sizes (where the efficiency is 98% or better), the ratio E_1/E_2 of voltage is very nearly N_1/N_2 The losses which occur in a transformer are iron losses and copper losses The iron losses are nearly constant and are present as long as the transformer is connected to the supply circuit Transformer regulation is much superior to alternator, rarely exceeding 5% A transformer is rated at its maximum continuous kva, on the secondary side, as limited by heating

When single-phase transformers are operated alone there is no obstacle to correct connections. When single-phase or polyphase operate in parallel, or when three single-phase transformers are connected into a three-phase bank, the terminals must be joined correctly on the basis of polarity The standard marking for polarity is an H_1 on the primary lead and an X_1 on the secondary. When the current is flowing towards the transformer in the H_1 lead it will be flowing away from it in X_1 A few typical connections for transformers are shown in Figure 2 Transformers which are operated in parallel

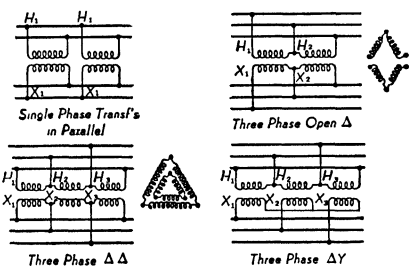


Figure 2 Some typical transformer connections

should have equal ratios of transformation, equal impedances, and have their terminals connected in accordance with the polarity markings

The losses in a transformer appear as heat which should be carried away from the windings as soon as possible At present transformer windings are cooled either by oil or by air

Most power transformers (instrument transformers excepted) are oil insulated and of the self-cooled type If the oil is kept in good condition the solid insulation of the windings will usually remain likewise In addition to its insulating qualities, the oil should have low viscosity and high coefficient of expansion for good circulation The expansion of the oil, while essential to good circulation, has a disadvantage in that air is exhaled or inhaled due to the total increase or decrease of oil volume in the tank This phenomenon, called "breathing," is the principal source of water or sludge in the oil Water comes from the condensation of atmospheric moisture "breathed" into the tank, sludge, from the oxidation of the surface of the oil A conservator tank is used on some transformers to expose the minimum of oil surface to the air

Small current and potential transformers may be divided into two classes, i e, tripping transformers and instrument transformers The former are used primarily with relays and trip coils of switching equipment, the latter with measuring instruments Small transformers are of importance because their applications in the central station are exceedingly numerous. They are used for two very good reasons, to protect station operators from contact with high voltage, and to permit the use of trip coils, instruments, etc, of moderate current and voltage

capacity. Through the use of small transformers low voltage circuits can be obtained which reflect the characteristics of high voltage ones to a practical degree of accuracy. (F.T.M.)

TRANSFUSION. Transfer of blood from one person to another. The person from whom the blood is taken is known as the donor. The patient receiving the blood is the recipient. Both the donor and recipient must be of the same **blood group** and, furthermore, must be tested to make sure that the two bloods will be compatible. In emergencies when there is no time for grouping, a donor of the universal type (Group I. Jansky. Group IV. Moss. Group O. International) may be used, although this is not desirable.

At present transfusions are used in many conditions while formerly they were used only as a measure of last resort. After any severe hemorrhage transfusion is life-saving. In severe **anemia**, in the course of severe infections, preoperatively to prepare a patient for a severe operation, post-operatively after a severe operation, in shock, in septicemia, and in many other conditions transfusions are the best therapeutic measure known.

There are many methods of transfusion. They may be generally divided into the direct and indirect methods. Of the direct methods, the most popular is the Lindeman or multiple syringe method. Here one doctor withdraws the blood by means of a syringe which is attached to the needle inserted in a vein in the donor's arm and another doctor injects the blood into the patient through a needle in his vein. Before each syringe is used again it is rinsed through several normal saline solutions. Other direct methods are by means of a machine which alternately withdraws blood from the donor and injects it into the patient. The machine is connected with the donor and patient by means of rubber tubing.

With the indirect method the total amount of blood to be given is withdrawn at one time into a suitable container. It is then mixed with a chemical—sodium **citrate**—to prevent clotting. The blood is then strained and is run into the patient from the container by gravity through rubber tubing connected with a needle in the patient's vein. (R.S.M.)

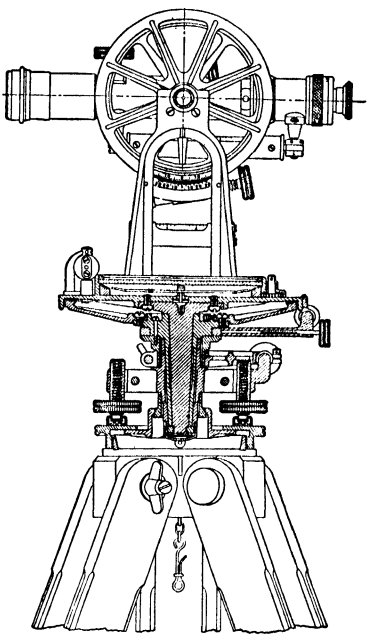
TRANSIENTS. Everyone has noticed that when an electric heater is turned on or off, the light from lamps on the same or closely connected circuits gives a slight flicker, and, if a radio receiver is operating at the time, it produces an audible click. A lightning flash or the sudden readjustment of connections in a transmission line may produce a similar "surge" of current. This is due to the fact that when the current in any part of a network changes, because of a change in the resistance of that part or the electromotive force operative in it, there is a readjustment of the potential differences and currents in the other parts. (See **Kirchhoff's Laws of Networks.**) Such readjustments take place very quickly, and the corresponding momentary fluctuations of current are called transients.

Mathematically, the general expression for the current in any circuit as a function of the time contains terms which rapidly become negligible; these are the transient terms. A very common and comparatively simple example is found in the case of an unbranched circuit having resistance R, inductance L, and series capacitance C, to which is suddenly applied an alternating electromotive force of low frequency n and maximum voltage E_0. If the switch is closed at a voltage maximum, the voltage at any time t (seconds) thereafter is $E_0 \cos 2\pi nt$, and the current is given by the equation

$$I = \frac{E_0}{\sqrt{R^2 + \left(2\pi nL - \frac{1}{2\pi nC}\right)^2}} \cos(2\pi nt + \Delta) + k_1 e^{m_1 t} + k_2 e^{m_2 t}$$

where Δ is the phase difference between electromotive force and current. (See **Alternating Currents.**) In the last two terms, k_1, k_2, m_1, and m_2 are constants depending upon the circuit characteristics R, L, and C. The quantities m_1 and m_2 are both negative; as a result, these exponential terms "decay" or fade away after a few cycles. Only the first term is therefore usually written. (L.D.W.)

TRANSIT. The transit is an instrument used by engineers and surveyors for measuring horizontal angles. Modern transits are usually equipped with a level attached parallel to the telescope, and a graduated vertical circle as well, so that the transit may be employed as a level, and may also be used to read vertical angles. It



Transit.

may also be equipped with **stadia** wires. An exceptionally accurate transit of the type used for precise surveying is known as a theodolite. A transit is constructed largely of metal, and is mounted upon a wooden tripod. A tripod plate (foot plate) is screwed to a tripod head provided on the tripod. This tripod plate contains the socket of a ball and socket joint, and has a smooth surface upon which leveling screws may rest. The base of the instrument is carried on a vertical conical shaft which turns in a socket, on the lower end of which is a ball which is a part of the ball and socket joint just mentioned. The conical socket carries also projections into which the leveling screws are threaded. By operating these leveling screws, the shaft may be accurately aligned in vertical position. The shaft carries at its top a horizontal plate on which are mounted at right angles two levels which are used by the instrument man to guide and operate the leveling screws, so that the plate may be horizontal, and the shaft vertical. A compass is also mounted on this plate. The telescope is mounted on horizontal trunnions which are supported on standards attached to the above mentioned plate (limb). The telescopes are usually erecting, although many favor the inverting telescope. The motion of the telescope around

the vertical axis can be accomplished by loosening clamping screws and swinging it at will until it is brought to sight on the desired object It can then be clamped, and small additional motions obtained by the use of a **vernier** adjustment The horizontal plate is graduated so that the angles may be read to fractions of a degree (F T M)

TRANSIT OF VENUS OR MERCURY. Both **Venus** and **Mercury** revolve about the **sun** in **orbits** which lie inside of the orbit of the **earth** about the sun Accordingly, if the planes of the planetary orbits coincided with the plane of the ecliptic, once during the **synodic** period of each planet the object should pass between the earth and the sun Because of the small angular diameter of the planets relative to that of the sun, at the time they pass between the earth and sun they appear as small black spots moving across the brilliant disk of the sun Such a phenomenon is known as a transit of Venus or a transit of Mercury

The orbits of both Mercury and Venus are inclined to the plane of the ecliptic with the result that transits do not occur during each synodic period, but only when the planet happens to come to inferior conjunction close to the passage through a **node.** Transits of Mercury can occur only in May and November, when the earth crosses Mercury's line of nodes, those of Venus occur only in June and December Since Mercury is closer to the sun than Venus, transits of Mercury are more common than those of Venus Transits of Mercury during the second quarter of the present century occur on November 8, 1927, May 11, 1937, and November 12, 1940 The last transit of Venus came in 1882 and the next will take place in 2004

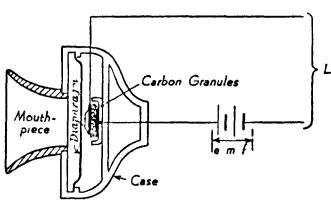
The first recorded observation of a transit of Venus was made in England in 1639 by Horrocks Four transits have been observed since that time Since observations of the duration of transit of the planet across the disk of the sun made from widely separated positions on the earth provide a method for determination of the important astronomical constant known as solar parallax, expeditions were always dispatched to observe the phenomena Within recent years more accurate methods for determination of solar parallax have been devised, and henceforth, transits of planets across the sun will be of value only for the purpose of obtaining accurate positions of the objects and thus improving the orbital **elements.** (W K G)

TRANSLOCATION. The **carbohydrates** formed in **photosynthesis** rarely accumulate in the leaf for any great length of time, or in any quantity Instead, they are carried to other parts of the plant, where they are stored or become sources for energy needed for growth and other vital processes The movement of these carbohydrates from the place of formation to other parts of the plant is called translocation Two important questions arise in connection with this problem First, in what tissues does the movement actually occur, and second, what is the cause of the movement?

Nearly all attempts to find an answer to the first question point to the **phloem** as the tissue through which the carbohydrates move An early experiment, often repeated since, which suggested such a conclusion, is that of ringing or girdling, that is, removing a complete ring of bark from a stem After this was done, it was observed that carbohydrates accumulated above the ring, often to such an extent as to cause noticeable swelling, but no swelling occurred below the ring The obvious conclusion was that carbohydrates had moved down through the bark to the removed ring and accumulated there, being unable to pass into the wood and around the ring In a variety of experiment of this kind rings have been removed at various levels of the stem, in many cases two rings are removed from the same stem All these experiments tend to support the same conclusion, that it is in the phloem that the carbohydrates move. In recent years further support of this conclusion has been given by chemical analyses of the bark from various parts of the stem and at various times These analyses show that the amount of carbohydrate in the bark does vary from time to time during the day. Similar analyses on woody tissues show little variation in carbohydrate content Neither of these experiments have answered the question of the actual part of the cell concerned in movement of the carbohydrates, nor have any of the many other experiments given any answer

Attempts to find an answer to the question of cause of movement have been unsuccessful It was natural to consider diffusion of materials as a possible cause But even under the best of conditions diffusion would be very much slower than the observed rates of movement Since the cells of the phloem contain **protoplasm,** it has been suggested that the rapid streaming of this substance could account for carbohydrate movement However, direct observation does not reveal any rapid streaming of the protoplasm of the phloem cells Several other theories have been advanced, but none generally accepted (See also **Heredity.**) (R M W)

TRANSMITTER. A telephone transmitter is used to convert **sound** waves to **electrical energy,** or to use sound waves to control the current supplied by a battery or generator The carbon granule transmitter is one of several types which have been successful, and, in addition, has been widely used in this country A simple



Principle of the telephone transmitter

transmitter of this type operates as shown in the accompanying figure A metallic plunger attached to a diaphragm bears against a cup of selected carbon granules The transmitter circuit is connected to include a path through these packed granules When a person speaks into the mouthpiece, voice waves set the diaphragm into vibration corresponding to the waves received Motion of the diaphragm compresses or releases the carbon granules, varying the resistance and current in the transmitter circuit In a successful transmitter the variation of current duplicates the train of sound waves constituting the input to the diaphragm The variable resistance of the carbon is explained by considering the contact areas between adjacent granules to be altered by the deformations of the granules under the pressure created by the diaphragm

The radio transmitter is the assembled and interconnected group of equipment capable of radiating high frequency, modulated electrical waves to a wave propagating medium which will carry it to the **antenna** of the receiver, wherever that may be The essential parts of a transmitter for wireless telephony are audio frequency amplifiers, radio frequency oscillator, radio frequency amplifiers, antenna, and power input **Radio frequency** oscillation can be obtained from spark or arc oscillators While these were acceptable for wireless telegraphy, they do not produce the high frequency oscillations required for wireless telephony, and are superseded by the vacuum tube oscillator The **audio frequency** amplifier works entirely with nondirectional current modulated by the microphone. After amplification, this signal is used to modulate the radio frequency

oscillation. The radio frequency oscillator operates at a frequency which is kept under close control by a crystal so that tuning of the receiving set can be sharp, and there will be a minimum of interference between adjacent broadcast bands (F T M)

TRANSPIRATION. The loss of water in the form of vapor from a plant is called transpiration This loss is greatest from the leaves, where it occurs mostly through the minute openings or **stomata** in the **epidermis.** Many factors effect the rate of water loss, some directly and others indirectly Intense light greatly increases the rate of loss, as does an increase in temperature Strong winds also increase the rate of loss An increase in the humidity of the atmosphere around the plant causes a decrease in the rate of transpiration

Naturally the amount of water lost is proportional to the number of leaves through which transpiration goes on If the number is so great that the rate of loss is greater than the rate of absorption of water from the soil by the roots, the life of the plant is seriously threatened The leaves wilt and droop Some may fall from the plant, thus reducing the transpiring surface and equalizing the balance between absorption by the roots and loss by transpiration In other plants the rate of transpiration is reduced by changes in the leaves they may roll up tightly, so that the stomata do not open directly to the air but in an enclosed chamber The action of the stomata is an important factor in controlling the loss of water

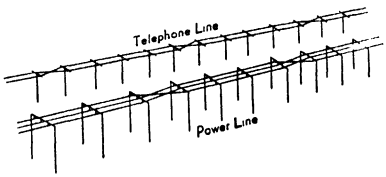
Transpiration has been called a necessary evil which the plant must suffer It has also been thought to benefit the plant by bringing about a lowering of the temperature within the tissues of the plant There is little evidence which supports this idea There may be a lowering of the temperature, but it is too slight to be of any significance Transpiration is considered an important factor in the **ascent of sap,** the loss of water from the **mesophyll** cells of the leaf causing a tension which acts as a pulling force bringing water up from the lower parts of the plant

Transpiration must be considered when plants are transplanted When the plant is lifted from the soil, many of its roots are damaged, reducing the absorbing surface If the transpiration surface is not reduced, the loss of water may be too great and the plant wilt Often the disturbance is so great that recovery is impossible and the plant dies To prevent this as far as possible it is usual to remove a part of the leaves of transplanted plants or to prune off much of the top

Many plants also lose water in liquid form This loss is called guttation Commonly the loss occurs in special structures called hydathodes, located around the edge of the leaf or at its tip On cool days or nights, especially if the atmosphere is very humid, this water accumulates in drops over the hydathode It is very frequently incorrectly called dew In some plants the amount of water lost this way is considerable The frequently cultivated elephant's ear may lose a drop a second, or more, from the hydathode located at the tip of each leaf A similar loss of liquid water occurs in many **fungi,** the mycelium becoming covered with exuded drops of water (R M W)

TRANSPOSITION. In mathematics, in the process of solving an equation, it is common to add or subtract the same number to both sides of the equation, this is called transposition

An electric power line which parallels a telephone line induces in the latter voltages which distort and otherwise affect the intelligence transmitted on the telephone wire To avoid **cross talk,** the transposition of the relative position of the conductors in the telephone and power circuit is employed so that to the fullest extent possible the induced voltages in the telephone line may be neutralized The telephone line may be transposed, the power line, or both. Due to the difference of phase relations induced in a long line, it is not sufficient merely to transpose once between termini, but the transpositions must be located relatively close together Some amount of induced voltage will occur if the telephone line is transposed and not the power line Conditions will be better if both lines are transposed Power and telephone companies have coordinated their transposition now for some time, and have been successful in eliminating the



Coordinated transpositions

worst of the inductive effects of parallel lines An elementary scheme of transposition coordinated between power and telephone service is shown herewith (F T M)

TRAP. A general term for fine-grained, **basic** and therefore dark colored **igneous** rocks, having a relatively high specific gravity The term is derived from an old Scandinavian word meaning a stair, because these rocks, as particularly well displayed in the 3000-foot cliffs of the Faroe Islands, develop architectural forms simulating colossal stairways The term is also used as a synonym for **basalt,** especially by contractors who use it for road metal Compare with **whinstone.** (R M F)

TRAUMA. Any injury to the body caused by an outside physical force such as by a fall, blow, or weapon, etc Traumatic surgery is surgery that deals with injuries, and is usually of an emergency nature (R S M)

TRAVERSE. A traverse is a series of connected straight lines, forming the outline of a plot of land or the center line of a roadway or railway The traverse is obtained by means of a survey Ordinarily, the **transit** and tape are used, the transit being successively set up over each point constituting the junction of two adjacent lines The distances between transit stations (the length of the straight lines) are measured by taping with a graduated tape or **chain** The **bearings** of the lines or the angles between the lines, as well as the length of the lines are noted by the instrument man at the time of the survey in a field book These field notes are later employed to map the traverse by one of the several methods available, such as **tangent offsets,** latitudes, and departures, coordinates, etc (F T M)

TRAVERSE TABLES In many problems in surveying and navigation (e g, the important navigational problem of **dead reckoning**) the solution of a plane right triangle becomes necessary In traverse tables the plane right triangle is solved without the necessity of using tables of **trigonometric functions.** The tables are constructed by tabulating for successive values of one apex angle the two sides of the triangle as functions of the hypotenuse The traverse tables as published for navigational purposes solve the dead reckoning problem by tabulating difference of latitude and departure as functions of the distance for each course either in quarter points of the compass or every degree Since the tables must contain pages for each value of the apex angle they are more bulky than ordinary trigonometric tables However, the rapidity with which the plane triangle may be completely solved more than compensates for the time lost in turning pages, particularly when extreme accuracy is not required in the solution (W K G)

TRAVERTINE. Carbonated waters dissolve large amounts of **calcium** carbonate, especially under high

temperature Such waters reaching the earth's surface as hot springs often deposit the calcium carbonate, in great quantities This material is called travertine from the ancient name for Tivoli, Italy, where a very thick deposit occurs Travertine may be compact, crystalline, fibrous or, if rapidly deposited, spongy and porous The less compact varieties are known as tufa. Travertine is being formed at the Mammoth Hot Springs, Yellowstone National Park and at many other localities. A banded travertine used as an ornamental stone is called **onyx marble** or Mexican onyx (R M F)

TREE-CREEPER. Aves, Passeriformes A small dull-colored bird (**Aves**) with a long curved beak It seeks its prey, consisting of insects and other small creatures, in the crevices of bark, moving about the trunks and branches of trees in any position The group is represented in North America by the brown creeper, *Certhia familiaris*, and its several subspecies (A W L)

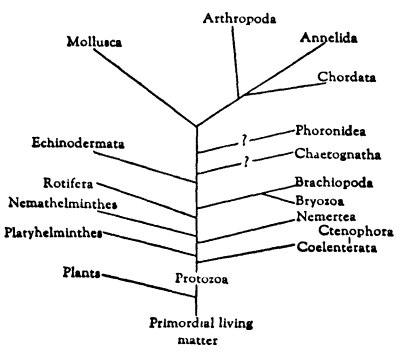
TREE-FERNS. **Paleobotany.**

TREE HOPPER. Insecta, Homoptera. An **insect** of moderate size with a peculiarly formed **thorax**, prolonged over the hinder part of the body and in many species with other projections of bizarre form These insects make up the family Membracidae, related to the **leaf hoppers** and spittle bugs

The buffalo tree hopper, *Ceresa bubalus*, sometimes damages twigs of fruit trees by laying eggs in the bark and is occasionally troublesome in the garden through sucking the juices of young seedlings Clean cultivation is an effective control (A W L)

TREE OF HEAVEN. **Ailanthus.**

TREE OF LIFE. Phylogenetic tree A diagrammatic scheme for showing the probable evolutionary relationship of the various kinds of animals Arising from primordial living matter and now found at their simplest in the one-celled forms, all animals may be traced through graded relations to their present condition While some points in the scheme are subject to various opinions, the following diagram is a good example·



Tree of Life

(A W L)

TREE-PIE. Aves, Passeriformes A bird (**Aves**) of the Oriental region related to the magpies The colors of these birds are shades of brown, black, and gray and their beaks are relatively short, but in habits they resemble the magpies (A.W L)

TREE SHREW. Mammalia, Insectivora *Tupaia* Small arboreal animals of the Oriental region. They resemble squirrels closely in general form and in the long tail but the muzzle is long and sharp as in other **shrews.** One species is remarkable for the featherlike form of the tip of the tail, which is elsewhere clothed with short hair The group is interesting chiefly because it has been regarded by one school of thought as probably ancestral to the primate stock. (A W L)

TREE TOAD, TREE FROG. Amphibia, Anura. Small animals like the other **frogs** and **toads** in form but largely of arboreal habits The toes are provided with adhesive disks at the tips The spring peeper and the cricket frog, each about an inch in length, are well known North American species Our tree frogs deposit their eggs in the water but in some species the larval stage is passed in the egg, which is attached to a leaf The extensive family Hylidae includes tree frogs of every continent Species of another family occur in Madagascar and South America (A W L)

TRELLIS DRAINAGE. The type of drainage pattern which is similar to a trellis or fireman's ladder Trellis drainage is characteristic of the canoe-shaped valleys of the Appalachians (R M F)

TREMATASPIS. **Fossil Fishes.**

TREMATODA. The flukes, a class of flatworms (Phylum **Platyhelminthes**) They are very variable in size, are flattened or rounded in cross section, and are exclusively parasitic Flukes resemble the free-living flatworms (Turbellaria) more closely than tapeworms, but in addition to their parasitic habits they differ in having the mouth usually near the anterior end of the body and the intestine usually forked and sometimes provided with anal openings The body is covered with a **cuticle** and bears suckers and in some species hooks or spines by which the worm attaches itself to the host

Many flukes hatch from the egg as free-swimming **larvae** and pass through a life cycle in two or more hosts before attaining maturity The passage from host to host is made with the changes in the metamorphic cycle

Some flukes attach themselves to the gills or skin of fishes while others live in the internal organs of various animals Man is affected by four types, the liver, lung, blood, and intestinal flukes, found chiefly in tropical and oriental countries Since some of these parasites pass some stages of their **metamorphosis** in fishes, the eating of uncooked or imperfectly cooked fish is dangerous in regions where they occur

The class is divided into two subclasses and five orders

Subclass Monogena External parasites with a single host
- Order Monopisthodiscinea Small species on the skin and gills of fishes Body without suckers but with a posterior disk bearing hooks
- Order Monopisthocotylinea With or without anterior suckers No oral sucker Posterior end with a sucking disk, usually bearing hooks Parasitic on marine fishes
- Order Polyopisthocotylinea Posterior lobe with at least two suckers On gills and in mouths of fishes, and on skin or in bladder of amphibians and reptiles

Subclass Digena Internal parasites with two or more hosts With one or two suckers
- Order Gasterostomata Mouth at the middle of the body Parasitic in fishes and marine mollusks
- Order Prosostomata Mouth at the anterior end A large order Many species, attacking many invertebrate and vertebrate hosts. (A W L)

TREMOLITE. The mineral tremolite is a **calcium-magnesium silicate** corresponding to the formula $H_2Ca_2Mg_5(SiO_3)_8$ belonging to the **amphibole** group. The replacement of magnesium by ferrous iron causes tremolite to approach **actinolite** in composition Tremolite is **monoclinic**, developing bladed prismatic crystals,

but it is frequently found in compact columnar, granular, or fibrous masses The perfect prismatic cleavage at angles of 56° and 124° typical of this group is to be noted; hardness, 5–6.; specific gravity, 2 9–3 1; luster, vitreous to silky; color, varies from white or whitish gray through shades of green or greenish yellow, transparent to opaque Tremolite is formed as a result of contact **metamorphism** and occurs in **marbles, dolomites,** and **schists** It may alter to **talc.** Tremolite is found in Switzerland, in the St Gotthard region, being named for the Tremola Valley, and is common elsewhere in Europe In the United States it occurs in Maine, Pennsylvania, and New York In Canada tremolite has been found in Quebec and Ontario

Hexagonite is a pinkish purple variety of tremolite which contains a small amount of manganese So called because it was at first believed to be **hexagonal** It has been since shown to be monoclinic, and is found in St Lawrence County, New York. Some nephrite and asbestos is tremolite (E S C S)

TRENCH MOUTH Vincent's **Angina.**

TREPANG. Holothuroidea.

TREPHINE. 1 A hollow, circular, saw-tooth, drill-like, instrument that is used for removing a round disk of bone from the skull This opening may then be enlarged or several of these drill holes may be made or connected so as to raise a piece of bone to expose a portion of the brain 2 To open the skull with a trephine The skull is usually operated upon for removal of an intracranial **tumor,** to stop a bleeding vessel, to relieve intercranial pressure that cannot be treated in any other way, or to drain a brain abscess (R S M)

TRIANGLES It is shown in **geometry** that the three sides and three angles of a plane triangle are so related that when any three parts, excluding the case of three angles, are given, the other three parts are determined, so that the triangle is fixed in shape and size Geometry also gives methods for constructing the triangle by geometrical constructions with straight edge and compasses when three appropriate parts are given

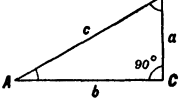
The process of finding the unknown parts of a triangle from a set of given parts is called the solution of the triangle

If the known parts of a triangle are given by their numerical values, we may draw the triangle to scale, carrying out the geometric constructions and measurements with a graduated ruler, compasses, and protractor, and then on the completed figure we may measure off the required parts with ruler and protractor, and obtain the numerical measures of these parts This is called the graphic solution of triangles This method is limited in accuracy, however, many important practical problems in which only a moderate degree of accuracy is required can be readily solved by the graphic method, it is also of use as a check on the trigonometric solution of triangles

The trigonometric solution of triangles is based on calculations with the use of formulas This method is capable of any desired degree of accuracy

To solve a right triangle:

Choose one of the formulas expressing the definition of one of the trigonometric functions of one of the acute angles of the triangle which involves an unknown part (side or angle) and two known parts, and solve for the unknown part



We also use the geometric relations $A + B = 90°$, and the Pythagorean theorem $a^2 + b^2 = c^2$.

Every oblique triangle can be solved by means of the methods for solving right triangles, by division into two right triangles by drawing a perpendicular from one vertex to the opposite side or opposite side extended Special formulas are also available for the solution of oblique triangles.

The law of sines is: Any two sides of a plane triangle are proportional to the sines of the opposite angles·

$$\frac{a}{b} = \frac{\sin A}{\sin B}, \quad \frac{b}{c} = \frac{\sin B}{\sin C}, \quad \frac{c}{a} = \frac{\sin C}{\sin A};$$

also

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C} = D,$$

where D is the diameter of the circumscribed circle of the given triangle

The law of cosines is The square of any side of a plane triangle is equal to the sum of the squares of the other two sides minus twice the product of these two sides and the cosine of their included angle

$$a^2 = b^2 + c^2 - 2bc \cos A,$$
$$b^2 = c^2 + a^2 - 2ca \cos B,$$
$$c^2 = a^2 + b^2 - 2ab \cos C$$

The law of tangents is· The tangent of half the difference of any two angles of a plane triangle is equal to the difference of the two opposite sides divided by their sum, multiplied by the cotangent of half their included angle

$$\tan \tfrac{1}{2}(A - B) = \frac{a - b}{a + b} \cot \tfrac{1}{2}C,$$
$$\tan \tfrac{1}{2}(B - C) = \frac{b - c}{b + c} \cot \tfrac{1}{2}A,$$
$$\tan \tfrac{1}{2}(C - A) = \frac{c - a}{c + a} \cot \tfrac{1}{2}B$$

The half-angle formulas for a plane triangle are

$$\tan \tfrac{1}{2}A = \frac{r}{s - a}, \quad \tan \tfrac{1}{2}B = \frac{r}{s - b}, \quad \tan \tfrac{1}{2}C = \frac{r}{s - c},$$

where $s = \frac{1}{2}(a + b + c)$, and

$$r = \sqrt{\frac{(s - a)(s - b)(s - c)}{s}}.$$

The best formulas for use in checking the solution of an oblique triangle are the Mollweide's formulas

$$\frac{a + b}{c} = \frac{\cos \frac{1}{2}(A - B)}{\sin \frac{1}{2}C},$$
$$\frac{a - b}{c} = \frac{\sin \frac{1}{2}(A - B)}{\cos \frac{1}{2}C},$$

and four others obtained by cyclic interchange of letters

The fundamental formula for the area of a triangle is

area = ½ base × altitude.

If the angles of the triangle are denoted by A, B, C and the opposite sides by a, b, c, then

area $= \sqrt{s(s - a)(s - b)(s - c)}$, where $s = \frac{1}{2}(a + b + c)$,

area $= \frac{1}{2}ab \sin C = \frac{1}{2}bc \sin A = \frac{1}{2}ca \sin B$;

$$\text{area} = \tfrac{1}{2}a^2 \frac{\sin B \sin C}{\sin (B + C)} = \tfrac{1}{2}b^2 \frac{\sin A \sin C}{\sin (A + C)} = \tfrac{1}{2}c^2 \frac{\sin A \sin B}{\sin (A + B)}.$$

In the solution of oblique triangles, four cases need to be distinguished.

I Given one side and two angles, a, A, B.
II Given two sides and an angle opposite one of them, as a, b, A.
III Given two sides and the included angle, as a, b, C
IV. Given the three sides, a, b, c.

All oblique triangles can be solved, by use of natural functions (i e, the actual values of the trigonometric functions), by use of the law of sines, the law of cosines, and the angle formula $A + B + C = 180°$, as follows:

Case I, given a, A, B: Angle C may be found by the angle formula, then b and c may be found by use of the law of sines used twice

Case II, given a, b, A. Angle B may be found by use of the law of sines, angle C from the angle formula, and c by the law of sines again

Case III, given a, b, C. Side may be found by the law of cosines, and angles A and B from the law of sines used twice, or angle A by the law of sines and angle B from the angle formula.

Case IV, given a, b, c. The angles may all be found by the law of cosines, or angle A from the law of cosines and angles B and C from the law of sines, or angle A from the law of cosines, angle B from the law of sines, and angle C from the angle formula

In all cases, the solution may be checked by Mollweide's formulas

Case II is called the ambiguous case, as there may be one solution, or two solutions, or no solution Given a, b, A.

(1) If $A < 90°$ and $a < b \sin A$, no solution
(2) If $A < 90°$ and $a = b \sin A$, one solution, a right triangle
(3) If $A < 90°$ and $b > a > b \sin A$, two solutions, oblique triangles
(4) If $A < 90°$ and $a \geq b$, one solution, an oblique triangle
(5) If $A > 90°$ and $a \leqq b$, no solution
(6) If $A > 90°$ and $a > b$, one solution, an oblique triangle

All oblique triangles can be solved, by the use of logarithms, with the law of sines, the law of tangents, the half-angle formulas, and the angle formula, as follows

Case I, given a, A, B Angle C is found from the angle formula, then the law of sines is used to find b, c

Case II, given a, b, A Use the law of sines to find angle B, the angle formula to find angle C, then the law of sines to find c

Case III, given a, b, C Use the law of tangents to find $\frac{1}{2}(A - B)$, from this and the angle formula find A and B, then use the law of sines to find c

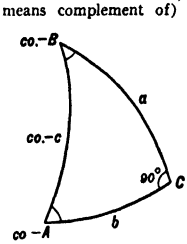
Case IV, given a, b, c Use the half-angle formulas to find $\frac{1}{2}A$, $\frac{1}{2}B$, and $\frac{1}{2}C$

Mollweide's check formulas are adapted to logarithmic calculation

The solution of right spherical triangles is based on the following formulas (where C is the right angle)

$$\sin a = \sin A \sin c,$$
$$\sin a = \tan b \cot B,$$
$$\cos A = \cos a \sin B,$$
$$\cos A = \tan b \cot c,$$
$$\cos c = \cot A \cot B,$$
$$\sin b = \sin B \sin c,$$
$$\sin b = \tan a \cot A,$$
$$\cos B = \cos b \sin A,$$
$$\cos B = \tan a \cot c,$$
$$\cos c = \cos a \cos b$$

Let the five values a, b, $co\text{-}A$, $co\text{-}B$, $co\text{-}c$ (where co- means complement of) be arranged in order as indicated in the accompanying figure Denote any one of these as a middle part, then two of the other parts are adjacent to it and the other two parts are opposite to it The above ten formulas are summarized in the following rules, known as Napier's rules of circular parts:



Spherical triangle (Napier's rules)

(1) The sine of a middle part is equal to the product of the tangents of the adjacent parts.

(2) The sine of a middle part is equal to the product of the cosines of the opposite parts.

The solution of oblique spherical triangles is based on the following formulas

$$\text{Law of sines} \quad \frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}.$$

$$\text{Law of cosines} \quad \cos a = \cos b \cos c + \sin b \sin c \cos A,$$
$$\cos A = -\cos B \cos C + \sin B \sin C \cos a$$

Half-angle and half-side formulas

$$\tan \tfrac{1}{2}A = \sqrt{\frac{\sin (s-b) \sin (s-c)}{\sin s \sin (s-a)}} \quad \text{where } s = \tfrac{1}{2}(a+b+c),$$

$$\tan \tfrac{1}{2}a = \sqrt{\frac{-\cos \sigma \cos (\sigma - A)}{\cos (\sigma - B) \cos (\sigma - C)}} \quad \text{where } \sigma = \tfrac{1}{2}(A+B+C)$$

Napier's Analogies (Formulas)

$$\frac{\tan \frac{1}{2}(a-b)}{\tan \frac{1}{2}c} = \frac{\sin \frac{1}{2}(A-B)}{\sin \frac{1}{2}(A+B)}, \qquad \frac{\tan \frac{1}{2}(a+b)}{\tan \frac{1}{2}c} = \frac{\cos \frac{1}{2}(A-B)}{\cos \frac{1}{2}(A+B)},$$

$$\frac{\tan \frac{1}{2}(A-B)}{\cot \frac{1}{2}C} = \frac{\sin \frac{1}{2}(a-b)}{\sin \frac{1}{2}(a+b)}, \qquad \frac{\tan \frac{1}{2}(A+B)}{\cot \frac{1}{2}C} = \frac{\cos \frac{1}{2}(a-b)}{\cos \frac{1}{2}(a+b)}$$

Delambre's Analogies

$$\frac{\sin \frac{1}{2}(A-B)}{\cos \frac{1}{2}C} = \frac{\sin \frac{1}{2}(a-b)}{\sin \frac{1}{2}c}, \qquad \frac{\sin \frac{1}{2}(A+B)}{\cos \frac{1}{2}C} = \frac{\cos \frac{1}{2}(a-b)}{\cos \frac{1}{2}c},$$

$$\frac{\cos \frac{1}{2}(A-B)}{\sin \frac{1}{2}C} = \frac{\sin \frac{1}{2}(a+b)}{\sin \frac{1}{2}c}, \qquad \frac{\cos \frac{1}{2}(A+B)}{\sin \frac{1}{2}C} = \frac{\cos \frac{1}{2}(a+b)}{\sin \frac{1}{2}c}$$

The area of a spherical triangle is given by the formula

$$\Delta = \frac{\pi R^2 E}{180},$$

where $E = A + B + C - 180°$ is the spherical excess of the triangle and R is the radius of the sphere, and E is also given by L'Huilher's formula

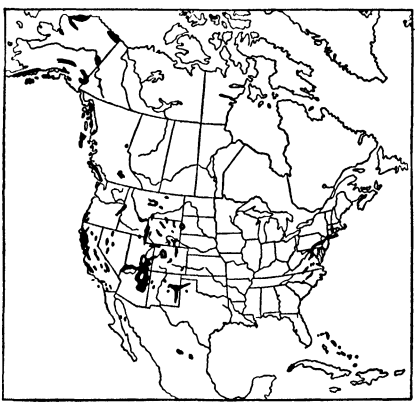
$$\tan \tfrac{1}{4}E = \sqrt{\tan \tfrac{1}{2}s \tan \tfrac{1}{2}(s-a) \tan \tfrac{1}{2}(s-b) \tan \tfrac{1}{2}(s-c)},$$

where $s = \frac{1}{2}(a + b + c)$ (L L S)

TRIANGULATION In **surveying** the field work necessary to obtain the angular measurements between the sides of a series of connected triangles, and the length of one or more of the sides, is known as triangulation The system of connected triangles is called a triangulation system The topographic surveying of land requires the establishment of control points of known position and elevation This control usually takes the form of a series of surveyed triangles, with the apexes located on prominent points in the area, such as peaks, mounds, cliffs In laying down a network of triangles, a fairly level region is selected on which to measure a straight **base line** The **transit** is then set over one end of this base line, and the bearings of the different selected control points taken The transit is then taken to the other end of the base line, and the bearings are again taken to the same points The base line is then plotted, and lines laid out from either end in accordance with the known bearings The intersection of the two bearings on any one station determines its position The United States Coast and Geodetic Survey has covered the country with a triangulation system, the sides of the triangles often being many miles in length The accuracy of triangulation depends upon the accuracy with which the instrument is constructed and read, and the precision with which the base line is measured The precision of triangulation is classified as first order, second order, third order, etc, first order triangulation being that in which the base line is required to be measured to an accuracy of one part in 25,000, and the average triangle closure being only one second The geodetic surveying calls for first and second order triangulation, but ordinary intermediate work is satisfactory with third or fourth order triangulation (F T M)

TRIASSIC PERIOD. The earliest, major subdivision of the **Mesozoic Era** of the geologic time-scale One of the oldest **systemic** terms and denoting a threefold division of the German formations into the lower or Bunter sandstones, the middle or Muschelkalk limestones, and the upper or Keuper copper-bearing shales.

The term Triassic was proposed by Alberti in 1834 The period began about 200 million years ago and lasted for about 50 million years The maximum thickness of formations, 25,000 feet, occurs in the Alps In eastern North America, especially in Massachusetts, Con-



Map showing the surface distribution (areas of outcrops) of Triassic and Jurassic strata in North America Some areas of doubtful age and extent not shown in British Columbia All Atlantic Coast Areas are Triassic In much of the western United States the Triassic and Jurassic have not yet been satisfactorily separated

necticut, and New Jersey, occur a thick series of red sandstones, arkoses, shales, and argillites of fresh water origin, containing the footprints of the earliest known **dinosaurs**. Interbedded with the sedimentary formations are numerous **basalt** lava flows and **sills** This eastern facies of the Triassic is called the Newark Series after the type locality in New Jersey In Arizona and New Mexico occur fresh-water **clastic sediments** containing the prostrate fossil trunks of ancestral Sequoias in which the original body structures have been perfectly replaced by silica Some of the tree trunks are over 150 feet long and 3 to 6 feet in diameter In the Cordilleran region the Triassic formations are marine Triassic rocks also occur in South America, British Isles, western Europe, Asia, Africa, and Australia During this period there were great changes in the plants and animals, as disclosed by the fossils **Ferns, cycads,** and **conifers** predominated among the plants The modern corals, **hexacoralla**, predominate over the earlier **tetracoralla** of the **Paleozoic Cystoids** and **Blastoids** have become extinct The **brachiopods** are less abundant, their place being taken by the pelecypods Modern insects begin their development in this period, and the modern (bony) fishes are ascendant Among the terrestrial animals, the **Paleozoic amphibia** (Stegocephalia) are replaced by the dinosaurs The highest types of marine invertebrates are **ammonites** Marine reptiles, called **Ichthyosaurs,** and flying reptiles called **Pterosaurs,** first appeared in Europe Small reptilian-like mammals also made their first appearance The economic products of this period are chiefly salt, gypsum, and copper In eastern North America the period closed with relatively slight uplift and block-faulting of the Newark Series, called the Palisades Disturbance In the Pacific Coast region there was a withdrawal of the marine waters to mark the close of the period (R M P)

TRIBO-ELECTRIFICATION. Frictional Electricity.

TRIBOLUMINESCENCE. Luminescence.

TRICERATOPS. Fossil reptiles.

TRICHINA. Nemathelminthes, Nematoda A small roundworm parasitic in the intestine and muscles of mammals The species is now classified as *Trichinella spiralis* but it commonly retains the name trichina from that of an older genus

Adult worms develop in the intestine and bear living young which migrate through the intervening tissues and encyst in voluntary muscle fibers, where they perish unless the flesh is eaten by another animal and the cysts are dissolved in the process of digestion (A W L)

TRICHINIASIS. Infection in the human caused by a worm of the class called **nematodes** The worms are found in infected pigs and man is infected by eating infected pork Cooking pork thoroughly will kill any of the worms present After ingestion the worm develops to the adult stage in the small intestine Countless **embryos** are given off which penetrate the walls of the intestine, enter the circulation, and finally lodge in muscle tissue, where they remain stationary in development, encysted in this muscle tissue

The symptoms depend on the number of embryo worms that develop in the intestine The first symptoms accompany the development of the worms in the small intestine These consist of abdominal pain, cramps, vomiting, and diarrhea On the ninth or tenth day after eating the infected pork, and corresponding to the migration of the embryos to the muscles of the body, high fever, marked tenderness, swelling, and pains develop in the body muscles Some cases resemble typhoid fever Mild cases last for two weeks, more severe may last for six weeks, and be followed by many months of weakness

The mortality varies in different outbreaks from 1% to 25% The average mortality is about 6%

The treatment is mainly directed to relief of symptoms and general supportive measures Prophylaxis is important Thorough cooking of pork destroys all the infecting parasites In many countries pork is examined in the slaughter house for their presence (R S M)

TRICHOCYST. A slender structure found in the outer layer of the body in many species of one-celled animals (ciliates) They are discharged from the body under stimulation, forming a fine thread with a cap at the base Although they have been interpreted as defensive structures they have also been regarded as organelles of attachment They are varied and are not yet wholly understood (A W L)

TRICHOGYNE A trichogyne is a beak-like or thread-like projection from an **oögonium** which functions to receive the **sperm** cells and to convey the sperm nucleus to the oogonium (R M W)

TRICHOPTERA. Caddis fly An order of **insects** closely related to the more primitive moths Many species are mothlike but all differ from the great majority of moths in their rudimentary biting mouth parts (A W L)

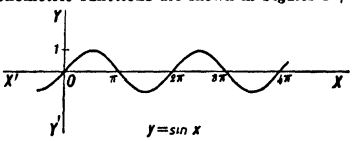
TRICLADIDA. Turbellaria

TRICLINIC SYSTEM. Crystallography.

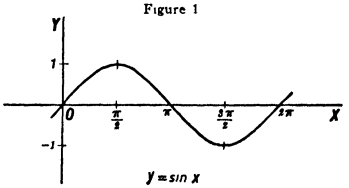
TRIDYMITE. The mineral tridymite is, like quartz, **silicon** dioxide, SiO_2, but is a high temperature variety, probably stable above 870° C It has a conchoidal fracture, is brittle, hardness, 7, specific gravity, 2 28–2 33, vitreous luster; usually colorless and transparent It is found chiefly in volcanic rocks of the more acidic types like **rhyolite, trachyte,** and **andesite.** It is not a particularly uncommon mineral, occurring in Germany, France, Italy, Japan, the Island of Martinique, Mexico, and in the United States in Wyoming and Washington Tridymite is **hexagonal** but when heated to about 1470° C passes into an **isometric** form, cris-

tobalite, which was first noted in the andesitic lavas of the Cerro San Cristobal, Pachuca, Mexico, together with tridymite Cristobalite has been found also in California and in Germany. (E S C S)

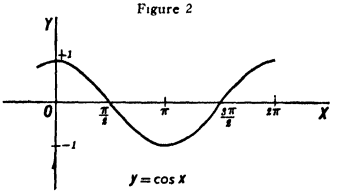
TRIGONOMETRIC CURVES. The **graphs** of the **trigonometric functions** are shown in Figures 1–7



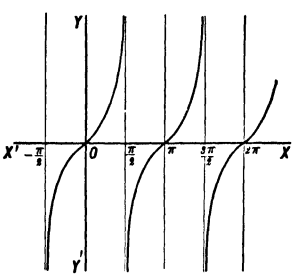
$y = \sin x$
Figure 1



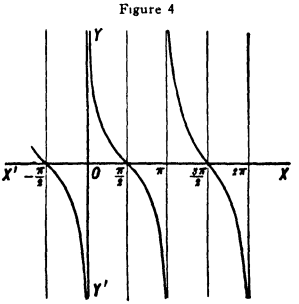
$y = \sin x$
Figure 2



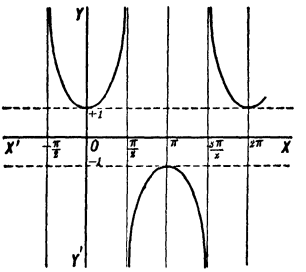
$y = \cos x$
Figure 3



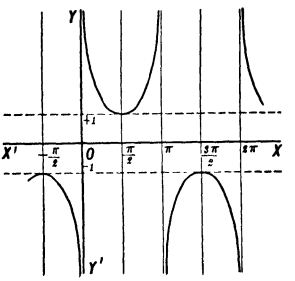
$y = \tan x$
Figure 4



$y = \cot x$
Figure 5.



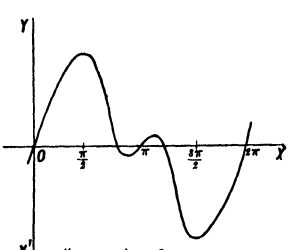
$y = \sec x$
Figure 6



$y = \csc x$
Figure 7

The graph of $y = \sin x$ is a wave-curve Its amplitude is its greatest height 1, its wave-length is 2π The graph of $y = a \sin x$ has amplitude a and wave-length 2π The graph of $y = \sin bx$ has amplitude 1 but wave-length $2\pi/b$ The graph of $y = a \sin bx$ has amplitude a and wave-length $2\pi/b$ The graph of $y = a \sin(bx + c)$ has phase difference of c from that of $y = \sin x$ The cosine graph differs from the sine graph in phase by $90°$ or $\frac{\pi}{2}$

By adding corresponding **ordinates** of several simple sine wave-curves, we obtain new types of wave-curves, as for example that in Figure 8



$y = \sin x + \sin 2x$
Figure 8

The graph of the equation $y = ae^{-kt} \cos(\alpha t + \beta)$ is shown in Figure 9 It represents a damped vibration curve (L L S)

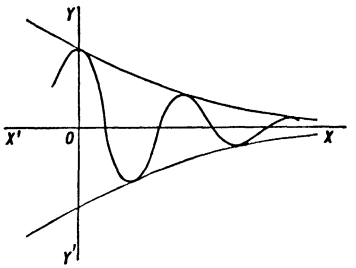


Figure 9 Damped vibration wave

TRIGONOMETRIC DIFFERENTIALS Integration, Technique of.

TRIGONOMETRIC EQUATIONS A trigonometric equation is a conditional **equation** which involves one or more **trigonometric functions** of an unknown angle

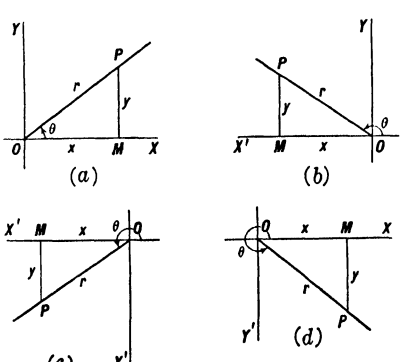
Trigonometric equations have an endless number of solutions, due to the fact that trigonometric functions are **periodic functions**

In solving trigonometric equations there are many methods which can be used, but one useful method in simple cases is to express all functions occurring in the equation in terms of one function, and then solve this equation algebraically for that function, from this the value of the unknown angle can then be found at once The fundamental trigonometric identities will often be needed in transforming equations to simpler forms (L L S)

TRIGONOMETRIC FUNCTIONS Let θ be any **angle** placed in standard position, with initial side along OX, and let P be any point on its terminal side, drop a perpendicular PM from P to the X-axis Let x,y,r be the **abscissa, ordinate,** and **radius vector** of P The **ratios** of these three directed distances are called the trigonometric ratios for angle θ, they are

$$y/r,\ x/r,\ y/x,\ r/y,\ r/x,\ x/y$$

Each of these six trigonometric ratios for an angle depends only on the angle and not on the position of the point chosen on the terminal side of the angle and each



ratio changes when the angle changes In other words, each trigonometric ratio is a **function** of the angle The trigonometric ratios are therefore called the trigonometric functions

The trigonometric ratios or trigonometric functions are named as follows

$y/r =$ sine of θ, written sin θ,
$x/r =$ cosine of θ, written cos θ,
$y/x =$ tangent of θ, written tan θ,

and the reciprocals of these

$r/y =$ cosecant of θ, written csc θ (or cosec θ),
$r/x =$ secant of θ, written sec θ,
$x/y =$ cotangent of θ, written cot θ (or ctn θ)

The functions are undefined when θ is such that a zero denominator occurs in these definitions

$(\sin\theta)^2$ is written $\sin^2\theta$, $(\cos\theta)^2$ is written $\cos^2\theta$, $(\tan\theta)^n$ is written $\tan^n\theta$, etc

Other functions sometimes used are

versed sine of θ vers $\theta = 1 - \cos\theta$,
coversed sine of θ covers $\theta = 1 - \sin\theta$,
haversine of θ hav $\theta = \frac{1}{2}(1 - \cos\theta) = \frac{1}{2}$ vers θ,
exsecant of θ exsec $\theta = \sec\theta - 1$

The algebraic signs of the trigonometric functions in the various quadrants are

Quadrant	sin	cos	tan	csc	sec	cot
I	+	+	+	+	+	+
II	+	−	−	+	−	−
III	−	−	+	−	−	+
IV	−	+	−	−	+	−

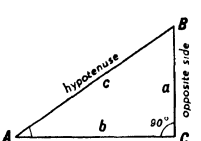
When any one of the trigonometric functions is given, the others are determined and may be found by use of the fundamental relations between the functions, or by a geometric method

The trigonometric functions of quadrantal angles are given by the table

	0°	90°	180°	270°	360°
sin	0	1	0	−1	0
cos	1	0	−1	0	1
tan	0	∞	0	∞	0

As $\theta \to 90°$ through smaller values, $\tan\theta \to +\infty$, and as $\theta \to 90°$ through larger values, $\tan\theta \to -\infty$, etc

As a special case of the general definitions, we may formulate the definitions of the trigonometric functions of an acute angle in a form adapted to right triangle applications as follows



Let A be any given acute angle and construct a right triangle by drawing BC perpendicular to AC Then the definitions of the trigonometric functions of angle A may be written thus

$$\sin A = \frac{\text{opposite side}}{\text{hypotenuse}} = \frac{a}{c},$$

$$\cos A = \frac{\text{adjacent side}}{\text{hypotenuse}} = \frac{b}{c},$$

$$\tan A = \frac{\text{opposite side}}{\text{adjacent side}} = \frac{a}{b},$$

$$\csc A = \frac{\text{hypotenuse}}{\text{opposite side}} = \frac{c}{a},$$

$$\sec A = \frac{\text{hypotenuse}}{\text{adjacent side}} = \frac{c}{b},$$

$$\cot A = \frac{\text{adjacent side}}{\text{opposite side}} = \frac{b}{a}$$

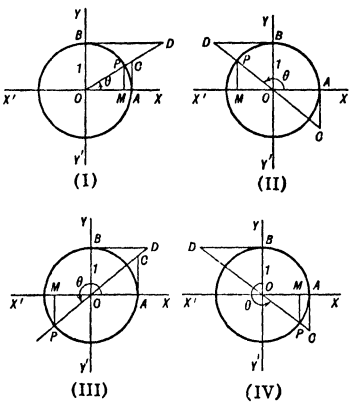
Each trigonometric function of the complement of an acute angle is equal to the co-function of the angle

$$\sin(90^\circ - A) = \cos A, \quad \cos(90^\circ - A) = \sin A,$$
$$\tan(90^\circ - A) = \cot A, \quad \cot(90^\circ - A) = \tan A,$$
$$\sec(90^\circ - A) = \csc A, \quad \csc(90^\circ - A) = \sec A$$

The trigonometric functions of 30°, 45°, 60° are given in the following table

Angle	sin	cos	tan
30°	$\frac{1}{2}$	$\frac{1}{2}\sqrt{3}$	$\frac{1}{3}\sqrt{3}$
45°	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}\sqrt{2}$	1
60°	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}$	$\sqrt{3}$

The trigonometric functions may be represented graphically, both in magnitude and sign, by certain geometric



Line representation of trigonometric functions

line segments Draw a unit circle (of radius 1) with the vertex of the given angle at the center of the circle Let P be the point where the terminal side of angle θ cuts the circle, and draw PM perpendicular to $X'X$, AC perpendicular to $X'X$, BD perpendicular to $Y'Y$ Then for each quadrant, the trigonometric functions are represented, in numerical value and in sign, by the following directed line segments.

$\sin\theta$ is represented by MP,
$\cos\theta$ is represented by OM,
$\tan\theta$ is represented by AC,
$\cot\theta$ is represented by BD,
$\sec\theta$ is represented by OC,
$\csc\theta$ is represented by OD.

The variations of the trigonometric functions in the different quadrants are shown in the following table:

Quadrant	Sine	Cosine	Tangent
I	0 to +1	+1 to 0	0 to $+\infty$
II	+1 to 0	0 to −1	$-\infty$ to 0
III	0 to −1	−1 to 0	0 to $+\infty$
IV	−1 to 0	0 to +1	$-\infty$ to 0

The range of values of the trigonometric functions is the following sine and cosine never can be greater than +1 nor less than −1, the secant and cosecant can never be between +1 and −1, while the tangent and cotangent may take all positive and negative values

Reduction to the first quadrant may be made as follows

To find any trigonometric function of any angle θ, take the same function of the acute angle A between the terminal side of θ and the X-axis, and prefix the algebraic sign given by the rule of signs for the quadrants.

For the trigonometric functions of supplementary angles The sine of an obtuse angle is equal to the sine of the supplementary acute angle, the cosine of an obtuse angle is equal to minus the cosine of the supplementary acute angle, and the tangent of an obtuse angle is equal to minus the tangent of the supplementary acute angle

The trigonometric functions of a negative angle are given by the formulas

$$\sin(-\theta) = -\sin\theta,$$
$$\cos(-\theta) = \cos\theta,$$
$$\tan(-\theta) = -\tan\theta$$

An odd function $f(x)$ is one for which $f(-x) = -f(x)$, and an even function is one for which $f(-x) = f(x)$, for all values of x The sine, tangent, cosecant, and cotangent are odd functions, and the cosine and secant are even functions

Reduction formulas for the trigonometric functions

$$\begin{cases} \sin(90^\circ - \theta) = \cos\theta \\ \cos(90^\circ - \theta) = \sin\theta \\ \tan(90^\circ - \theta) = \cot\theta \end{cases} \quad \begin{cases} \sin(180^\circ - \theta) = \sin\theta \\ \cos(180^\circ - \theta) = -\cos\theta \\ \tan(180^\circ - \theta) = -\tan\theta \end{cases}$$

$$\begin{cases} \sin(90^\circ + \theta) = \cos\theta \\ \cos(90^\circ + \theta) = -\sin\theta \\ \tan(90^\circ + \theta) = -\cot\theta \end{cases} \quad \begin{cases} \sin(180^\circ + \theta) = -\sin\theta \\ \cos(180^\circ + \theta) = -\cos\theta \\ \tan(180^\circ + \theta) = \tan\theta \end{cases}$$

$$\begin{cases} \sin(270^\circ - \theta) = -\cos\theta \\ \cos(270^\circ - \theta) = -\sin\theta \\ \tan(270^\circ - \theta) = +\cot\theta \end{cases} \quad \begin{cases} \sin(270^\circ + \theta) = -\cos\theta \\ \cos(270^\circ + \theta) = \sin\theta \\ \tan(270^\circ + \theta) = -\cot\theta \end{cases}$$

$$\begin{cases} \sin(360^\circ - \theta) = -\sin\theta \\ \cos(360^\circ - \theta) = \cos\theta \\ \tan(360^\circ - \theta) = -\tan\theta \end{cases} \quad \begin{cases} \sin(360^\circ + \theta) = \sin\theta \\ \cos(360^\circ + \theta) = \cos\theta \\ \tan(360^\circ + \theta) = \tan\theta \end{cases}$$

When n is an even integer, any trigonometric function of $n\ 90^\circ \pm \theta$ is numerically equal to the same function of θ, when n is an odd integer, any trigonometric function of $n\ 90^\circ \pm \theta$ is numerically equal to the co-function of θ, the algebraic sign of the result is that of the given function of $n\ 90^\circ \pm$ an acute angle

The six trigonometric functions are related to each other by various relations The fundamental relations are

(*a*) The reciprocal relations

$$\csc\theta = 1/\sin\theta, \quad \sin\theta = 1/\csc\theta,$$
$$\sec\theta = 1/\cos\theta, \quad \cos\theta = 1/\sec\theta,$$
$$\cot\theta = 1/\tan\theta, \quad \tan\theta = 1/\cot\theta$$

(*b*) The square relations

$$\sin^2\theta + \cos^2\theta = 1,$$
$$1 + \tan^2\theta = \sec^2\theta,$$
$$\cot^2\theta + 1 = \csc^2\theta$$

(*c*) The quotient relations

$$\tan\theta = \frac{\sin\theta}{\cos\theta}, \quad \cot\theta = \frac{\cos\theta}{\sin\theta}$$

Formulas for the trigonometric functions of the sum and difference of two angles are

$$\sin(x \pm y) = \sin x \cos y \pm \cos x \sin y,$$
$$\cos(x \pm y) = \cos x \cos y \mp \sin x \sin y,$$
$$\tan(x \pm y) = \frac{\tan x \pm \tan y}{1 \mp \tan x \tan y}$$

These are often called the addition theorems for the trigonometric functions

From these are obtained the following formulas for transforming sums and differences of trigonometric functions into products, and products into sums and differences

$$\sin x + \sin y = 2\sin\tfrac{1}{2}(x+y)\cos\tfrac{1}{2}(x-y),$$
$$\sin x - \sin y = 2\cos\tfrac{1}{2}(x+y)\sin\tfrac{1}{2}(x-y),$$
$$\cos x + \cos y = 2\cos\tfrac{1}{2}(x+y)\cos\tfrac{1}{2}(x-y),$$
$$\cos x - \cos y = -2\sin\tfrac{1}{2}(x+y)\sin\tfrac{1}{2}(x-y),$$

and

$$2\sin x\cos y = \sin(x+y) + \sin(x-y),$$
$$2\cos x\sin y = \sin(x+y) - \sin(x-y),$$
$$2\cos x\cos y = \cos(x+y) + \cos(x-y),$$
$$-2\sin x\sin y = \cos(x+y) - \cos(x-y)$$

Formulas for the trigonometric functions of a double angle are

$$\sin 2x = 2 \sin x \cos x,$$
$$\cos 2x = \cos^2 x - \sin^2 x,$$
$$= 1 - 2 \sin^2 x,$$
$$= 2 \cos^2 x - 1,$$
$$\tan 2x = \frac{2 \tan x}{1 - \tan^2 x}$$

Half-angle formulas for the trigonometric functions are

$$\sin \tfrac{1}{2}x = \pm\sqrt{\frac{1 - \cos x}{2}},$$
$$\cos \tfrac{1}{2}x = \pm\sqrt{\frac{1 + \cos x}{2}},$$
$$\tan \tfrac{1}{2}x = \pm\sqrt{\frac{1 - \cos x}{1 + \cos x}}$$
$$\tan \tfrac{1}{2}x = \frac{1 - \cos x}{\sin x} = \frac{\sin x}{1 + \cos x}$$

Transformation of $a \cos x + b \sin x$ is given by

$$a \cos x + b \sin x = c \cos (x - \alpha),$$

where $c = \sqrt{a^2 + b^2}$, $\tan \alpha = b/a$,

$$a \cos x + b \sin x = c \sin (x + \beta),$$

where $c = \sqrt{a^2 + b^2}$, $\tan \beta = a/b$

All co-terminal angles have the same values for their trigonometric functions

$$f(\alpha \pm n\ 360°) = f(\alpha),$$

or

$$f(\alpha \pm 2n\pi) = f(\alpha),$$

where f denotes one of the trigonometric functions

Hence, all six trigonometric functions are **periodic functions** with the period 2π (radians), or 360°. This is the least period for sine, cosine, secant and cosecant, but tangent and cotangent have also a smaller period π (or 180°) since

$$\tan (x + \pi) = \tan x, \qquad \cot (x + \pi) = \cot x$$

and

$$\tan (x + k\pi) = \tan x, \qquad k \text{ any integer, etc}$$

The trigonometric functions all repeat their values in cycles of 360°

When the angle is small and expressed in **radian measure,** the sine, tangent and the angle have important relations, expressed by

$$\lim_{\theta \to 0} \frac{\sin \theta}{\theta} = 1 \quad \text{or} \quad \sin \theta \approx \theta,$$

$$\lim_{\theta \to 0} \frac{\tan \theta}{\theta} = 1 \quad \text{or} \quad \tan \theta \approx \theta,$$

when θ is small and is expressed in radians

A function expressible in the form $y = c \sin (kx + \phi)$, where c, k, ϕ are constants, is a simple harmonic function, c is the amplitude, ϕ is the phase angle and k determines the period $k/2\pi$ is the frequency and $2\pi/k$ is the period. It may also be written in the form $y = a \cos kx + b \sin kx$ (L L S)

TRIGONOMETRIC IDENTITIES. Trigonometric Functions.

TRIGONOMETRIC INTEGRALS Integration, Technique of

TRIGONOMETRIC RATIOS. Trigonometric Functions.

TRIGONOMETRIC TRANSFORMATIONS Trigonometric Functions.

TRIGONOMETRY. The name "Trigonometry" is derived from two Greek words meaning measurement or solution of **triangles**

While the solution of triangles forms an important part of modern Trigonometry, it is by no means the only part or even the most important part In the development of methods for the solution of triangles by computation, certain **functions** of **angles** occur, and the study of the properties of these functions and their applications to various mathematical problems, including the solution of triangles, constitutes the subject matter of Trigonometry.

In Plane Trigonometry, the solution of plane triangles is considered, Spherical Trigonometry treats of the solution of spherical triangles

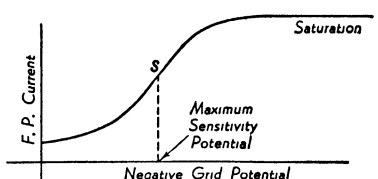
An idea of the subject-matter usually assigned to Trigonometry may be gained by consulting the following topics **Angles, Degree Measures of Angles, Radian Measure of Angles, Trigonometric Functions, Trigonometric Curves, Trigonometric Equations, Inverse Trigonometric Functions, DeMoivre's Theorem, Logarithms, Triangles.** (L L S)

TRILOBITES. Invertebrate paleontology.

TRIODE. A three-electrode, thermionic **vacuum tube.** The thermionic current in a hot-cathode tube is unidirectional, that is, reversal of the voltage stops the current, so that the tube acts as a "valve" or **rectifier** If between the hot filament and the anode or "plate" of such a tube there is interposed a wire mesh or grid, and if this third electrode is given a slight negative potential or bias, the effect is to reduce the flow of electrons somewhat, by an amount dependent upon this potential For a suitable adjustment of the voltages and the filament temperature, the thermionic current may prove very sensitive to changes in the grid potential Very feeble electric oscillations communicated to the grid may then appear as large fluctuations in the main thermionic current, and the triode becomes an **amplifier.** This device, originated by DeForest, is now a most important factor in **radio** reception and in many other types of apparatus requiring high amplification of electric impulses.

By so connecting the circuits that the current fluctuations are made to "feed back," that is, to affect the grid voltage, the amplifier becomes regenerative, tending to build up the fluctuations to a maximum Large tubes so operating are used to produce the electric oscillations necessary for the emission of the carrier wave in radio broadcasting, sometimes radiating energy at the rate of many kilowatts The details of the circuits used for these purposes often involve highly complicated radio technique

To secure the greatest sensitivity, the potential of the



Characteristic curve for typical triode, which is most sensitive at S

grid is adjusted to a value dependent upon the particular triode This value is indicated on the "characteristic curve" of the triode as the point S of maximum slope (see figure), where the filament-to-plate current varies most rapidly with the grid potential. (L D W.)

TRIPLE INTEGRAL. Let $f(x, y, z)$ be a **continuous function** in a region V of space Let this region be divided up into n sub-regions ΔV_k, and let (x_k, y_k, z_k) be any point in ΔV_k Then form the sum $\sum_{k=1}^{n} f(x_k, y_k, z_k)\Delta V_k$ Let

$n \to \infty$ and let the greatest diameter of each $\Delta V_k \to 0$ The **limit** of this sum is then called the triple integral of $f(x, y, z)$ extended over the region V, and we write

$$\lim_{\Delta V_k \to 0} \sum_{k=1}^{n} f(x_k, y_k, z_k)\Delta V_k = \iiint_V f(x, y, z)dV$$

An iterated triple integral

$$\int_{x_1}^{x_2}\left[\int_{y_1}^{y_2}\left(\int_{z_1}^{z_2} f(x, y, z)dz\right)dy\right]dx$$

means a series of successive integrations, z_1 and z_2 will in general be functions of x and y, and y_1 and y_2 will in general be functions of x, and x_1 and x_2 will be constants Such an iterated (or repeated) triple integral is sometimes written

$$\int_{x_1}^{x_2}\int_{y_1}^{y_2}\int_{z_1}^{z_2} f(x, y, z)dz\,dy\,dx,$$

or

$$\int_{x_1}^{x_2} dx \int_{y_1}^{y_2} dy \int_{z_1}^{z_2} f(x, y, z)dz$$

A triple integral may be interpreted geometrically as a **volume.**

The fundamental theorem for triple integrals may be stated A triple integral $\iiint_V f(x, y, z)dV$ extended over a region V is equal to an iterated triple integral of the form

$$\int_{x_1}^{x_2}\left[\int_{y_1}^{y_2}\left(\int_{z_1}^{z_2} f(x, y, z)dz\right)dy\right]dx,$$

where the limits $z_1, z_2, y_1, y_2, x_1, x_2$ depend on the boundary of the region V

In **spherical coordinates,** the element of volume $dx\,dy\,dz$ in a triple integral becomes $r^2 \sin\phi\, d\phi\, d\theta\, dr$

In **cylindrical coordinates,** the element of volume $dx\,dy\,dz$ becomes $r\,d\theta\,dr\,dz$ (I I S)

TRIPLE POINT. Three-phase Equilibrium.

TRIPLE PRODUCTS OF VECTORS. The triple scalar product of three **vectors** $(\mathbf{a} \times \mathbf{b})\ \mathbf{c}$ is a **scalar,** which may be represented by the volume of the parallelopiped on **a, b, c** as adjacent edges

An important formula for the triple scalar product is

$$(\mathbf{a} \times \mathbf{b})\ \mathbf{c} = \begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix}$$

This triple scalar product $(\mathbf{a} \times \mathbf{b})\ \mathbf{c}$ is sometimes denoted by $[\mathbf{a}\ \mathbf{b}\ \mathbf{c}]$

The condition that three vectors **a, b, c** lie in one plane is $(\bar{\mathbf{a}} \times \bar{\mathbf{b}})\ \bar{\mathbf{c}} = 0$, or $[\bar{\mathbf{a}}\ \bar{\mathbf{b}}\ \bar{\mathbf{c}}] = 0$

The triple vector product $(\mathbf{a} \times \mathbf{b}) \times \mathbf{c}$ is represented by the important formula

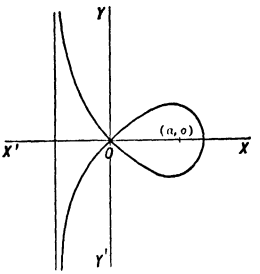
$$(\mathbf{a} \times \mathbf{b}) \times \mathbf{c} = (\mathbf{c}\ \mathbf{a})\mathbf{b} - (\mathbf{c}\ \mathbf{b})\mathbf{a} \quad \text{(L L S)}$$

TRIPLOBLASTIC ORGANIZATION. A form of organization based on three embryonic **germ layers** With the exception of the phyla **Protozoa, Porifera, Coelenterata,** and possibly **Ctenophora,** all animals begin their development with the formation of these three layers, ectoderm, mesoderm, and endoderm The ectoderm and endoderm develop first as outer and inner layers of the body wall, and the development of **diploblastic** animals proceeds by the differentiation of adult structures from these layers In triploblastic groups a third layer forms between the two, from this mesodermal layer other parts of the adult are formed (A W I)

TRISECTRIX OF MACLAURIN. This curve is the **locus of the equation in rectangular coordinates**

$$x^3 + xy^2 + ay^2 - 3ax^2 = 0$$

It can be used for the trisection of an angle (L L S.)



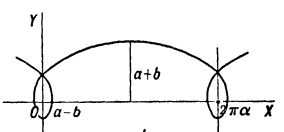
Trisectrix

TRITOCEREBRUM The third (posterior) division of the brain of **arthropods** It is derived from the pair of ganglia of one segment of the head (A W L)

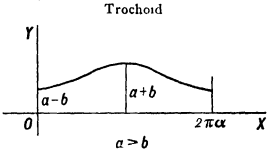
TROCHELMINTHES. Rotatoria

TROCHOID A trochoid is a mathematical curve which may be regarded as a generalization of the cycloid

If a circle of radius a rolls along a straight line, the locus of a point P on a radius of the circle at a distance b from the center is called a trochoid If $b > a$ (point outside the circle), the curve is frequently called a prolate cycloid, and if $b < a$ (point inside the circle), the curve is called a curtate cycloid



Trochoid



Trochoid

Parametric equations of the trochoid are

$$x = a\theta - b \sin\theta,\quad y = a - b\cos\theta$$

(L L S)

TROCHOPHORE. An invertebrate larva with a bent or curved tubular alimentary tract (**Digestive System**) lined with ciliated (**Cilia**) tissue The surface of the body bears an encircling band of cilia and a tuft at the apex of the body These larvae develop from the fertilized egg and after drifting and swimming for a time undergo a transformation to become adults

Trochophore larvae are found in the phyla **Bryozoa, Brachiopoda, Phoronidea, Annelida,** and **Mollusca.** They are also called trochospheres (A W L)

TROCHUS The ciliated (cilia) disk at the end of the body of a **rotifer** In many species the end of the body is flattened and is surrounded by two rows of cilia, with the mouth opening between The outer part is called the cingulum and the disk surrounded by the inner row of cilia the trochus (A W L)

TROCTOLITE. Gabbro

TROGON. Aves, Cuculiformes A brilliantly colored and beautifully feathered bird (**Aves**) of the Oriental

region, tropical Africa, and Central and South America A single species, the Coppery-tailed trogon, *Trogon ambiguus*, enters southern Texas and Arizona These birds have a moderately large beak, strong and curved Crests and plumes are highly developed in some of the males, and in this sex the tail is sometimes very long

The **quezal** of Central America is one of the most widely known of the trogons, probably because it has been pictured frequently on postage stamps of Guatemala and partly because its brilliant colors persist in museum specimens The male is brilliant green with blood-red under parts below the breast. It has a very long tail, drooping plumes over the wings, and the head bears a rounded crest (A W L)

TROJAN GROUP This is the name applied to a group of eleven asteroids which carry the names of the various heroes of the Trojan wars This group of asteroids all have their periods and mean distances nearly identical with the planet **Jupiter** The group is of great theoretical interest because of the fact that they represent examples of the solution of the **three-body problem** proposed by Lagrange Lagrange proved theoretically that an object so located that it is equidistant from both Jupiter and the sun would be in a stable position, i e, would remain there and continue to go about the sun with the same period as Jupiter The members of the Trojan group all behave in approximately this manner, each of them being within 20° of the vertex of an equilateral triangle with the sun and Jupiter at the other vertices They move about this vertex in a complex curve and will remain in this vicinity unless they are perturbed out by the attraction of **Saturn** (W K G)

TROPACOCAINE **Alkaloids.**

TROPHALLAXIS. An interchange of nourishment between the various members of colonies of insects The older idea that instinctive parental care is the basis of the concern manifested by **ants** and **termites** for the welfare of other individuals of the colony has been substituted by recognition of this interchange The insects exude secretions at the surface of the body which are licked off by others This reward is apparently responsible for much of the solicitude Even the insects of other species living within such colonies are welcome guests in some cases because of a similar contribution to their hosts The relationship has complex ramifications which explain other aspects of colonial organization, such as cannibalism, that are difficult to reconcile with the older interpretations of mutual aid within the colony (A W L)

TROPHI. **Mastax.**

TROPHOSOME One of several terms used to designate individuals that take in and digest food in colonies of primitive animals, or the stage of development of an individual during which it eats and grows Trophosome is applied to the **polyp** stage of **Hydrozoa**, also called gastrozooids The term trophozooid is applied to an early stage in the development of the **coral** polyps of the family Fungidae, known as mushroom corals, and the term autozooid to individuals that take food in **alcyonarian** colonies The root appears again in trophozoite, applied to the growing stage of some parasitic Protozoa (**Sporozoa**) (A W L)

TROPHOZOITE. **Trophosome.**

TROPHOZOOID. **Trophosome.**

TROPINE. **Alkaloids.**

TROPINONE. **Alkaloids.**

TROPISM. For the use of this term in botany, see **Movement in plants** In zoology, a tropism is an unavoidable response of an animal to some environmental stimulus involving the orientation of the body in relation to the causative factor In very simple animals this type of reaction is common **Protozoans**, for example, may always move toward or away from light, and even animals with organized nervous systems may have some nerve paths associated in such a way that a given condition always evokes the same reaction This type of response is also called a taxis, a term applied to the responses made without a nervous system and at the other extreme to simple reflexes, which may be nervously intricate although they are automatic

Both tropism and taxis are combined with various prefixes for special cases Thus a topotropism or topotaxis is a reaction toward the inciting stimulus and a phobotropism is a withdrawal from the stimulus These reactions are also designated as positive and negative Reactions to chemical stimuli are sometimes called chemotropisms Light evokes phototaxis By such terms any special orientation of this nature may be concisely expressed (A W I)

TROUPIAL. Aves, Passeriformes A name derived from the French and applied variously to members of the family Icteridae, including the **orioles**, **blackbirds**, and New World **grackles** The name has been used by various writers for the grackles, for the orioles, and for all members of the family Also spelled troopial (A W L)

TROUT. Pisces, Teleostei A leading game fish (**Pisces**) found in cold waters, including lakes and streams and in some species salt water The various species commonly called trout have been classified with the **salmons** in the genus *Salmo*, and separately in the genera *Trutta*, *Salvelinus*, and others They vary greatly in size and to a slight extent in game qualities The scales are minute to small and the flesh is superior

Trout are common in streams of the northern hemisphere and have been widely transported for stocking other than their native waters The brook or speckled trout, *Salvelinus fontinalis*, is the most widely distributed species, ranging from Maine to the Dakotas and northward throughout the continent Rainbow trout, *Trutta iridea*, from the west coast, are now widely stocked in other waters, and everywhere trout fishing is important imported species, including the European brown trout, *T trutta*, and the Lochleven trout, are to be expected The group includes almost two score of species in North America alone, many without other common names than trout while others are called redfish, green-back, steelhead, blue-back, saibling, and yellow-fin The lake trouts live in deep water and attain great weight The mackinaw or common lake trout has been recorded up to 90 pounds

In North America the relative merits of the trout and bass as game fishes will probably always remain a matter of opinion Trout fishing with the fly rod has long been regarded as the aristocrat of piscatorial sports, next to salmon fishing, which is less widely available, but the small-mouth bass has many devotees as a fish for the fly rod and his superiority to the trout is often loyally maintained Probably also anglers will continue to catch the fish that their waters offer, and to be sure that it is the best of all fishes! (A W L)

TROUT-PERCH. Pisces, Teleostei A common fish (**Pisces**) of the Great Lakes and the rivers of the eastern half of the United States, rare in the south. It attains a maximum length of about ten inches, with scales like the perches and otherwise similar to the trout It is one of two species of the family Percopsidae (A W L)

TROUTON-NOBLE EXPERIMENT. **Ether.**

TROUTON'S LAW. **Heat of Vaporization.**

TRUFFLE. Ascomycetes.

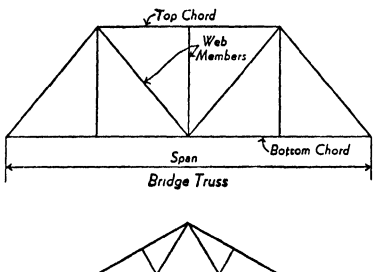
TRUMPETER. Aves, Gruiformes. *Psophia* A long-legged and long-necked bird (**Aves**) of South Amer.ca The few species are characteristically terrestrial in habits, living in the forests and flying poorly They live in flocks and are said to be tamed in Brazil for the protection of domestic fowls, with which they live contentedly The word also appears in the names of the trumpeter-hornbills of Africa and the trumpeter swan of North America, both species of other orders. (A W L)

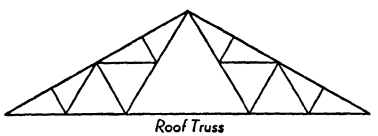
TRUNCUS ARTERIOSUS. The great arterial vessel leading from the **heart** of **vertebrates** in the primitive unpaired condition and in the **embryo** All blood leaving the heart passes through this vessel, which is differentiated to form the conus arteriosus and the ventral aorta in the fishes and persists as a short trunk in the **amphibians** In the **reptiles** its subdivision to form the aorta and the pulmonary artery is begun and in the birds and mammals this splitting is complete The truncus is divided by the growth of a pair of ridges in a spiral course along opposite walls These ridges unite to form a partition (A W L)

TRUNK. 1 The body of a **vertebrate**, bearing the neck and head at one end and the tail at the other, with the two pairs of appendages attached laterally or ventrolaterally near the two ends The trunk contains the body cavity in which the viscera lie, and is supported by the vertebral column and the ribs It is divisible into an anterior thorax and a posterior abdomen

2 The proboscis of the elephant This is a muscular organ formed of the elongated nose and upper lip It contains the greatly elongated nasal passages, which are used for raising water and small particles of food, such as grain, to the mouth by inhaling them into the terminal parts of the tubes The appendage is also used for grasping by prehension and by the opposition of two fingerlike processes at its tip (A W L)

TRUSS. A truss is a framed structure composed of a series of adjoining triangles which are formed by straight members, all lying in one plane The members are connected at their points of intersection by **pins** or **gusset** plates or by welding The point of intersection is called a panel point or joint Since rigidity of the truss is secured by triangles which cannot deform without changing the length of the sides, it is generally assumed that loads applied at the panel points will produce direct **stress** only. This will be true if the gravity axes of the members meet at the panel points and the effect of secondary bending stresses, caused by the **deflection** of the truss, is disregarded. If a load is applied to a member between the panel points it must distribute the load by beam action to the adjacent panel points. The top line of members of a truss is called the top **chord** and the lower line is known as the lower or bottom chord The members connecting the top and bottom chords are called web members The span of the truss is the horizontal distance center to center of end **bearings.**





Framed bridges consist of two or more parallel vertical trusses which support the floor system The **lateral** bracing in the plane of the top and bottom chords of bridges form the web members of horizontal trusses A roof truss is one which supports the roof of a building Trusses are also used over auditoriums to carry the loads from the floors above The members of a truss are usually made of steel or wood, although concrete trusses have been used for bridges Steel has the advantage over wood in that it has far greater strength and is less subject to deterioration, but the latter is frequently used for temporary structures (C W C)

TRYPANOSOME Protozoa, Mastigophora A one-celled parasitic animal found in the **blood** plasma of **vertebrates** The body is characteristically long and slender, with a single **nucleus** and one **flagellum** arising from a small basal body and running along the edge of an undulating membrane, sometimes through the greater part of the length of the body, forming a short free portion at the end These parasites constitute the genus *Trypanosoma*

Some species of trypanosomes cause serious diseases of man and domestic animals Among them *Trypanosoma gambiense*, the cause of African sleeping sickness, has been widely publicized This species is transmitted by the **tsetse fly**, a blood-sucking insect related to the stable fly of our own continent In South America Chagas' disease is caused by a trypanosome transmitted by a bug Still another species causes the very destructive disease, nagana, which affects both wild and domestic animals in Africa (A W L)

TRYPANOSOMIASIS (SLEEPING SICKNESS). A chronic parasitic disease of African and South American regions characterized by wasting, fever, lassitude, or profound lethargy The parasites responsible for the disease are known as *Trypanosoma gambiense* and *Trypanosoma rhodesiense* (African forms) and *Trypanosoma cruzi* (South American form) The parasites are transmitted by the **tsetse fly,** in which these parasites undergo various changes

The incubation period in man varies from ten to twenty days The acute stage is characterized by irregular fever, enlargement of the **lymph glands** and skin rashes Later, after a latent period of months or years, brain symptoms occur (Sleeping Sickness) This chronic stage is characterized by headache, mental dullness, paralysis, coma, and convulsions, usually with eventual slow death A form of this disease occurs which is acute throughout its course, resulting in death Treatment is difficult as regards cure Various combinations of drugs are used, especially such compounds of **arsenic** as are used in syphilis (R S M)

TRYPSIN. Enzymes.

TSETSE FLY. Insecta, Diptera *Glossina* A blood-sucking **fly** found in Africa from the southern borders of Arabia and the Sahara Desert to northern South Africa About fifteen species of these flies have been recognized, varying considerably in habits and distribution Several of these species are definitely linked with the transmission of **trypanosomes** which cause diseases of man and animals, and none of them are immune from suspicion as carriers

These flies are related to the stable fly of North America (Family Muscidae). Their chief characteristics are the projection of the proboscis forward from the head and the position of the wings, which are folded over the body so that they overlap completely when at rest

Tsetse flies suck plant juices as well as blood, and are known to attack animals of many species, both warm- and cold-blooded They show many interesting reactions. Moving objects attract them more readily than others, and they see dark colors more readily than light. White persons are said to be bothered very little by them when in the company of negroes Some species frequent watercourses while others are found in dry areas

The problem of controlling tsetses in Africa has been important because of the great virulence of the diseases that they transmit (A W L)

TSUNAMI (SUNAMI). Earthquakes.

TUATARA, TUATERA. Reptilia, Prosauria A primitive **reptile**, *Sphenodon punctatus*, of New Zealand, superficially like the lizards but different in several anatomical details It is chiefly noteworthy for the high development of the pineal or median eye (A W L)

TUBE. The tube is a hollow cylindrical body having a length much greater than its diameter Generally the tube is used to conduct a fluid, though it may also be used as a container Tubes are made of many and varied materials, in fact, almost anything that may be worked into tubular shape has a use somewhere as a tube steel, iron, copper, brass, glass, cardboard Metal tubes may be made by rolling a piece of skelp to tubular shape and welding or soldering the joint This type of tubing has been superseded by seamless tubing, by virtue of the development of processes for producing seamless tubes from a billet A billet is heated to a plastic state, then pierced by forcing it over the point of a mandril with revolving rolls which work the metal from the center towards the outside, so that a short thick tube is produced This intermediate product is then passed between several other mandrils and rolls, each one of which effects a thinning of the tube wall and an elongation After passing through finishing rolls, the tubes are discharged to cooling and straightening tables Seamless tubes may also be produced by cupping a circular plate The plates are first pressed into bowl-shape and then drawn through several dies, each succeeding one being of smaller diameter The dies eventually bring the tube down to the final shape A steel tube is differentiated from a steel **pipe** by the seamless character, and by the nominal size The tube is sized by its external diameter, the pipe by its nominal internal diameter (F T M)

TUBE FOOT. A characteristic appendage of **echinoderms**, associated with the **water vascular system** In the starfishes (**Asteroidea**) the tube feet are rounded protuberances in the ambulacral grooves along the under surface of the rays They are cupped at the tips and grip surfaces by adhesion and suction The tube feet of brittle stars are without suckers Those of sea urchins (**Echinoidea**) form respiratory organs, and a group of ten around the mouth are sensory Tube feet of **sea cucumbers** are suctorial with the exception of a group around the mouth that form the **tentacles** (A W L)

TUBERCULOSIS. A chronic or acute infectious disease caused by an invasion of the body with the *Bacillus tuberculosis* It may exist without causing symptoms (quiescent tuberculosis) or with symptoms (acute tuberculosis) The symptoms of tuberculosis depend on the organ involved, the virulence of the strain of tubercle bacilli and the resistance of the individual infected Like syphilis, any portion of the body may be involved in the tubercular process, although the commonest site is the lungs.

Tuberculosis was known to the Greeks and excellent descriptions of the disease date from the time of Hippocrates. Galen regarded it as infectious Robert Koch in 1882 demonstrated the causative organism

The disease is exceedingly widespread and is found in animals as well as in man It is most common in bovine animals, and there is also an avian form It is estimated that tuberculosis causes about one-eighth of all deaths In civilized portions of the world there has been a progressive reduction in the morbidity and mortality from this disease This is due to (1) better economic and social conditions, (2) the present campaign against tuberculosis with its educational aspect toward hygiene and opportunity for diagnosis, (3) earlier diagnosis of the disease both by clinical and x-ray examination, (4) protection of the healthy from active cases, (5) better forms of treatment, especially artificial **pneumothorax** and surgical collapse therapy, (6) fewer cases of tuberculosis and therefore less spreading of infection by fewer individuals

It is estimated that there is 1% of the population that has the disease in active form and 1% that has it in the arrested form There are about nine active cases for each tubercular death

The bovine form formerly caused considerable tuberculosis in children from drinking infected milk Under modern conditions with inspected cattle and pasteurization this source of infection is comparatively rare

The bacilli are present in all tubercular lesions and from these lesions notably those in the pulmonary system, numberless bacilli are spread by expectoration in congested districts These bacilli may live in dry sputum for years and in the form of dust they are distributed over wide areas In cities nearly everyone is constantly breathing in live tubercle bacilli It is only when the resistance is lowered or overwhelming numbers of bacilli gain access to the body that the disease develops Perhaps natural immunity gained by constant exposure to small doses of the organism protects to some extent those who live in congested areas

There are certain individuals who, either by heredity or environment, have a special predisposition toward the development of the disease However, even in these individuals tuberculosis cannot develop without exposure to the disease

All ages are susceptible, but death from tuberculosis is most likely to occur in young adult life Certain races are more subject to tuberculosis than others This was true with the American Indians, who had no previous exposure until the white race brought a new disease to them The Negro and Irish races also seem to suffer more from the disease than others Certain occupations have a predisposing effect in that unsanitary surroundings, and particularly exposure to dust, increase its incidence

The possible modes of infection in tuberculosis are as follows The chance of hereditary and congenital transmission is quite small The common method of transmission is through droplet infection sprayed into the air by coughing or the drying of tubercular sputum which is spread around as dust In a tubercular hospital, where patients are instructed in careful habits, there is less chance of spread of tuberculosis than in the ordinary street The air breathed out of the lungs in normal respiration is not infected It is the coughing that ejects the tubercle bacilli for spread of the disease Milk was formerly a common source of infection It causes the pulmonary more often than the gastrointestinal form, as the lungs act as filters for tubercle organisms taken into the intestines

Under present-day conditions opportunity for infection with the tubercle bacillus is always present for the majority of individuals Increasing numbers of children, as they become older, become infected with the organism, until by early adult life at least 50% of the race is infected However, this primary infection of tuberculosis does not mean active disease. It is estimated that only one person out of sixty infected develops active tuberculosis By means of the tuberculin skin test it is possible to tell whether the person has had the initial tuberculous infection

This original infection of tuberculosis is practically always unnoticed as few if any symptoms occur with it Once infected with it, individuals may react in different ways A great deal remains to be discovered as to why some individuals develop active tuberculosis while others, although infected, do not become ill. The lesion following primary infection may remain quiescent and clinically inactive for years or a lifetime Many of the original infections heal and disappear or leave a scar Certain individuals who develop tuberculosis do so from a lighting up of this original lesion. Certain factors influence this recrudescence of the original infection. environmental conditions, hygiene, opportunities for reinfection, conditions of stress and strain—all are of utmost importance in lighting up an old infection. Other factors to be considered are hereditary and constitutional conditions, complications of pregnancy, acute and chronic illness, **trauma**, and any other conditions that lower the individual's resistance

Other individuals after their original infection become sensitized or **allergic** to future tuberculosis infection, especially when opportunities for exposures to tuberculosis are frequent and repeated at short intervals Massive dose of infection, with the bacillus, is also a factor in these "tuberculized" individuals

Fortunately, the great mass of individuals, having been exposed in early life to tuberculosis and having the original infection, develop a relative immunity—never absolute—to further average exposure to tuberculosis Tuberculosis exposure in races who have never known the infection results in a severe form that wipes out a good portion of those infected, as mentioned above in regard to the American Indian

Only the relatively common clinical forms of tuberculosis are mentioned below Tuberculosis, of course, can involve any organ or tissue of the body

Acute miliary tuberculosis is an almost hopeless form of overwhelming infection with the tubercle bacillus It is a form of **sepsis** comparable to sepsis seen with **Staphylococci** and **Streptococci**. The body is suddenly overwhelmed with large number of virulent bacilli It probably results from an active tuberculous focus being situated in a blood or lymph channel In such a situation numberless bacilli can be freed directly into the circulation, to be deposited throughout the system This acute hopeless infection may clinically be divided into three groups (1) the typhoid form, (2) the pneumonic form, and (3) the meningeal form, named according to the predominating symptoms Treatment is of no avail

Tuberculosis of the lymph glands is a form that was more common twenty-five or more years ago than it is at present The answer lies in pasteurization of milk and other hygienic measures that are being used against tuberculosis Lymphatic tuberculosis is usually due to entry of the bacillus through the mouth and gastrointestinal tract Every lymph gland acts as a filter, and it is relatively easy for them to collect sufficient foreign material in their field of drainage to become actively infected In former days the name scrofula was applied to tuberculosis and syphilitic infection of the lymph glands During that period the two diseases were not differentiated The term was particularly used in relation to tuberculosis of the cervical glands in the neck It has always been noticed that those infected with this disease seldom develop disease of their lungs This is believed to be due to immunity conferred from a mild type of tubercular infection

The groups of lymph glands most often involved are cervical glands, the glands at the root of the lung, and the mesenteric lymph glands in the abdomen

Treatment is less often surgical than in former days Heliotherapy, **x-ray**, general hygienic measures, and **vitamin** therapy are usually sufficient.

Pulmonary tuberculosis usually occurs as a chronic disease marked by more or less frequent acute phases A rarer form is an acute form of tuberculosis pneumonia very similar to lobar or bronchial pneumonia. In this acute form the prognosis is poor, as the mortality is high

Chronic pulmonary tuberculosis is the commonest of all forms of this disease It is a disease usually of young adult life. Climate and season have little to do with its incidence Close confining occupations, especially coupled with damp, sunless, and unsanitary surroundings, greatly predispose to this disease The same holds true of living conditions, and it also accounts for the high incidence of tuberculosis in the city as compared to the country

The common form of pulmonary tuberculosis is characterized by areas of softening and ulceration in the lung tissue With adverse conditions within and without the body, the destructive process spreads with varying rapidity The ordinary case passes through acute and chronic stages, with intervening periods of comparative freedom of symptoms Cavity formation in the lungs invading a blood vessel may cause profuse hemorrhage This hemorrhage may be the first noticeable symptom The common symptoms of the average case of pulmonary tuberculosis are variable and are not marked during its early stages A slight, mild chronic cold may mark the onset Malaise, loss of weight and strength, a very slight fever late in the day and increased pulse rate, are usually seen early Chronic coughs with or without sputum is one of the characteristic symptoms Frequently this cough is diagnosed as being due to chronic bronchitis Blood-streaked sputum or frank hemorrhage occurs in about half the cases Any blood brought up from the lungs should be considered as due to tuberculosis unless proved otherwise Pain in the chest sooner or later makes its appearance in most cases, and may be due to adhesions, pleurisy, neuritis, pressure of enlarged glands, etc

The fever is a constant symptom at some time in every case of tuberculosis and results from absorption of the poison produced by the tubercular organism or absorption from the necrotic tissue in the lung. Every known type of fever is found in this disease Gastrointestinal symptoms are common in all stages of the disease

Diagnosis is made by means of a careful history, physical examination, x-ray, and sputum examination

The prognosis in tuberculosis is complicated by many factors Several years of strict regime are necessary for arresting or curing the disease Even after apparent cure, there are certain limitations, as relapses may occur Recovery is more sure when the disease is treated during its early phases Many never recover from tuberculosis because the regime is not followed for a sufficient number of years Deaths in early tuberculosis cases at the end of six years run about 50% to 60%

In the treatment of tuberculosis certain fundamentals must be adhered to They are cheerfulness, good food, fresh air, and bed rest In certain sections of the country, climate is more favorable than in other sections Usually high, dry, sunny climates are the most favorable, such as is found in the Adirondacks, the Rocky Mountain plateau, New Mexico, Arizona, etc. Few drugs are needed in the treatment of tuberculosis

Many selected cases are best cured by the use of artificial **pneumothorax**. Healing is more rapid because the affected lung is put to rest Sterile air is introduced into the pleural cavity, causing collapse of the diseased lung The amount of air introduced is measured by means of a manometer, first devised in connection with pneumothorax work by Saugman about 1908. It is used whenever persistent progressive unilateral pulmonary tuberculosis does not respond to ordinary measures Hemorrhage is usually stopped quickly if collapse therapy can be given Since the introduced air is gradually absorbed, the pneumothorax treatment must be repeated at intervals and is usually continued for a period of two years at least.

When pneumothorax fails due to pleural adhesions or infection of the pleura, thoracoplasty or permanent surgical collapse of the chest by multiple rib resections in two- or three-stage operations saves many otherwise doomed cases This operation is only performed by competent surgeons skilled in chest surgery Crushing of the phrenic nerve, which temporarily paralyzes the diaphragm, is also used at times, either alone or in conjunction with thoracoplasty

Tuberculosis of the circulatory system is quite rare

The serous membranes may be involved, the **pleura** and the **peritoneum** most commonly Tuberculous pleurisy is usually secondary or a reactive agent of a latent infection dating back to childhood Any attack of pleurisy should be considered tuberculous until proof to the contrary has been obtained Unless complicated by pulmonary tuberculosis this form of tuberculosis is usually benign It must be treated, however, similarly to any other form of tuberculosis to prevent its development into a more serious condition

Peritonitis due to tuberculosis is a secondary infection, the original focus being elsewhere The disease may progress rapidly, improve or heal spontaneously Its occurrence and cure is more common than statistics indicate In its chronic stages heliotherapy and high vitamin therapy are of assistance Introduction of oxygen into the peritoneal cavity or simple opening of the cavity have at times arrested the disease

The alimentary tract is often the seat of a tubercular infection The mouth, tongue, pharynx, and tonsils may be involved Laryngeal tuberculosis is exceedingly painful The esophagus and stomach are only rarely affected Intestinal tuberculosis is more common and is usually secondary to pulmonary tuberculosis, although in children it may be primary The only symptoms may be unduly marked fever, loss of weight, and vague abdominal stress X-ray diagnosis is most important

Tuberculosis of the brain and spinal cord is less common than tuberculous meningitis All forms of tuberculosis of the central nervous system are usually fatal

Tuberculosis of the urogenital system is fairly common The kidneys, bladder, seminal vesicles, and fallopian tubes are most frequently involved Unilateral tuberculosis of the kidney is treated by removal of the kidney (R S M)

TUBULARIAE Hydrozoa.

TUBULIDENTATA. The **aard-varks.** An order of mammals found only in Africa Based chiefly on the form of the teeth, which are composed of numerous subordinate parts penetrated by radiating tubules The animals themselves are thick-bodied clumsy creatures with long snouts The name means earth-pig and refers to their somewhat piglike appearance (A W L)

TUBULIFORM GLANDS. Silk glands of **spiders** whose secretion is used in forming the cocoon to contain the eggs They occur only in the female (A W L)

TUCOTUCO. Mammalia, Rodentia Ratlike burrowing animals of South America They have gray fur and red incisor teeth The tail is only moderately long and is clothed with short fur A closely related form with vestigial ears is known in Chili by the name cururo (A W L)

TUCUXI. Mammalia, Odontoceti A fresh-water **dolphin** found in the Amazon river system It belongs to a family differing from that which contains the bouto (A W L)

TUFA. Sinter.

TUFF. Tuff or volcanic tuff is a sedimentary rock, resulting from the partial or complete consolidation of the products of explosive volcanic eruptions Tuffs may be well sorted and stratified, due to the action of wind or water, or may have an unsorted, heterogeneous character As particles making up a tuff become coarser the rock grades into an **agglomerate.** (E S C S)

TULAREMIA. An infectious disease caused by *Bacterium tularense* It occurs primarily as a fatal disease of rodents, mainly rabbits and hares It may be transmitted to man by the bite of certain flies or ticks, or by handling the raw meat of infected rodents Most of the cases have been described in the United States, forty-three states having reported cases The only other countries reporting cases are Norway, Russia and Japan Human infection has occurred in the majority of cases from dressing wild rabbits Infection is not transmitted from man to man

The incubation period of the disease averages about three days The onset is acute, with headache, vomiting, body pains and fever The **lymph glands** draining the infected area, often become infected and ulcerated In certain cases the eye has been primarily infected Convalescence is slow and it may require six months to a year before a return to normal health occurs One attack confers immunity The mortality rate is about four per cent The disease is often erroneously diagnosed as influenza, typhoid, tuberculosis or undulant fever Accurate diagnosis can always be made by an agglutination test of the blood of an infected patient

Prevention may be accomplished by the wearing of rubber gloves in dressing wild rabbits Treatment is symptomatic (R S M)

TULIP Lily family

TULLIBEE Pisces, Teleostei. A common fish (**Pisces**), *Leucichthys tullibee*, of the small lakes from Minnesota to New York and northward into Canada One of the ciscoes or lake herrings Also recorded as the mongrel whitefish and said to occur in small numbers in the Great Lakes (A W L)

TUMBLE-BUG. Insecta, Coleoptera A **beetle** of the family Scarabaeidae which forms and buries balls of dung Numerous species of scavengers in this family have the same habit They are said to use the dung as a supply of food during periods when they remain under ground, and also to bury a ball with an egg attached, to provide food for the developing larva The balls of dung are often much larger than the beetles themselves, and their clumsy maneuvers in rolling their booty to the place where it is to be buried are responsible for the name tumble-bug (A W L)

TUMOR. 1 Any swelling or abnormal enlargement of a part of the body

2 A growth or mass of tissue which develops in the body that serves no use and grows independently of surrounding tissues They are divided into two classes, **benign** and **malignant** tumors (**cancer**) The benign tumors do not spread over the body and cause symptoms only when they are large enough to interfere mechanically with surrounding structures or functions of the body, and they never metastasize or recur after complete excision Examples of benign tumors are fibroids of the **uterus,** fatty and fibrous tumors, and simple cysts Malignant tumors, or cancerous growths do invade surrounding tissues, disseminate throughout the body (metastasize) by means of the blood and lymph vessels, may recur after removal, cause constitutional symptoms, and terminate fatally unless early surgery, with or without the use of X-ray or radium therapy, is resorted to

There are many theories regarding the cause of tumors, but as yet no adequate explanation has been produced. (R S M)

TUNA, TUNNY. Pisces, Teleostei A large marine fish, *Thunnus thynnus,* of the **mackerel** family It attains a maximum weight of more than 1500 pounds and

is highly valued both as a game fish and for food About 15,000,000 pounds are canned annually in California

As a game fish the tuna has no superior It is an unusually vigorous fighter, readily taken with rod and reel on flying fish bait Specimens over 100 pounds are frequently caught and a record fish, more than ten feet long, was taken off the coast of Nova Scotia only a few years ago

The tuna is also called the albacore and horse-mackerel (A W L)

TUNDRA. The tundras are the Arctic plains which, while supporting **mosses** and **lichens** in profusion, and, locally, various flowering shrubs, are treeless The top soil is usually a black muck, the subsoil is perpetually frozen: (R M F)

TUNG OIL. Fixed oils.

TUNGSTEN. Symbol. W. Atomic number: 74. Atomic weight 183 92 Density 19 (1 0–19 1) Melting point 3370°. (**Isotopes:** page 239).

Tungsten is a silver-white to steel-gray, brittle, hard metal, not oxidized by air at ordinary temperature but burns at high temperature, best dissolved by a mixture of **hydrofluoric** and **nitric acids.** Tungsten is used in the production of special alloy tool steels for cutting purposes (16%–20% W), in electric lamp filaments, and in specially hard alloys, *e g*, "carboloy" (tungsten carbide and **cobalt**) and "stellite" (cobalt, 55%, **chromium**, 35%–40%, tungsten, 3%–10%) chemically related to chromium, **molybdenum,** and **uranium** elements

Discovered by d'Elhujar brothers in 1783 Occurs as **scheelite** (calcium tungstate, $CaWO_4$) and **wolframite** (iron and manganese tungstate) chiefly obtained in China Fusing the ore with sodium carbonate and nitrate yields sodium tungstate (Na_2WO_4), which is extracted with water and later acidified, whereupon tungstic oxide (tungsten trioxide, WO_3) is obtained The oxide is reduced by heating with **carbon** or with **hydrogen** to form tungsten metal, from which by "swaging" (rapid mechanical hammering at 1500° C in an electric furnace in an atmosphere of hydrogen) ductile wire is obtained

Chlorides Chlorides of the following composition are reported WCl_4 WCl_5, WCl_6, $WOCl_4$, WO_2Cl_2

Oxides Tungsten dioxide (WO_2), brown solid, by reduction of the trioxide by hydrogen below 700° C, which upon continuation of the same treatment above 780° C forms tungsten metal; ditungsten pentoxide (W_2O_5), blue solid, by reduction of the trioxide by hydrogen at 250°–300° C, tungstic oxide, tungsten trioxide (WO_3), lemon-yellow solid, converted by alkalis to soluble tungstates, by heating with **chlorine** to tungsten oxychloride (WO_2Cl_2), by heating with **hydrogen** sulfide or sulfur to tungstic sulfide (WS_2), by alkalis to tungstates Ammonium phosphotungstate is insoluble, likewise the potassium compound, but the sodium compound is soluble in water (R K S)

TUNIC. The tough enveloping layer or **test** of the **ascidians.** It is formed of a material similar to cellulose, and is the source of the name tunicate applied to some of these animals (A W L)

TUNICATA. Urochordata.

TUNING FORK The tuning fork is a convenient device for preserving a comparatively pure harmonic vibration frequency at nearly constant value It is a U-shaped bar of elastic material, usually steel (but in some modern forks, of fused quartz), the prongs of which vibrate alternately toward and away from each other, with two nodes near the bend of the U The fork may be set vibrating by striking one prong with a mallet, and will, after a moment to allow some high overtones to die out, emit a nearly pure musical tone Large forks are often made to be driven electrically, like an electric bell or buzzer, and will then vibrate continuously for an indefinite time Tuning forks are used in many experiments on **musical sounds,** as standards of pitch, and also for the control of electric oscillations and electric timing devices A fork may be tuned by grinding off the ends of the prongs or by means of sliding weights attached to the prongs Once tuned, the frequency varies only with changes in the elastic modulus of the material. This is slightly dependent upon temperature, hence, for precise work, a fork should be kept in a thermostatically controlled enclosure (L D W)

TUR. Mammalia, Artiodactyla A wild **goat** of the Caucasus mountains It is a large species with strong, slightly spiral horns Although closely related to the sheep it has the characteristic beard of the goats (A W L)

TURBELLARIA. The free-living flatworms, a class of the phylum **Platyhelminthes.** Unlike the parasitic members of this phylum, these worms have a cellular ectodermal covering bearing cilia, with the exception of a few parasitic members which resemble the flukes and tapeworms in the absence of cilia The free-living members of the class also have sense organs located at the anterior end of the body, including a pair of eyes and tentacles The mouth opens on the ventral surface, either near the head or near the end of the body, and the alimentary tract (**digestive system**) is branched in many forms to extend widely through the body The terminal portion of the tract forms a protrusible proboscis The turbellarians are **hermaphrodite** with very few exceptions

Flatworms of this group are often common in small streams and ponds, and some are marine They glide over surfaces by the action of the cilia of the lower surface, aided by the secretion of a trail of mucus, or move by undulations produced by muscular action Their food consists of small animals, living or dead

The class is divided into four orders.

Order Acoela Without a hollow gut The endodermal cells are fused together These worms live in **symbiosis** with algae contained in the cells of the body

Order Rhabdocoelida Mouth anterior, leading into an unbranched gut Chiefly fresh-water species Some small marine forms

Order Tricladida Mouth approximately central Gut with three main branches This order includes the common fresh-water forms, *Dendrocoelum* and *Planaria,* and some species that live in moist situations on land Some are large and brightly colored

Order Polycladida Mouth behind the middle of the body Gut with many branches from a small main portion Marine species Some large and leaflike (A W L)

TURBOT. Pisces, Teleostei A large **flatfish,** *Psetta maxima,* of the European side of the Atlantic It reaches a length of three feet and is regarded as the best food fish of the group On the Atlantic coast of North America a small and useless related species is commonly called the window pane (A W L)

TURBULENCE. Turbulence refers to a condition of flow of a **fluid** in which the fluid does not flow in fixed streamlines. In non-turbulent flow there is no transverse velocity to the streamline Turbulent flow is characterized by components of velocity transverse to the main line of flow The flow of water is turbulent except for low velocities in small conduits Turbulence provides mixing and seems to reduce the surface friction of a fluid The mixing is desirable where heat is being transferred by conduction to the fluid, since it prevents establishment of a heated layer next to the wall Turbulence has many engineering uses, and offers, as well, some highly technical problems. The turbulence of gases undergoing combustion in a furnace is of great importance in certain furnaces as a means for preventing blanketing of burning fuel particles by carbon dioxide.

In recent years the importance of turbulence in the field of aeronautics has come to be recognized, since it is present in **wind tunnels**, but not ordinarily in free air Consequently, the results obtained from wind tunnels must be duly modified and corrected for the absence of turbulence in free air when those results are to be applied to full scale design (F T M)

TURKEY. Aves, Galliformes *Meleagris* A large game bird (**Aves**) of North and Central America Wild turkeys are now abundant in some of the protected areas of the eastern states, and in the southwest they may be found in wild areas In comparison with their former abundance, however, they are now rare. The eastern species is easily distinguished from the western by the absence of white tips on the feathers of the tail and rump A third species occurs in Central America (A W L)

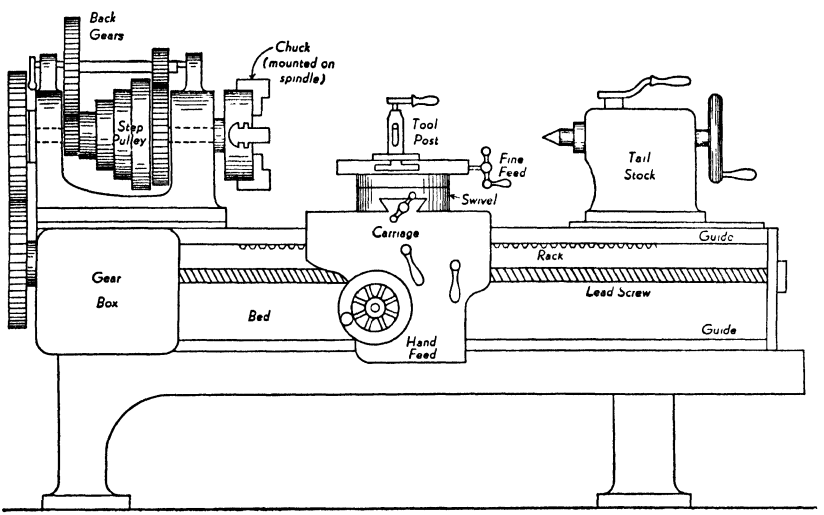
TURMERIC. *Curcuma longa* Zingiberaceae The name turmeric has been given to both the plant, *Curcuma longa*, and to its derivatives, a dye and a drug, which are obtained from the swollen **rhizomes** of the plant

Curcuma, a native of southern Asia, is widely grown in India and other tropical Asian and East Indian lands, where it is used as a drug as well as a condiment and dyestuff The plant has long smooth pointed leaves, and dull yellow flowers To prepare it for use, the yellow-brown aromatic rhizome is cleaned and cut into pieces 1 to 2 inches long The cut surfaces show the bright yellow color of the substance of the rhizome These cut pieces are dried in an oven and then ground In western countries turmeric is sometimes used as a dye, as an ingredient to curry powder, and in chemistry, where it is a test for alkali Other species of *Curcuma* yield products used in making Oriental tonics and **medicines.** (R M W)

TURNBULL'S BLUE. **Ferricyanic Acid and Ferricyanides.**

TURNING. The operation of turning consists of the shaping of stock into a piece having a circular outline at all cross-sections Turning involves the controlled cutting of the work by a tool which is brought to bear against it while it is revolved by a spindle. The work may be affixed to the spindle through the medium of a **chuck** which is screwed to the spindle, or it may be held between centers and driven from the face plate, screwed to the spindle, by means of a lathe "dog" The operation of turning is thus clearly distinguished from a cutting job such as milling, wherein the work is not necessarily circular on all sections taken at right angles to its axis, and from spinning of metal, wherein hollow shell parts resembling externally what may be performed on the lathe, are created by pressing a revolving ductile sheet of metal over a preformed pattern In spinning, chips are not cut from the work, and furthermore, it is used only with such plastic metals as copper and aluminum Turning may be performed on any material which will retain its rigidity when held in a lathe, and from which a small shaving or chip can be cut by a tool without disturbing the underlying part Wood and metal, however, are the chief materials which require turning The wide range of turning done on these raw materials may be exemplified in wood by comparing the sizes of the small cabinet maker's bench lathe with the gigantic veneering lathes which unwrap, as it were, sheets of veneer from logs ten feet long and several feet in diameter In the metal working lathe, the extremes are even more pronounced At the small end there is the jeweler's lathe, which may machine so delicately that the work must be viewed through a magnifying glass, and on the opposite extreme, such huge installations as car wheel lathes, and other special types even larger

From the various classes of metal working lathes briefly mentioned under the head of **machine tool,** the engine lathe is taken as the subject of description in this article, as it is a general purpose lathe more widely used than any other type, and is satisfactory for illustrating the basic principles of turning As is seen in the figure, a head and tail stock are mounted upon a substantial bed The tail stock is movable longitudinally upon machined ways, to which it may be clamped by a suitable handle The tail stock contains a recess into which may be fitted a cone center, a boring bar, a drill, and the like, and which may be advanced slowly by a hand wheel driven screw The tail stock is employed when boring, and when turning between centers The

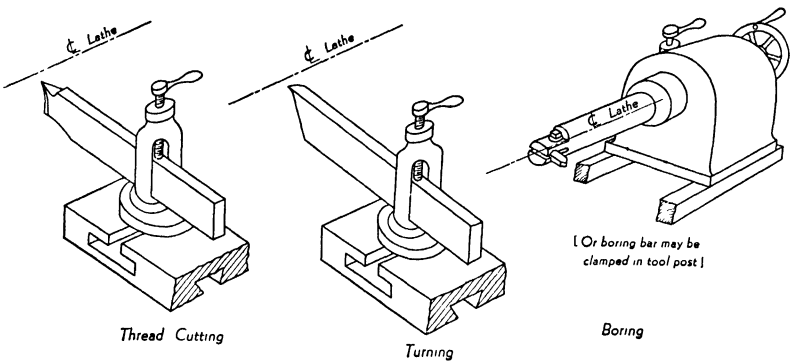


Principle of the engine lathe.

head stock is fixed and contains bearings for a spindle. On the end of the spindle is screwed a chuck, and on it is mounted also, free to turn, a step **pulley,** which will be driven from a **countershaft.** This step pulley can be locked to the spindle, or it can be connected to the spindle through a system of **reduction gears** known as back gearing, which can be thrown in or released at the will of the operator Thus in the example shown, with a four step pulley and single reduction back gears, eight spindle speeds are possible On the end of the spindle opposite to the chuck is mounted a **gear** which mates with one on a shaft extending into the gear box The gear box contains change speed gearing by means of which the ratio of rotative speed of the lead screw and spindle is altered at will It is the lead screw extending from the gear box along the bed of the lathe which distinguishes the "engine" lathe from a plain lathe The carriage slides upon machined guide rails and carries on it a cross feed, a fine feed, a swiveling head, and the tool post The carriage can be moved either by the lead screw, or manually by a hand feed wheel which, through reduction gearing, engages a pinion on the fixed rack The operator will often move the carriage manually when turning short pieces, but when turning long pieces between centers, or when cutting screw threads, the carriage will be driven by the lead screw The interposition of a swiveling head between the coarse cross feed and the fine feed permits the latter to be set at any desired horizontal angle

As an example of the use of the lathe for cutting screw threads, suppose it were desired to cut a thread having twenty-four teeth to the inch, ie, twenty-four pitch Assume the lead screw to be ten pitch Then when the lead screw had made 10 revolutions, the spindle should have made 24 The gear reduction should be so chosen that the spindle makes 2 4 revolutions while the lead screw revolves once In practice it is not necessary to compute the speed reduction of the whole gear train, since the manufacturers provide an indexing handle on the gear box, by which it may be readily and quickly set for any desired condition within the range of the lathe The particular spindle speed chosen will be selected with respect to the allowable cutting speed of the material being turned For heavy turning, many lathes are provided with a pump and circulation system, so that a "cutting fluid" may be discharged on the work at the point of the tool, cooling and lubricating it This cutting fluid is lard oil, or some water-soluble liquid

The common wood lathe is fitted with a head and tail stock, but with no back gears, gear box, lead screw, or carriage A movable tool rest is provided, and the tools so supported are held against the work and fed by hand Thus considerable personal dexterity and skill may enter into wood turning, where it does not in metal turning The tools employed for wood turning are provided with wooden handles so that they made be readily and firmly grasped, and with cutting edges of various types as needed for the job Some of the more common wood turning tools are the gouges, the flat chisels, and cutoff tools Due to the development of inexpensive and satisfactory bench turning outfits, this art has reached into the schools and homes to a large degree, and its manipulations are much more generally known than is true of metal turning (F T M)



Lathe tools

TURNIP. Brassica.

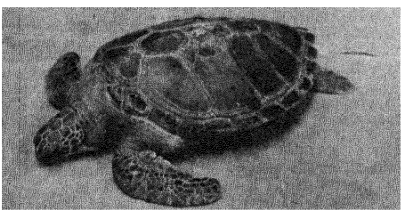
TURNSTONE. Aves, Charadriiformes *Arenaria* Shore birds (**Aves**) related to the plovers and oyster-catchers They are found chiefly in the far north, migrating southward, chiefly along the coasts, in both the Old and New Worlds They winter as far south as Patagonia. (A W L)

TURPENTINE. Resins; and Pistachio; and Terpenes.

TURQUOIS. The mineral turquois is a hydrated **phosphate** of **aluminum** and **copper.** Its exact composition is doubtful, the formula may be expressed $H_8Al(OH)_8$ $6Cu(OH)(PO_4)_4$, iron is often present. This mineral is found in minute **triclinic** crystals, but chiefly massive as seams and crusts The fracture is conchoidal, hardness, 5–6 , specific gravity, 2 6–2 8 , luster, soft waxy, color, may be various shades of blue, bluish green and green, essentially opaque It takes a good polish and the sky blue, varieties have long been used as a gem material Unfortunately many beautiful blue stones in time change their color to some greenish hue, usually not attractive, rendering them practically valueless For hundreds of years turquois has been mined in Persia where it is found with **limonite** filling crevices in a brecciated **trachyte-porphyry;** and because it found its way into Europe through Turkey it became known as turquois, from the French word *turque,* Turkish Other mines were worked by the Egyptians in ancient times on the Sinai Peninsula. Turquois is also found in Siberia, Turkestan, Saxony and France, and in the United States in Arizona, California and New Mexico A blue stone that has passed for turquois is in reality odontolite, from the Greek meaning tooth, usually fossil teeth or bones colored with iron phosphate Odontolite is softer than true turquois, has a somewhat higher specific gravity, 3 0–3 5, and may be distinguished by chemical tests, or by a microscopical examination which will reveal its organic structure (E S C S)

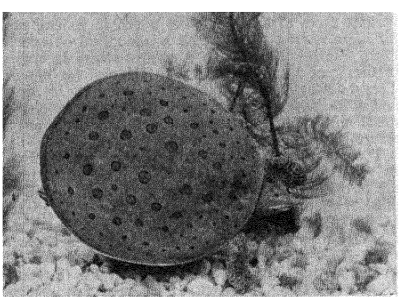
TURTLE. Reptilia, Chelonia. A **reptile** with a broad flattened body enclosed in a shell formed of a dorsal carapace and a ventral plastron, united at the sides. Most species are able to withdraw the head, legs, and tail into the shell for protection. The exposed parts of the skin are scaly.

Many turtles are partially aquatic and some marine



Atlantic green turtle. (Courtesy of N. Y. Zool. Soc.)

species leave the water only to deposit their eggs. In the latter the legs are developed as broad flippers. Turtles are to be found along almost any stream and are often abundant. The group includes both herbivorous and carnivorous species. The flesh of some species is regarded as an unusual delicacy.



Soft-shelled turtle. (Courtesy of N. Y. Zool. Society.)

Some species of turtles are known by distinctive vernacular names, as **slider, cooter,** and **terrapin,** and a number of them are called **tortoises.** (See also **Fossil Reptiles.**) (A.W.L.)

TURTLE STONE. Concretion.

TWILIGHT. Twilight is produced primarily by **reflection** of the light of the sun from the upper atmosphere of the earth, but effects of **scattering of light,** and **refraction** also enter into the period of duration of twilight. Morning twilight begins and evening twilight ends when the sun is about 18° below the **horizon,** although this value varies somewhat with the purity of the atmosphere.

The angle which the path of the sun at setting makes with the horizon depends upon the **latitude,** the sun setting perpendicular to the horizon at the **equator.** The apparent velocity of the sun on the equator is practically constant for all latitudes and all seasons, but the time required for the sun to get 18° below the horizon will be much shorter at the equator than in high latitudes. Accordingly, the duration of twilight in the tropics is much shorter than it is in high latitudes such as Scotland.

The so-called twilight arch may be observed above the eastern horizon on a clear evening as the sun sets in the west. This is a blue segment bounded by a faintly reddish arc, and is in reality the shadow of the earth cast on the upper atmosphere. (W.K.G.)

TWILIGHT SLEEP. A light anaesthesia produced by the hypodermic use of **morphine** or **scopolamine.** It has been used in labor and also pre-operatively and post-operatively. In this state the patient is not totally unconscious, but does not remember the occurrence of any pain. It is not often used in labor at present as more satisfactory drugs are available. (R.S.M.)

TWIN CRYSTALS. Those **crystals** in which one or more parts regularly arranged are in reverse position with reference to the other part or parts. They often appear externally to consist of two or more crystals symmetrically united, and sometimes have the form of a cross or star (Dana). (R.M.F.)

TWINS. Two individuals born at the same birth. **Identical** twins are twins developing from one fertilized ovum. They are always of the same sex and similar in appearance. Fraternal twins are twins developing from two fertilized ova. These may be of either sex, and may or may not be of similar appearance. (R.S.M.)

TWISTED CURVES. Curves in Space.

TWITCHELL'S REAGENT. This is a catalyst for the **hydrolysis** of **fats.**

TWO-BODY PROBLEM. The so-called two-body problem is the foundation of **celestial mechanics.** The solution of the problem requires two fundamental assumptions (1) that two and only two objects exist in the universe, and (2) that some law of force between the two objects is given. With these assumptions admitted the two body problem may briefly be stated as follows: given the relative positions of two objects at any instant, together with their motions and masses at that instant, to predict the positions and motions of the objects at any subsequent instant.

The two-body problem was first solved by **Newton** by considering the motions of the individual planets about the sun. To satisfy the first assumption of the problem Newton assumed that the force between the sun and an individual planet was so much greater than the force between any two planets, that the sun and the planet could be considered, as a first approximation, to be isolated in space. The inclusion of the forces between the different planets as well as the force between the sun and the individual planet leads to the **three-body problem.** When Newton first attacked the two body problem no law of force between objects in space was known, but the **Keplerian laws of planetary motion** had already been empirically derived. Newton was familiar with the characteristics of **centrifugal force** and realized that no object could revolve about another (as the moon does about the earth) unless there is some force of attraction between them to counteract the centrifugal force. Considering as a first approximation that the orbit of the planets about the sun is circular he found that if the force of attraction between the sun and the individual planets varies inversely as the square of the distance then, and only then, does the so-called harmonic law of Kepler result.

Newton realized that in his establishment of a theoretical foundation for the third of Kepler's laws of planetary motion he had violated the first, for Kepler specified that the motion must always be elliptical and Newton had used the circle (a very particular ellipse). The mathematics of Newton's time was not sufficiently developed to permit of a solution of the problem of elliptical motion and Newton was forced to develop the theory of fluxions, the parent of the modern **calculus,** to accomplish his solution. Using the Cartesian system

of geometry and his own theory of fluxions, Newton was able to show that all three of the Keplerian laws of planetary motion were consequences of the planets moving about the sun under the influence of a force emanating from the sun and varying inversely as the square of the distances of the objects from the sun In a similar manner Newton was able to explain the motions of **Jupiter's satellites,** and the motion of the moon about the earth Newton firmly believed that the force involved was the so-called force of gravitation which had been described some time previous in connection with the laws of falling bodies on the earth He stated the law in its familiar form that. every particle of matter in the universe attracts every other with a force which varies directly with the product of the masses of the two objects and is inversely proportional to the square of the distance between them

With the law of force between the two objects thus stated Newton was able to completely solve the two body problem as stated in the opening paragraph of this article Publication of his solution was delayed for many years, because Newton was unable to verify his hypothesis numerically, since the distance between the earth and the moon was imperfectly known Subsequent applications of the two body problem have lead to modern methods for **orbit** computation and the multitude of other problems in the field of celestial mechanics. Within recent years the two body problem has had a number of applications in the treatment of problems in atomic structure (W K G)

TWO-CYCLE. Two-cycle refers to a sequence of operations by means of which the cycle of the **internal combustion engine** is performed It is a shortened form of "two-stroke cycle," which may be taken to imply that the cycle is completed in two strokes of the piston The two-stroke actions to be described here should be compared with the four-stroke described under **four-cycle.**

A two-cycle engine must be so arranged that it can be supplied with a fresh charge when the **piston** is in the extreme outward position In general, any internal combustion engine must first introduce the fresh charge, compress it, then ignite and expand it after combustion, obtaining power, then exhaust the products of combustion To obtain all these functions in two strokes of the piston, it is necessary to shorten the period of time that can be allotted to induction and exhaust For this reason, the **volumetric efficiency** of the two-cycle engine is inferior to that of the four, and, although it receives a power impulse every revolution, instead of every two revolutions, the power falls short of being double that of the four-cycle engine of corresponding size and speed

In a simple type of two-cycle engine, valves are replaced by ports in the cylinder, which are uncovered by the piston as it nears lower dead center One cylinder port leads to the atmosphere, and through it the burned gases are expelled by the pressure remaining in the cylinder The other port opens from a by-pass to the crankcase, and through it a slightly compressed charge is delivered to the cylinder when the piston uncovers the port. In some types, the gas is compressed in the crankcase by the piston, but this is often done by an external compressor of a piston or rotary type The extremely short time which the ports are open renders the two-cycle engine less suitable for high speeds than the four-cycle engine However, with certain modifications, the speed may be considerably increased without great sacrifice of efficiency One method is to place auxiliary poppet exhaust valves in the cylinder head, mechanically operated, to aid in clearing the cylinder of burned gas, and this will also aid indirectly in obtaining a better induction of the fresh charge However, the introduction of an exhaust valve nullifies one important advantage of the two-cycle principle, namely, the absence of such valves (F T M)

TYCHO BRAHE (1546–1601). Tycho Brahe was born in 1546 the eldest son of a Danish noble family who were, according to one biographer, "as noble and ignorant as sixteen undisputed quarterings could make them" For one born in the period when the nobility spent its time in hunting and killing, it was fortunate that Tycho had an uncle with no son of his own who was a more educated man than was Tycho's own father This uncle gave Tycho a good education and sent him to the University to study law Entering the University of Copenhagen at the age of thirteen he experienced an event which was destined to influence all of his future life. An **eclipse** of the sun was predicted for August 21st, 1560, and, when the eclipse took place very close to the predicted time, Tycho was inspired to devote the remainder of his life to the observation and study of the celestial bodies He was sent on to Leipzig with a tutor to continue his study of the law, but instead he spent all of his money for books and instruments and sat up most of the nights studying the skies.

In 1563 he observed a conjunction of Jupiter and Saturn and finding that the existing tables of those planets were considerably in error, he formed the resolution to correct them In 1565 his uncle died and made Tycho his heir Tycho immediately returned to Denmark where he was greeted with ridicule for his desire to continue astronomical observations To escape derision he returned to Germany and finally settled down in Rostock where he was rash enough to become involved in a duel in which his nose was cut completely off For the remainder of his life he was adorned with various types of artificial noses which in general excited far more interest than did his astronomical observations From Rostock he went to Augsburg where he was able to fire some kindred spirits with the zeal for observing They built a huge quadrant which stood in the open air and with which a large number of observations were made until the instrument was finally wrecked in a severe storm

Tycho returned to Denmark in 1571 where his fame as an observer had preceded him In order that he might obtain better instruments he turned to the study of alchemy and might well have become lost in the mazes of this useless profession had it not been for the appearance of a brilliant **nova,** or new star, in November, 1572 This turned his zeal back again to astronomy and from that time on he devoted his entire life to the study of the heavens Frederick II of Denmark recognized the genius of Tycho and gave him a large estate in Norway, an ample pension for life, and a large sum of money with which to build an observatory. The observatory was constructed between Copenhagen and Elsinore and was the first real astronomical observatory built

The observatory, which he called Uranienburg (the castle of the heavens), became the Mecca to which all of the scientists and nobility of the world came either to study with the great observer or to satisfy idle curiosity Tycho was never a diplomat and, in these times, would undoubtedly have been classed as a radical He insulted many of the nobles with the ultimate result that complaints were lodged against him with the Danish king From that time on Tycho led an unhappy life His estate and pension were taken away from him and he was forced to flee the country, leaving his wife and instruments to follow him when he could obtain a new location The Emperor, Rudolph II, of Bohemia was enlightened enough to give Tycho refuge and in Prague the instruments were again set up and the observations resumed Students flocked to Prague to study, and among them was one Johann **Kepler,** to whom Tycho was very kind and who was destined to surpass his master in later years

The contributions of Tycho to astronomy were purely observational in character He was not a theoretical worker, but when he died he left behind him a great mass of observational material which was used by Kep-

ler in the development of his famous laws of planetary motion. His most notable attempt at theoretical work was to develop a theory for the solar system in which the earth remained stationary with the sun revolving about it. The other planets all revolved about the sun as in the **Copernican** theory. Tycho undoubtedly proposed this complicated system because he recognized the comparative simplicity of the **Copernican** over the **Ptolemaic** theory, but his own observations failed to reveal the apparent change in position of the stars as required by the moving earth of the Copernican theory. (W.K.G.)

TYLOSAURUS. Cretaceous.

TYLOSES. Tyloses are balloon-like outgrowths which develop from the living **parenchyma** cells in the woody tissues of older portions of stems. The protrusions push through the **pits** in the cell wall and gradually fill the lumen, or tube, of the cell until the latter is completely clogged. (R.M.W.)

TYMPANUM. A thin membrane associated with organs of hearing. The tympanum vibrates in response to sound waves and its vibrations are communicated to the nerve endings of the auditory organ. In **insects** the tympanum is a modified area of the integument. In **vertebrates** the tympanum or **ear** drum develops as a specialized area of the skin in the region of the ear, and persists in this condition in the **amphibians.** In the higher classes of vertebrates this area is depressed until it lies at the inner end of the canal of the outer ear. (A.W.L.)

TYPE METAL. Alloys.

TYRANNOSAURUS. Cretaceous; also Fossil Reptiles.

U

UDAD. Mammalia, Artiodactyla. The Barbary **sheep,** *Ammotragus lervia,* a large African species with a growth of long hair extending from the throat down over the fore legs. The horns are long, heavy, and strongly curved. This species has been called the udad, aoudad, or audad, but according to some writers the name arui is applied to it by the Arabs. (A.W.L.)

UINTAITE. Gilsonite.

UINTATHERIUM. Eocene. Fossil Mammals.

ULCER. A shallow, open sore that penetrates the skin or mucous membrane. They are usually sluggish in character, showing little tendency toward healing. Ulcers occur on the surface of the body, especially the legs as a result of impaired circulation, and are most commonly associated with varicose veins, **diabetes,** and **arteriosclerosis.** They may also occur in certain forms in **syphilis, tuberculosis,** and other diseases. **Cancerous** growths may become ulcerated, especially in the later stages. Ulcers are prone to form following a trivial injury in areas of the body where circulation is poor.

Ulcer of the right leg due to varicose veins. The large, tortuous vessel draining this area can be seen.

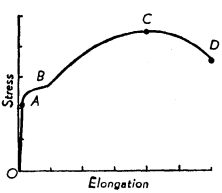
Ulcer of stomach or duodenum is a common disease due to a variety of factors. First, a break in the lining membrane of the organ must occur, and second, it is kept open and increases in size due to digestion by the gastric juices. Other factors, however, must be present, such as a disturbance of circulation and functional disorders of the nerves supplying the organ. They are most apt to occur in the thin type of person who is easily worried, fatigued and generally under par.

Ulcers can occur in the intestinal tract. They accompany typhoid fever, and in certain forms of **colitis** are a constant finding in the large intestine. Tuberculosis may also be accompanied by internal ulceration. (R.S.M.)

ULTIMATE ANALYSIS. One of the methods of reporting the analysis of a fuel is on the basis of the chemical elements present, and their proportions by weight. Since such an analysis reports the composition of a substance in terms of its ultimate elements, it has been called the ultimate analysis. Essentially, it is a chemical analysis, as contrasted to the physical basis of the **proximate analysis.** The analysis of a fuel, solid, liquid, or gaseous, as the case may be, for the purpose of resolving it into an ultimate analysis, is a process requiring the trained knowledge of the chemist, the apparatus of a well equipped chemical laboratory, and no inconsiderable perfection of technique. For this reason, the taking of an ultimate analysis has become a specialized subject. Through several years of fuel research and experimentation, many data on the ultimate analyses of coals from different seams have been accumulated, and it is safe to say that very few commercial seams of the present time are without a published analysis of their typical product.

Combustion calculations are essentially calculations of chemical reactions. Any quantitative work starting with chemical reactions must rest on a knowledge of weights of the elements entering into the reaction. It is to be expected, therefore, that the ultimate analysis would be required for combustion calculations. It is in the field of combustion calculations that the engineer is to be found making extensive use of the ultimate analysis of his fuel. (F.T.M.)

ULTIMATE STRENGTH. The ultimate strength is the maximum unit **stress** which can be developed in a structural material, based on the original cross-sectional area. If a specimen of a structural material, such as steel, is clamped in a testing machine, and subjected to slowly increasing tension, it gives slightly, due to its elastic properties. (See **Elasticity, Adhesion and Cohesion.**) The elongation is so slight that sensitive instruments must be employed to detect the elongation, but nevertheless it exists. Up to a certain point known as the proportional or elastic limit, the elongation is directly proportional to the stress, and if the load is withdrawn, the specimen recovers its original length. The relationship between stress and elongation is shown plotted in the accompanying figure. The point *A* is the proportional limit. Further increase or tension brings on increasing rate of elongation, and the material will suddenly yield to considerable elongation without a proportional increase of stress. This is known as the yield point. The initial yield having been brought about, the specimen recovers, in some measure, the ability to carry more stress with greater elongation until the ultimate strength of the material is reached, when considerable stretch occurs, and unless the load is relieved very rapidly, the critical section "necks down," and fracture occurs. The ultimate strength of most carbon steel is approximately 60,000 pounds per square inch, the yield point 40,000 pounds per square inch, and the proportional limit 30,000 pounds per square inch. By properly alloying (See **Alloys**), these points may be pushed considerably higher; for example, in tempered vanadium steel, where the ultimate strength may be over 125,000 pounds per square inch; chrome molybdenum, over 240,000 pounds per square inch. (F.T.M.)



Stress-strain diagram for steel.

ULTRABASIC. A term proposed by Judd in 1881 for exceedingly **mafic igneous rocks** composed largely, if not entirely, of the ferro-magnesian minerals such as **olivine** and **pyroxene.** The limiting figure of total **silica** is approximately 45 percent, or barely sufficient to supply the needs of the basic silicates. (R.M.F.)

ULTRAMICROMETER. Condenser.

ULTRAMICROSCOPE. The ultramicroscope is not an instrument of extraordinary magnifying power, as its name might suggest; the term has reference rather to a special system of illumination for very minute objects. Such objects as colloidal particles, fog drops, or smoke particles, are held in liquid or gaseous suspension in an enclosure with an intensely black background (usually of the **black-body** type), and illuminated by a convergent pencil of very bright light entering from one side and coming to focus in the field of view,—the so-called "Tyndall cone" familiar in experiments on **scattering.** With this arrangement, objects too small to form visible images in the microscope produce small **diffraction** ring systems, which appear as minute bright

specks on a dark field. The device is used in studying the **Brownian movement,** in the Millikan droplet method of measuring the electronic charge (See **Electron**), in observing ionization tracks in the **cloud chamber,** etc. (L.D.W.)

ULTRASHORT WAVES. Electric Oscillations and Electric Waves.

ULTRASONICS. Elastic waves of frequencies far beyond the range of audibility, called ultrasonic or supersonic waves, present some interesting aspects. Such waves are conveniently produced by quartz crystal oscillators (See **Piezo-Electricity**) designed for frequencies ranging up to 200 or 300 kilocycles per second. Various acoustic phenomena may be demonstrated in these high ranges, and the waves are useful in illustrating principles of optics. For example, it is possible to construct a coarse, concave **diffraction grating** to form the **spectrum** of such sounds, or an ultrasonic **interferometer** to measure their wave lengths.

Some curious effects are observed when the oscillator is immersed in a vessel of oil. The surface of the liquid bulges up into an agitated heap and emits a spray. If the oscillator is placed at the bottom of the vessel and a horizontal metal plate is lowered into the oil, the plate experiences a distinct upward thrust which has pronounced maxima and minima as the plate is pushed downward, corresponding to the **interference** nodes and antinodes of "stationary" waves. A glass rod held between the fingers and dipped into the oil is so violently (though silently) agitated that its friction may burn the fingers. Small animals in water thus agitated quickly die, and blood corpuscles are destroyed, which suggests caution in exposing the body to such high-frequency vibrations. The waves have been used in **sounding** the depth of water. (L.D.W.)

ULTRAVIOLET RADIATION. A range of radiation of frequencies next higher than those of the visible violet. If light from an open **arc** is passed through a quartz prism and allowed to fall on a white wall, the familiar **continuous spectrum** appears, ranging from the extreme red to the extreme violet. But if we substitute for the white wall a suitable fluorescent screen, the spectrum is seen to extend considerably beyond the violet, that is, into the region of shorter wave lengths known as ultraviolet. This spectral region has been observed over more than three "octaves" of the radiation frequency scale, roughly from 4000 angströms at the extremity of the violet to below 400 angströms. The ultraviolet range has pronounced photographic and ionizing effects, and so is easily detected. The chief hindrance to its study is its rapid absorption in most forms of matter; even air is a serious obstacle to the shorter ultraviolet waves. The **sun** is an intensely hot source of radiation, but its spectrum ceases quite abruptly just below 3000 angströms because, it is believed, of absorption by atmospheric gases, chiefly oxygen and ozone. (This is fortunate, as the shorter radiations may be very injurious to living tissues; sunburn is attributed in large measure to them. Like x-rays, they should be applied to the body only under the direction of a doctor.) It is therefore necessary to turn to artificial sources, chief among which are solid-electrode arcs and, especially, the **mercury arc.** Since quartz and fluorite are much more transparent to ultraviolet than is glass, it is necessary that plates, lenses, and prisms for this region be made of these materials. Silver is a much poorer reflector of ultraviolet rays than certain alloys, so that mirrors and reflection gratings are made of the latter. Schumann developed the technique of spectroscopy in the far ultraviolet (the "Schumann region") and prepared plates especially adapted to its photography; so that now, with the vacuum spectrograph and Schumann plates, the ultraviolet spectra of substances are studied almost as thoroughly as the visible.

In medicine, ultraviolet radiation is used therapeutically as a tonic and stimulating measure in certain conditions, to promote healing of indolent and sluggish wounds and for disinfectant purposes. In certain diseases it is curative as in **rickets** and **tetany.** It is also used in bone and gland tuberculosis and in certain skin diseases. In 1924 it was shown by Hess and Steenbock that various foods became activated with **vitamin** D, showing marked antirachitic powers after being exposed to ultraviolet rays. Milk is commonly treated in this way as well as other foods. Viosterol is made by the ultraviolet irradiation of **egosterol.** (L.D.W., R.S.M.)

UMBEL. Flower.

UMBILICAL CORD. A tube-like structure extending from the navel of the **fetus** to the **placenta** of the mother. It contains two arteries and one vein and serves as an excretory, digestive, and respiratory mechanism for the fetus. (R.S.M.)

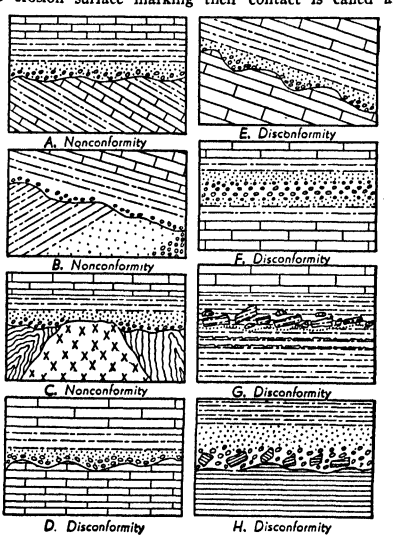
UMBILICUS. The scar on the ventral surface of the abdomen where the umbilical cord is severed at birth in the **placental** mammals. The navel. (A.W.L.)

UMBO. A rounded prominence near the hinged edge of a **bivalve** shell. In the shells of **molluska** an umbo appears on each valve, representing the point where the initial deposits of shell were formed. Many shells show lines of growth where the margin has extended little by little from the umbo. The lower valve of the shell of **brachiopods** extends behind the upper in a beak which is also called the umbo. This structure is perforated by the stalk of the animal. (A.W.L.)

UNAU. Sloth.

UNCERTAINTY PRINCIPLE. Quantum Mechanics.

UNCONFORMITY. If **deposition** in a given area is interrupted for a time by **erosional** processes, then renewed, a dissected surface will separate the two groups of beds, which are then said to be unconformable, and the erosion surface marking their contact is called an



Types of unconformities. (Field, *Outline*, Barnes & Noble.)

unconformity. If this unconformable relationship of two rock groups is of limited extent, the unconformity is then said to be local, if of wide extent it is called a regional unconformity. If two groups of sedimentary rocks are separated by an unconformity on tilted beds, it is then called a nonconformity or angular unconformity. When the plane of erosion occurs between relatively horizontal formations it is called a disconformity. Principal types of unconformities are illustrated on page 1165. *A* represents a nonconformity having an irregular erosion surface, developed on the upturned edges of different formations, and covered with a basal conglomerate which grades through sandstone and shale into limestone. In *B* the nonconformable series has also been deformed together with the second wave of deformation which affected the already deformed beds beneath the unconformity. *C* represents a major nonconformity in which the erosion surface truncates highly metamorphosed formations and batholithic intrusives. The basal conglomerate rests upon a plane of erosion which, in itself, must represent a great physical hiatus or lack of stratigraphic record for this region. *D* and *E* represent disconformities which have been developed upon a prelithified surface. In *E* the disconformable formations have been subsequently deformed (tilted). *F* represents a graduational contact, or one in which erosion and depositions have been relatively continuous. *G* represents a gradational contact developed in plastic sediments, with the development of mud cracks and intraformational conglomerates. *H* represents a disconformity in which the basal breccia is composed of the lithified fragments of the older formations, plus foreign clastic material. As the fossils above and below the disconformity are the same, the disconformity, though pronounced, signifies slight, if any, hiatus (**diastem**). Disconformities of types *F, G,* and *H* may represent either slight or great hiatus. (Note) The true amount of hiatus can only be measured by paleontological means. With the exception of a major nonconformity, the physical evidence of hiatus (unconformity) is seldom a safe criterion alone. Thus the terms nonconformity and disconformity have structural but not necessarily stratigraphic, or time significance. (R.M.F.)

UNDERWING. Insecta, Lepidoptera. A **moth** whose fore wings are colored in dull shades of gray or brown, but whose hind wings are in most species brightly banded with black and some shade of yellow, orange or red. The name is used for the large moths of the family Noctuidae and the genus *Catocala*, although members of other genera are colored in a similar way. The genus *Catocala* is so extensive, with more than one hundred species in North America alone, that it has attracted the attention of specialists and has been studied in detail. For the same reason the moths are very likely to be seen without special search. They hide about buildings in the daytime, as well as on the trunks of trees. A flash of bright wings in the garage is quite likely to mean a disturbed underwing. (A.W.L.)

UNDULANT FEVER. Malta Fever.

UNDULATING MEMBRANE. A form of **organelle** found in some of the one-celled animals. Undulating membranes of two forms appear, one in the ciliates and the other in certain flagellates. The former is composed of numerous **cilia** associated in a row near the oral structures of the animal. The flagellate membrane is developed in the **trypanosomes** as a delicate membrane along one side of the body, bordered by the **flagellum.** It vibrates in an undulating movement as an organ of locomotion. (A.W.L.)

UNGUICULATA. A division of the class **Mammalia** used in the older classifications for the forms with claws. If used at all in modern classifications it is regarded as a division of the subclass Eutheria containing the orders **Insectivora, Dermoptera, Chiroptera, Carnivora, Rodentia, Edentata, Pholidota,** and **Tubulidentata.** (A.W.L.)

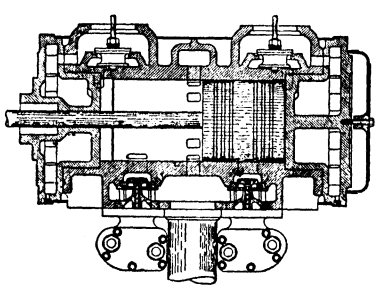
UNGULATA. An older division of the class **Mammalia** whose standing is like that of the Unguiculata. It includes the hoofed animals and related forms whose feet bear heavy nails or nail-like hoofs, embracing the orders **Artiodactyla, Perissodactyla, Proboscidea, Sirenia,** and **Hyracoidea.** Although the term is almost obsolete it persists commonly in reference to the members of the first two orders as the even-toed and odd-toed ungulates, respectively. (A.W.L.)

UNIAXIAL CRYSTALS. Double Refraction.

UNIFIED FIELD THEORY. Fields of Force; Relativity.

UNIFLOW. The term uniflow designates one-way flow of a fluid through a cylinder. While it is sometimes employed to differentiate between the flow of gases in two- and four-stroke cycle engines, uniflow has come principally to designate that improved type of **steam engine** in which the exhaust is arranged so that the steam flows from the end of the cylinder to exhaust ports located near the center, and does not reverse its direction of flow during exhaust, as is the case in the dual flow engine. This elimination of exhaust steam flow over inlet ports accounts for the major advance of the steam engine in recent years, because it eliminates **initial condensation** in ports and cylinder head. The overcoming of this rather large loss places the uniflow engine in a favorable position to compete with other types of prime movers. It is more expensive to construct, but so marked are its advantages that it has come to be the only type of steam engine considered where a large efficient engine is wanted.

Except for the cylinder construction, the uniflow engine is very similar to any other steam engine. The cross-section through the cylinder of a uniflow (sometimes written unaflow) engine shows how a ring of exhaust ports situated at the center of the cylinder will be uncovered by the **piston** as it nears the end of an expansion stroke. It also shows why the piston must be much longer in this type engine than in the dual flow. On the return stroke the piston covers the ports fairly early in the stroke, and a considerable amount of work would be drawn from the **flywheel** in compressing the steam during the long back stroke were it not for the fact that this uniflow is equipped with auxiliary exhaust valves which remain open a portion of the exhaust stroke, thus delaying the point of compression, and preventing the reabsorption of considerable work from the flywheel. This delayed compression does not produce higher thermal efficiencies than a full compression, but increases the power which may be devel-



Section of cylinder and valves of universal uniflow engine.

oped per cubic inch of piston displacement. Some manufacturers build full compression uniflow engines (F T M)

UNIFORM CONVERGENCE OF SERIES. An infinite series $\sum_{1}^{\infty} u_n(x)$, each of whose terms is a function of x defined in an interval I, is said to be uniformly convergent in that interval if it converges for every value of x in I and if, for any arbitrary $\epsilon > 0$, an index N independent of x exists such that

$$\left| \sum_{i=n+1}^{\infty} u_i(x) \right| < \epsilon$$

for every $n > N$ and for every value of x in I

The most important test for uniform convergence is the so-called Weierstrass' M-test

If the terms of $\Sigma u_n(x)$ are continuous functions of x in an interval I, and if $| u_n(x) | \leq M_n$ for every n and for all values of x in I and the M_n are positive constants, then if ΣM_n is convergent, the series $\Sigma u_n(x)$ is uniformly convergent in I and is also absolutely convergent in I

Some of the important uses of uniform convergence are indicated by the following theorems

If $\Sigma u_n(x)$ is uniformly convergent in an interval I and if its terms are continuous functions of x in that interval, then its sum is itself a continuous function of x in I

A series of continuous functions which converges uniformly in an interval I may be integrated term by term, provided the limits of integration are finite and lie in the interval I

If a uniformly convergent series be integrated term by term, the resulting series will be uniformly convergent

Any convergent series of functions may be differentiated term by term if the resulting series is uniformly convergent (L L S)

UNIFORMITARIANISM Cataclysm.

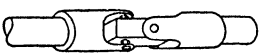
UNIRAMOUS LIMB. A crustacean appendage consisting of a single unbranching series of segments It is derived from the biramous appendage by the loss of the exopodite and is very well illustrated by the walking legs of the thorax of lobsters and related forms The chela of these animals is a modified uniramous appendage (A W L)

UNIT HEATER. When a means for producing heat is combined with one for circulating it within a building, the combination is known as a unit heater There are several manufacturers who supply unit heaters commercially, and in most cases the product takes the form of a steam-heated surface such as a cellular core, finned tube, or pipe coil Air is blown over this heating surface under the influence of a fan or blower, generally electrically driven Formerly unit heaters were employed principally in industrial buildings or mercantile buildings, but in recent years the desire of owners of steam or hot water heated homes to eliminate radiators from the rooms, and to obtain a measure of air conditioning, has led to the development of similar equipment for the home The domestic equipment is considerably different in design from the heavy, rougher, industrial types, but in it, also, is generally employed a heating surface over which a silent propeller type fan blows the air which, when heated, is passed through ducts or grills into the room. (F T M)

UNITS. Physical Measurements; Physical Magnitudes and Physical Equations; Metric System; C.G.S. System; Electric and Magnetic Units.

UNIVERSAL JOINT. The coupling of short shafts is accomplished in various ways, depending on the degree of alignment of the shafts, the power to be transmitted, and the conditions of service, i e, cleanliness, temperature, moisture, etc Where shafts are not in line, but are intersecting, a universal joint can be used to couple them, provided the shafts are not more than approximately 25° out of line One especially good feature of the universal joint is that within this limit the angle between the shafts may vary without adversely affecting the operation of the coupling

In a universal joint, the shafts are provided with U-shaped end fittings Pins through these end fittings pass through holes which are bored at right angles in a single connecting member, which may be as simple as a plain metal block, like the accompanying figure, or may be of a shape which permits equal strength with lighter weight and lower cost Although the driven member of the universal joint revolves at the same speed as the driving member, there being a positive mechanical connection, during any one revolution its speed varies from less than that of the driver to more as it takes up different positions relative to the connecting element If properly lubricated with grease or oil, and not operated at too great an angle, the universal joint is, for all practical purposes, equivalent to a straight line drive because of its high efficiency and of the negligible speed variation. One of the principal uses of the universal joint in its most advanced form, that is, as regards power transmitted, smoothness of operation, and high efficiency, is to be found in the drive of the automobile The connection of an axle which is unsprung, to the extension of the engine shaft, which, like the frame on which it is mounted, is a sprung weight, creates a condition of drive at a varying angle One, sometimes two, universal joints are used to provide flexibility of drive between the engine and the rear axle By virtue of its position in the car, this universal joint must be covered to exclude grit and dirt, which may readily be carried to it from the roadway Leather covers and spherical metal covers have been used for this service (F T M)



Universal joint

UNIVERSE. The term universe, in its complete physical sense, should apply to all matter in existence We know that this matter is not uniformly distributed, but rather that it is gathered into aggregates ranging in size from the smallest atom to the largest collection of matter known to astronomers

We have considerable knowledge regarding the small aggregates which make up objects on the surface of the earth We know something regarding the larger aggregates known as the planets, stars, nebulae, and other astronomical objects contained within the boundaries of the milky way, or galactic system We have observational data from which theories may be formed regarding the size and structure of our own local system and the milky way as a whole, but we are now approaching the region where we have nothing more than hypotheses which await more complete confirmation

What is beyond our milky way? Is this galactic system the largest aggregate of matter which exists in the universe? Such are questions upon which much research is being carried on at present and for which answers can by no means be considered as found It is in search of answers for such questions that the 200-inch telescope is being constructed

This much can be said at present we do know that there are many aggregates of matter which lie outside of the confines of our milky way Descriptions of these extra-galactic objects will be found discussed under the title of spirals

Statistical discussions indicate that the number of these objects may be as great as 10^{10}—a number comparable with the number of stars in our own galactic system Very recent studies have shown quite conclu-

sively that the extra-galactic objects are not uniformly distributed through space The term "galaxies of galaxies" has been applied to these, the largest aggregates of matter thus far discovered Far too little is known of them to permit of any discussion of their sizes and forms (W K G)

UNSTRATIFIED DRIFT. Till.

UPLIFT. If water should find its way from a **reservoir** to the surface between the base of a **dam** and its foundation, it would exert a pressure upwards against the base of the dam It would, in the extreme case, equal the full hydrostatic head corresponding to the height of the water surface above the base of the dam This water pressure is known as uplift, and could possibly overturn a gravity type dam if it were not prevented, or allowed for in the design Sometimes two-thirds of the static head is assumed to be acting as uplift Upl ft might be considered to be maximum at the upstream edge of the base, decreasing from that to zero at the downstream edge Where measures are taken to prevent uplift, the foundation must be very thoroughly grouted, cut-off walls must be let into the foundation near the upstream edge of the base, and drains provided to relieve any pressure which might be built up by a slow seepage (F T M)

UPSET. A bar or rod of metal is said to be upset when it is shortened and thickened on the end by heating and hammering A certain type of upsetting is known as swaging Bars or rods are upset for a number of reasons A round **tie rod** may be provided with screwed end connections which may develop the full strength of the rod if the end is upset, so that the section reduced by threading is still as large in area as the main body of the rod A rod is sometimes upset after being passed through a closely fitting hole in order to prevent its being withdrawn through the hole A method of making bolt heads is by upsetting part of a short round rod, then forging the head to the desired shape The heads of **eye-bars** are formed by upsetting (F T M)

URALITE. This is a metamorphic mineral It is a well-established fact that **pyroxene** rocks may be **metamorphosed** into **hornblende** rocks If the hornblende thus produced is fibrous and retains the original form of the pyroxene, it is called uralite, and the process by which the change is brought about is called **uralitization** It seems quite clear that uralitization is a chemical process which in many cases is accompanied by the generation of new minerals such as **calcite**, **epidote**, and **magnetite** Uralite was first observed in rocks from the Ural Mountains, hence its name (E S C S)

URALITIZATION. Uralite.

URANINITE. A mineral approximating the composition UO_3, but containing besides the higher oxide of **uranium**, UO_3, and oxides of **lead**, **thorium**, and rare earths The uraninite may occur as black **octahedral** crystals of high specific gravity (9 0–10 63), when in masses of pitchy luster is called **pitchblende** All uraninites and pitchblende contain a minute amount of radium It was in pitchblende obtained from the Joachimsthal in Czecho-Slovakia that Mme Curie discovered radium Other localities for uraninite are in Saxony, Rumania, Norway, Cornwall, East Africa, and in the United States in the pegmatites of Connecticut, North Carolina, and South Dakota, and in Gilpin County, Colorado An important occurrence of pitchblende is at Great Bear Lake, Northwest Territories, Canada, where it has been found in large quantities associated with silver, and is now a commercial source of radium (E S C S)

URANIUM. Symbol U Atomic number 92. Atomic weight. 238 14 Density 18 7 Melting point: < 1850° C

Uranium is a white metal, ductile, malleable, and capable of taking a high polish, but tarnishes readily on exposure to the atmosphere Finely divided uranium takes fire on exposure to air, and the compact metal burns when heated in air at 170° C Uranium metal slowly decomposes water at ordinary temperatures and rapidly at 100° C , is soluble in **hydrochloric acid** and in **nitric acid**, and is unattacked by **alkalis** Chemically related to **chromium**, **molybdenum**, and **tungsten**, and, like **thorium**, is radioactive In the radioactive decomposition radium is formed See **Radioactivity.** Discovered by Klaproth in 1789

Uranium occurs in **pitchblende** (75%–90% U_3O_8) and **carnotite** (62%–65%) The oldest and most celebrated deposit of pitchblende is that of Joachimsthal in Czecho-Slovakia, known since early in the sixteenth century, in the ore from which mine the discovery of radioactivity was made Carnotite is a **potassium** uranium **vanadate**, and occurs in southwestern Colorado and eastern Utah as an extensive deposit Richer ores have been found in recent years in Belgian Congo, and Great Bear Lake region of northern Canada Since the uses of uranium and its compounds are limited, the principal use of the ores is to secure the accompanying radium content.

Oxides Oxides of the following composition are reported UO_2, U_2O_5, UO_3, U_3O_8, UO_4 UO_3 and UO_3 have been well established, U_3O_8 is believed to be a mixture, UO_2 $2UO_3$ Uranium dioxide, brown to black solid, is obtained when uranium metal is burned in air at 170° C , and when U_3O_8 is heated in **hydrogen** at 650° C , U_3O_4, green solid, by heating any other oxide of uranium in air to 700° C , uranium trioxide, brick-red solid, by heating uranic acid, ammonium diuranate or ammonium uranyl carbonate to a maximum temperature of 300° C

Salts (1) Uranous, e g , chloride UCl_4, green color, strong reducing agents, and not fluorescent in violet light, (2) uranyl, e g , chloride UO_2Cl_2, yellow color, markedly fluorescent in violet light, readily reduced in solution to uranous by **zinc** metal, **tin** metal, **copper** metal, **iron** metal, and ferrous salts Small amounts of sodium uranate are used in ceramics to produce yellow glazes, and in the dyeing industry as a mordant. (R K S)

URANOTHORITE Thorite.

URANUS. (Cf tables of planetary data, page 865) Uranus, the first planet to be "discovered," was found accidentally by Herschel in 1781 while sweeping the sky with a seven-inch reflecting telescope of his own manufacture His discovery stirred up a tremendous amount of popular interest in astronomy, and history relates that during the weeks following the discovery, the streets in front of Herschel's house were crowded with people eager to get a view of the telescope and a glimpse of the discoverer Herschel named the planet Georgium Sidus (star of the Georges) in honor of the then reigning king of England, George III, but the name was never adopted on the continent Many Europeans called the planet Herschel, in honor of the discoverer, but the name Uranus, proposed by Bode, is the one which has survived

To the naked eye Uranus is barely visible as a sixth **magnitude** star, but in a telescope of moderate aperture the object appears as a disk The disk has a bluish green appearance, and no surface markings have ever been observed Early observations showed that the planet is very much flattened at the poles, which gives evidence of high rotational speed, but it was not until 1912 that Lowell and Slipher were able to prove, by the **Doppler principle**, that the period of rotation is about 10 75 hours The relatively high **albedo**, and low densities both give evidence of a thick layer of atmosphere about the planet Reasoning from purely theoretical grounds, on the basis of the mean distance of the planet from the sun, we find that the temperature of the surface of Uranus should be about 62° K

(—346° F). At such a low temperature all gases except possibly hydrogen, helium, and argon should be condensed out of the atmosphere However, within recent years, Dunham has shown the existence of a large amount of methane in the atmosphere of Uranus, which indicates that the temperature must be considerably higher than that given by purely theoretical reasoning

One strikingly interesting characteristic of Uranus is found in the fact that the axis of rotation lies almost in the plane of the ecliptic, being inclined to it by an angle of less than 10° Furthermore, the direction of rotation is opposite to that of all of the other members of the solar system

Uranus has two small **satellites**, both less than 1000 miles in diameter The orbit planes of these satellites lie close to the plane of the planet's equator, and hence are nearly perpendicular to the plane of the ecliptic The satellites revolve about the primary in the same directional sense as that in which the planet rotates, i e, in the retrograde direction (W K G)

URCHIN. 1 Mammalia, Insectivora The European **hedgehog** 2 Echinodermata, Echinoidea The sea-urchins and the related flat forms called cake urchins and sand dollars Although usually accompanied by a prefix, the name is commonly shortened, as in the case of the common green and purple urchins of the Atlantic (A W L)

UREAS Amines and Amides.

UREASE Enzyme

UREDINALES Rust fungi.

UREIDES See **Purine and Uric Acid Compounds.**

UREMIA. A disorder resulting from accumulation of toxic substances in the body due to impairment of **kidney** function The majority of cases complicate the latter stages of a severe **nephritis**, but uremia may complicate any interference with urinary secretion, whether it be due to a poison like mercury, stones in both kidneys, or sufficient enlargement of the **prostate** to block the urinary outflow, etc The normal level of the **urea** in the blood may be greatly elevated due to the inability of the kidneys to secrete this waste substance from the blood In uremia there is usually a cardiac element present since renal or kidney function is dependent on circulation

The symptoms of uremia are those of a general intoxication, headache, vomiting, dizziness, and diarrhea Psychic disorders are frequently present, delirium, stupor, coma, even hallucinations Convulsions occur frequently and may occur without warning Other symptoms that occur are those of the underlying nephritis

Treatment of uremia is directed toward the elimination of the accumulated toxic substances by aiding renal and cardiac function In any case of nephritis conditions which permit uremia to develop should be guarded against The prognosis is usually bad (R S M)

URETER The passage that connects each **kidney** with the **bladder**, through which the urine secreted by the kidney is carried Each ureter is about twelve to fourteen inches long and is extremely small in diameter (See **Excretory System**) (R S M)

URETHANES. Amines and Amides.

URETHRA. The narrow passage which extends from the **bladder** externally for the passage of urine In the female the urethra is about an inch and a half long and the external opening (meatus), lies above the **vagina**, between it and the **clitoris** In the male the urethra measures about eight inches, runs the entire length of the **penis**. It also serves to carry the seminal fluid to the outside The urethra is often the site of acute and chronic infection (See **Excretory and Urogenital Systems**) (R S M)

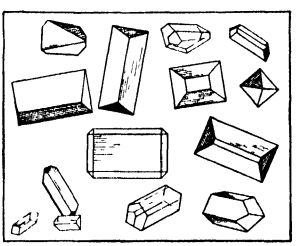
URIAL. Sha.

URIC ACID. Purine and Uric Acid Compounds.

URINARY BLADDER. Excretory and Urogenital Systems.

URINE. A transparent amber fluid, slightly acid in reaction, with a characteristic odor and a specific gravity varying from 1 005 to 1 030 Urine is **secreted** by the kidneys, passes through the **ureters** into the **bladder**, where it is stored and is discharged through the **urethra** The average amount secreted by the kidneys in twenty-four hours in health is about three pints The amount varies somewhat according to the quantity of fluid drunk and the amount lost through the skin, lungs, and intestinal tract

The urine may become cloudy on a vegetable diet due to precipitation of **phosphates** In disease cloudiness may develop from the presence of **pus**



Prismatic forms of triple phosphate crystals from urine (× 250) (From Todd and Sanford, *Clinical Diagnosis by Laboratory Methods*, W B Saunders Co)

Urine is the medium by which the body gets rid of a large portion of the toxic material that accumulates in the system and the end-products resulting from food **metabolism** The waste material is composed principally of urea, an end-product of **protein** metabolism, **ammonia**, **hippuric acid**, **purine** bodies, and salts, mostly **sodium** chloride

The important abnormal constituents of the urine which when constantly present signify some disease process are **albumin**, **glucose**, **acetone**, **pus**, red **blood** cells, and **bacteria** (R S M)

URINE ANALYSIS. The chemical and microscopical examination of the **urine** (R S M)

UROCHORDATA. Chordata A subphylum containing the marine animals known as **ascidians**, tunicates, salpians, and appendicularians They represent an extreme adaptation of primitive chordate structure for **sessile** or drifting life

Urochordates are characterized by the presence of a cuticular covering called the **test** or tunic, a word associated with the name Tunicata, also applied to the group They have a very large **pharynx**, occupying most of the body and perforated by many openings In some species these openings lead to the exterior and in others to a peribranchial chamber opening to the exterior by a constricted **cloacal** aperture Ordinarily, water bearing particles of food is taken into the pharynx by way of the mouth through ciliary (**cilia**) action, passes into the peribranchial space, and is discharged by the cloacal aperture When irritated, however, the animal may contract spasmodically and discharge jets of water from both mouth and cloacal aperture In the pharynx food is caught by an endostyle as in the **Cephalochordata**

The Urochordates are classified as follows:

Class Larvacea Appendicularians Forms resembling larval tunicates, with a trunk and tail Minute, free-swimming, and transparent
Class Ascidiacea The ascidians or sea-squirts Tailed and free-swimming as larvae but sessile as adults
Class Thaliacea The salpians Floating transparent forms, sometimes colonial Moderate in size (A W L)

URODELA. The **salamanders, newts,** and related forms of tailed **Amphibia.** An order, also named Caudata (A W L)

UROGENITAL SYSTEM. A term sometimes applied to the closely associated **excretory** and **reproductive** systems of the vertebrates The gonads and the kidneys arise from the same mass of embryonic tissue, the intermediate **mesoderm,** and as the ducts of the excretory system develop they are appropriated in part by the reproductive organs In the male the mesonephric or Wolffian ducts persist as the vasa deferentia, connected with the testes by modified mesonephric tubules, the vasa efferentia These parts do not persist in the female, where separate Mullerian ducts arise in association with the ovaries Both male and female genital ducts join the **cloaca** during embryonic development and here further intimate association is evident

The cloaca persists in all classes, but in only a few of the primitive mammals In most mammals a more or less complete separation takes place

This region of the gut bears the **allantois,** an extra-embryonic membrane, as a ventral appendage, and receives dorsolaterally the mesonephric ducts, from which the metanephric ducts or ureters branch to the kidneys The cloaca expands and the angle between the allantoic stalk and the intestine progresses in mammals until the chamber is subdivided into the dorsal rectum and the ventral urogenital sinus The latter receives the mesonephric ducts By its continued growth the common portion of these ducts is absorbed into its wall, so that the mesonephric ducts and ureters join it separately, the latter in front of the former The anterior part, bearing the ureters, together with a portion of the allantoic stalk, becomes the urinary bladder The slender posterior portion becomes the female urethra, the duct of the bladder, and in the male forms the proximal portion of the urethra External folds flanking the opening of the urethra form the labia minora of the female, between which the vagina, derived from the united parts of the Mullerian ducts, and the urethra open separately In the male these folds unite to form part of the penis, with an enclosed tube which becomes the distal or phallic portion of the urethra Thus in the male the urethra remains a common duct of the excretory and reproductive systems (A W L)

UROPOD. A swimmeret of certain **crustaceans,** modified as a broadly expanded swimming appendage The pair of uropods associated with the flattened **telson** form the fanlike tail of the **lobsters** and **crayfishes.** By powerful contractions of the abdomen this structure is used to scull the animal rapidly backward through the water (A W L)

UROSTYLE. A long rod of bone articulated with the last vertebra of the **frog** and related forms, in the skeletal axis Although this bone is not segmented, it shows evidences of being formed from coalesced vertebrae, like the os coccyx of **primates** (A.W.L)

URSA MAJOR (The greater bear) (Map, page 306) This **constellation** is probably best known for the asterism known in this country as the big dipper and in England as the plough or the wagon The constellation is circumpolar for both Europe and North America, and two of the **stars** in the dipper, known as the pointers, are very useful in locating the star **Polaris,** since the line joining them, if extended, will pass close to the celestial pole

The star Mizar (Zeta Ursae Majoris) at the bend of the handle of the dipper is an easy visual **double star.** Tradition says that this object was used by the American Indians as a test of vision, a person able to see this star as double being credited with good vision. The star is certainly one of the earliest doubles known, having been so named by the ancient Arabs (W K G)

URSA MINOR (The smaller bear) (Map, page 306) This **constellation** is best known because of the fact that the bright star at the end of the handle of the asterism, frequently referred to as the little dipper, is at present the closest bright star to the north celestial pole of rotation This star **Polaris** (Alpha Ursae Minoris) will be described elsewhere Other than this star the constellation contains very few objects of interest or importance (W K G)

URTICARIA. Hives The appearance on the skin of the body of firm, elevated, white, yellowish, or pinkish patches Itching is intense The patches may vary from the size of a pea to several inches in diameter The eruption is characterized by its changing character The patches may appear and disappear or change their position during the course of the day Usually the hives disappear as quickly as they develop Sometimes they may persist from twelve to twenty-four hours Hives may occur from a variety of causes, some of which are not well understood In general urticaria is caused by a **protein** substance or a poisonous substance derived from a protein, to which the susceptible individual is sensitive Certain protein foods, **serum** or **blood** injections, protein substance inhaled, or certain drugs may cause this type of eruption

Treatment consists, when possible, of the avoidance of the causative substance At times desensitization of the individual may be done During an attack **adrenalin** by hypodermic injection often gives relief (R S M)

USTILAGINALES Smuts.

UTERINE TUBES. Fallopian tubes.

UTERUS. A portion of the female reproductive passages in which the eggs or young are retained during all or part of **embryonic** development A uterus is found in some invertebrates, as the roundworms and **arthropods** In the mammals, accompanying their highly specialized reproductive processes, it is important It is formed in these animals either as a pair of chambers in the two Mullerian ducts or as a portion of the fused region of the two ducts Uteri of the latter kind are of three fundamental forms A duplex uterus is forked through most of its length, and is in reality a pair of chambers united at one end In the uterus bicornis there is an unpaired chamber of considerable extent, branching in front to form two diverticula bearing the oviducts A uterus simplex is an unpaired chamber

The wall of the uterus contains heavy layers of involuntary muscle and its lining is glandular and partially ciliated (cilia) The lining is specialized for the reception of the fertilized ovum in pregnancy, and takes part in the formation of circulatory connections with the developing **embryo** through the **placenta**

The human uterus is a hollow muscular pear-shaped organ in the female situated in the lower pelvic cavity between the **bladder** and the **rectum** The broader portion of the uterus is the upper portion, at each end of which the **fallopian tubes** enter The lower portion is called the **cervix** and projects downward into the **vagina** The virginal uterus is small, measuring about three inches long, two inches broad, and one inch in thickness During pregnancy the uterus enlarges enormously and may extend upward to the ribs After pregnancy the uterus is always a little larger than its

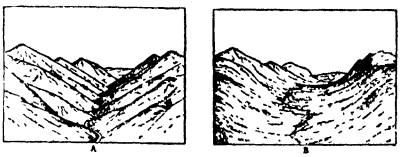
original state. After the change of life the organ becomes smaller.

Since the uterus is suspended and held in position by ligaments, its position may become disturbed. Anteversion indicates that the uterus is inclined too far forward, while retroversion indicates that the organ is displaced backward toward the rectum.

The function of the uterus is to receive the ova from the ovaries through the fallopian tubes. If the ovum is fertilized it is retained and development takes place within the uterine cavity. When development is complete the fetus is expelled from the uterus by contractions of the uterine muscular wall, aided by contractions of the abdominal muscles

The uterus may become involved in infectious processes, especially after childbirth and **abortions,** particularly of the criminal variety **Tumor** formation is common in the uterus, both of the benign and malignant variety. The most common benign tumor that occurs in the uterine wall is the development of fibroids. Removal of the uterus is called hysterectomy. The operation to correct mal-position is called suspension of the uterus (A.W L., R S M)

U-VALLEY. A river valley whose transverse profile has been changed from the V to the U-shape by the work of a glacier While the ice tongue is occupying the valley, any tributary glaciers or streams are unable to cut below the surface of the ice lying in the main valley. When the glacier finally melts the tributary valleys do not enter the main valley at grade but appear



Diagrams showing a stream-cut valley (A), and as it appears after glaciation (B) (After U S Geological Survey)

as hanging valleys. The stream which flows in a U-valley is called a misfit stream because it could not have transported the large glacial boulders among which it flows. (R M F)

UVAROVITE. Garnet.

UVULA. A soft, mass of tissue that hangs downward from the posterior of the soft palate above the base of the tongue. When it is too long and causes irritation or tickling in the throat it may be shortened by astringent solutions, or in extreme cases by surgery. (R S M.)

V

VACCINATION. Vaccinia.

VACCINE. A preparation made of weakened or killed **bacteria** or disease organisms and their **toxins**, which, when introduced into a person, produces active immunization against that specific disease stimulation of the production of antibodies Examples of common vaccines are those that immunize against **typhoid, whooping-cough, smallpox**, etc. (R.S M.)

VACCINIA (COWPOX). An eruptive disease of cows, the virus of which, when inoculated in a man, gives protection against smallpox.

Vaccinia is believed to be **smallpox** modified by passage through an animal. This so alters or attenuates the smallpox **virus** that a local lesion only is produced when the virus is inoculated in a man (vaccination).

It has been known by country people for centuries that cowpox will protect against smallpox, but it remained for Jenner in 1798 to put vaccination on a practical basis.

Revaccination should be done: (1) at intervals of seven to ten years, (2) repeatedly when previous vaccinations fail to "take"; (3) when exposed to a smallpox patient.

If smallpox occurs in a patient who has been vaccinated many years before so that its effect has worn off, the disease assumes a less serious form than without previous vaccination. (R S.M)

VACUOLE. A small globule of clear fluid in the cytoplasm of a **cell.** In preparations for microscopic study the contents of the vacuole are usually dissolved away, so that an open space alone remains, but even vacuoles whose contents are undisturbed usually appear vacant because of their transparency In the multicellular body fat cells afford a good illustration of vacuoles as globules of fat accumulate in them One-celled animals also offer a good example in the contractile or pulsating vacuole. This is a globule of clear liquid that forms and discharges periodically, sometimes at a fixed point in the cell. It is interpreted as an organ for the removal of surplus water with dissolved wastes from the **protoplasm.** (See **Cell**) (A.W L)

VACUUM. A perfect vacuum would be a region entirely devoid of matter. Because of diffusion and the volatility even of solids, this condition is merely an ideal, and even if we imagine it to be attainable, the old concept of a vacuum as mere emptiness is modified by evidence leading to the endowment of space with physical properties. Faraday's notion of **fields of force**, involving stresses in space, and the undulatory theory of **light** (not to mention the more recent relativistic aspects of the subject), have profoundly influenced scientific thinking in regard to space by endowing it with physical properties.

Experimentally a vacuum is simply a region of very low pressure, usually attained by some form of **air pump.** A pressure of a millimeter or so of mercury would be called a "rough vacuum," while one of 0 0001 millimeter is a "high vacuum." The best vacuum obtainable by artificial means at present is probably of the order of 10^{-8} millimeter; though such pressures cannot be measured with certainty. (L.D.W)

VADOSE. A geologic term referring to a type of circulating underground water. (R.M F)

VAGINA. A sheath. The term is most familiar in reference to the terminal portion of the female genital passages, which receives the intromittent organ of the male during **copulation.** This canal extends from the **vulva** upward to the **cervix** of the **uterus**, and is three to three and one-half inches long. The term vagina is also used in anatomy to designate other sheathlike structures, such as the fibrous sheath of tendons. This structure is called a vagina fibrosa when solid and a vagina mucosa when it contains a fluid-filled cavity surrounding the tendon. (A.W.L., R S.M.)

VALENCE. Valence is the capacity of an **atom** to combine with other atoms to form a **molecule.** It is specified as the number of **hydrogen** atoms or twice the number of **oxygen** atoms with which one atom of the element under question will combine. Thus nitrogen has the valence 3,2,4,5 in the compounds NH_3, NO, NO_2, N_2O_5 A further distinction is made by considering positive and negative valences. If the hydrogen is assigned the valence of plus one, and oxygen that of minus two, and if the valences in a compound are made to total up to zero, we have a formal scheme of positive and negative valences In ammonia, NH_3, the three hydrogen atoms each with a valence of plus one exactly balance the one nitrogen atom with the valence of negative three Many atoms possess more than one valence, but the principal valence is correlated with the periodic table and the **atomic structure** of the atom. (See **Chemical Composition**) The inert gases have the valence zero. The principal positive valence is the number of the group in which the element falls in the periodic table. Thus hydrogen is one, **lithium** also one, **boron** three, etc. Positive valences greater than four occur very rarely. The negative valence is eight minus the number of the group in the periodic table. Negative valences greater than four do not occur. For example, oxygen has the valence of eight minus six or two

On the basis of modern electronic theory of atomic structure we can classify the different types of valence. The guiding principle is that the atoms tend to assume an inert gas electronic structure of eight **electrons** in the outer shell (in the case of hydrogen it is two). To do this the atom either loses to, gains from, or shares with other atoms, electrons. This process leads to molecule formation. The following are the principal types of valences and their electronic interpretation.

Electrovalence or polar valence is associated with a transfer of an electron from one element to the other in order to complete by such a transfer the octet of each element. Thus in sodium chloride the sodium atom has one valence electron outside a closed octet of eight. By loss of this electron the **sodium** atom becomes positively charged sodium **ion** because the nuclear positive charge exceeds that of the electrons by one. On the other hand, the **chlorine** atom has a grouping of seven electrons in the outer shell. It picks up another electron to complete its outer shell to an octet, but in so doing obtains a total charge of one minus, becoming a chloride ion. The result is that in sodium chloride we are not dealing with sodium atoms and chlorine atoms but with sodium and chloride ions. This is experimentally substantiated. The forces holding the ions together are the **electrostatic forces**, which are equal to the product of the electronic charges on the ions divided by the product of the separation squared times the dielectric constant of the medium. Thus when the sodium chloride crystal is placed in solvent of high

dielectric constant such as water, the forces between the ions are weakened and the ions float away from each other. In other words, electrolytic **dissociation** takes place. It must be noted that polar valences have no specific directional effects in space. The electrostatic attraction is best satisfied by a close packing of the ions. Inasmuch as there are large stray electric fields present in polar compounds, they possess a high melting point and considerable hardness.

Homopolar or covalent bonds are formed by a different mechanism. Here again we have as the basis the tendency of each atom to complete its outer shell of electrons to eight, or in the case of hydrogen to a doublet. In contrast to polar valence, in covalence we have no direct transfer of electrons, but merely a sharing. In the case of molecular hydrogen each hydrogen atom with its one electron shares this electron with the other hydrogen. The result is that each atom in the molecule has at least part of the time a complete shell of two electrons. The electrons can be visualized as traveling in orbits encompassing the two hydrogen nuclei. It is a property of the covalent bond that it is not weakened by electrolytic solvents and that it has a definite direction in space. These directional effects of covalent bonds are expressed in stereochemistry. Thus, for example, the four valence bonds of the carbon atoms are arranged to extend from the center of a tetrahedron to the four corners. Furthermore, since there is a one-to-one saturation of the electron forces, the stray electric fields are negligible, the melting points are low, and the crystals are soft.

Another type of bond which occurs in solids is the metallic bond. It can be considered as an extreme case of sharing of electrons in that an electron gas (present in the crystal lattice) is shared not by two ions but by all the ions in the lattice. This electron gas is responsible for the metallic properties of certain solids, especially for thermal and electrical conductivity. (R.K.S.)

VALVE. For the meaning of this term as used in engineering, see **Valves.** For the meaning of valve as used in radio, see **Rectifiers.**

In zoology, a valve is a structure that regulates the flow of materials through a tubular organ. It may consist either of a muscular band in the wall of the organ or of a system of flaps that close together to impede flow in one direction.

The valves of the alimentary tract (**Digestive System**) are of the former type, consisting of a **sphincter** muscle encircling the tract within a projecting ridge of its lining. The chief valves are the **pyloric** at the union of the stomach with the **duodenum** and the ileo-colic at the junction of the small and large intestines.

In the **circulatory system** valves are highly developed in the vertebrate **heart** and appear in some tubular vessels. The latter, in **vertebrates**, are limited to the **lymphatic** vessels and veins of the extremities. They consist of paired folds of the lining with their convex surfaces toward the passage. Pressure against this surface separates the flaps of the valves, while pressure against their concave faces forces them together and blocks the passage.

In the heart the passages from veins to heart, from **auricles** to ventricles, and from heart to arteries are guarded by valves composed of two or three flaps, and in the fishes (**Pisces**) the proximal part of the ventral aorta is in some species developed as a valvular conus arteriosus. In the **mammalian** heart the openings of the pulmonary artery and aorta are guarded by valves of three parts, known as the semilunar valves. The valve between the right auricle and ventricle is also three-parted, and is called the tricuspid, while the mitral valve between the left auricle and ventricle has only two flaps. These last valves are reinforced by slender chordae tendineae extending from their edges to the opposite walls of the ventricles. The heart also has a valve of Thebesius or coronary valve at the opening of the coronary sinus and a Eustachian valve at the opening of the inferior vena cava. (A.W.L.)

VALVE GEAR. The mechanical linkage by means of which the **valves** of an **engine** are operated from its **crankshaft** is the valve gear. This term does not specifically apply to any type of engine, but is much more frequently used to describe the steam engine valve drive than any other. Although recognizing this fact, it seems pertinent here to describe very briefly the valve gear of the **internal combustion engine** (Figure 1). With

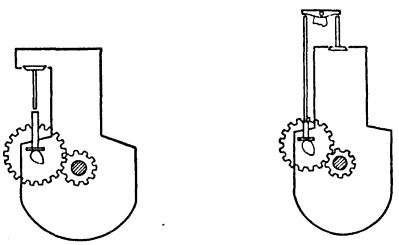


Figure 1. Types of four-cycle internal combustion engine valve gear.

very few exceptions, the internal combustion engine uses a poppet valve, which is actuated by a short reciprocation, the amplitude of which is well within the ability of a cam to produce. The cam is also an economical method of converting rotation to reciprocation for multicylinder engines because of the comparative ease with which a number of cams may be machined on a single shaft. The poppet valve is retained against its seat by a strong spring. When it is to be opened, a rod or lever is pressed against it, and moved far enough to create the necessary valve lift. This lifting motion is derived from the cam through a cam follower, and tappet rods or push rods, as illustrated in Figure 1. The camshaft itself is rotated by the crankshaft at one-half crankshaft speed (in the four-cycle engine). Camshaft drive must be positive, so gears or chains are always used.

The **steam engine** valve gear (Figure 2) cannot be so briefly treated because it is found in more varied

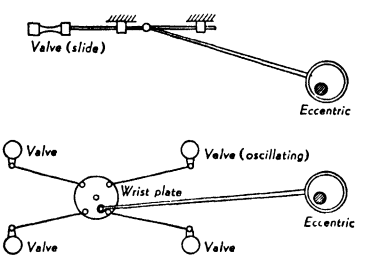


Figure 2. Steam engine valve gear.

forms, and because it has more mechanical details. Furthermore, the valve gear of a steam engine may be designed to give reversible operation, and to effect the governing necessary for constant speed at variable load. Steam engine valves can be plain sliding, oscillating, or poppet. The throw of the valve, or the amplitude of its reciprocation, is too large to be produced by a **cam** mounted on the **crankshaft**, so the drive usually originates from an **eccentric**. In a simple slide valve engine this eccentric is encircled by an eccentric strap, to which is fastened an eccentric rod. The eccentric rod is pinned to the valve stem so that the rotation of the crankshaft

will reciprocate the valve. Steam engines which are governed by the cut-off method have the governor action interposed between the crankshaft and the eccentric, that is, the eccentric is not keyed to the shaft, but is free thereon, being maintained in a position relative to the engine crank, determined by the load and controlled by the governor.

Engines with oscillating valves derive their motivation from an eccentric on the crankshaft, but there is interposed between the eccentric rod and the valve a wrist plate and valve reach rods. The Corliss engine illustrates this case. In a simple slide valve engine the eccentric angle leads the crank angle in the direction of rotation by a definite amount. If two eccentrics are provided, one on either side of the crank by this same angle, then the engine could be operated forward or reverse if the valve could be driven from either of the eccentrics. This idea is incorporated in the Stephenson valve gear. In locomotive practice, more flexibility of control than is possible in the simple valve gear just described is desired, and the gear used in most locomotives is a type which derives part of its motion from the cross-head, and part from the crankshaft. A detailed

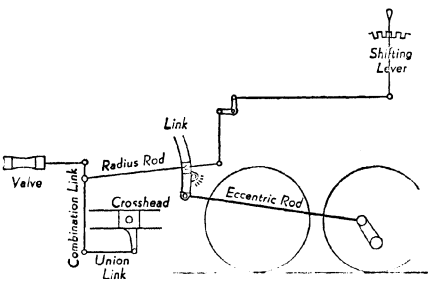


Figure 3. Walschaert's locomotive valve gear.

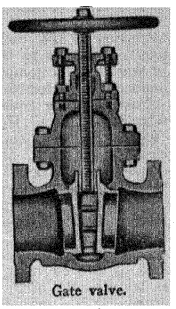
description of this gear is not in order; however, a skeleton diagram of the linkage is given in Figure 3. (F.T.M.)

VALVES. A pipe valve consists of a body to house it and to give a means of connecting it to the pipe, a valve seat, a valve, a valve stem, a top, a means of operating the stem—usually screw and hand wheel, and a packing to prevent leakage around the stem as it emerges from the top. Valves are furnished for either screwed or flanged connection. They are made of brass, bronze, malleable iron, cast iron, cast steel, and forged steel. Cast and forged steel are employed in high pressure-temperature service. Valve sealing materials (sometimes constituting the valve seat, sometimes attached to the valve face) include rubber for cold water, brass and bronze for ordinary temperatures, stainless steel, monel metal, and various other alloys for high temperatures.

Valves most used are the ordinary hand-operated globe and gate valves, and the check valves. These are classified thus:

1. Globe valves (straight and angle).
   a. Inside screw; outside screw.
   b. Screw bonnet top; bolted yoke top.
2. Gate valves (straight and angle).
   a. Rising stem; non-rising stem.
   b. Wedge valve (split and solid); parallel seat valve.
3. Check valves (lift and swing types).
   a. For vertical pipe.
   b. For horizontal pipe.

The globe valves do not allow a line to drain completely; also, they offer more frictional resistance than gate valves. They are frequently used in very small lines (both water and steam) and where the valve is to be used for throttling, as they can be closely regulated and the seats, which are liable to be cut away in throttling service, can be more easily replaced than in gate valves. Gate valves are used in large pipe lines, in high-pressure steam lines, and in all service where small friction loss is wanted. The gate valves are more expensive than the globe, and their longer stems require more clearance space for operation.


Gate valve.

Special valves of a great many types are also employed in piping systems.

Safety valves are primarily the boiler safety valves. The common form is the pop valve held against its seat by a heavy spring and having a "huddling chamber" to make it open quickly and remain open until a predetermined pressure drop (2–4% WSP) has occurred. The A.S.M.E. Boiler Construction Code requires boilers having more than 500 square feet heating surface, or those generating better than 2000 pounds of steam per hour, to have two or more safety valves. The safety valves should have sufficient relieving capacity to prevent more than 6% pressure rise at maximum rate of combustion.

In case more than one safety valve is used the smaller one can be set to pop at the desired maximum pressure and the larger at 2 or 3 pounds higher. The main safety valves of a large boiler operate to blow down several pounds pressure before closing. A smaller "vernier" safety valve giving less pressure drop between pop and close is installed, usually on the superheater outlet, though sometimes on the boiler lead, for the purpose of giving partial relief to the high pressure, warning the attendants of high pressure, preventing overheating of superheater tubes, and possibly forestalling popping of the main safety valves and the resultant waste of high potential heat. Since most safety valves discharge horizontally into a pipe that then turns upwards, an impulse force is given to the vent piping which, at least for large valves, needs special anchorage.

The relief valve is a form of safety valve, but usually intended for less severe service and of less importance from the safety viewpoint. Relief valves are applied to air, water, and steam lines, also to tanks, heaters, etc. Among them could be mentioned the back pressure valves and atmospheric relief valves. (See **Otto Engine, Steam Engine.**) (F.T.M.)

VAMPIRE. Mammalia, Chiroptera. Tropical American blood-eating **bats**, *Desmodus rufus* and *Diphylla ecaudata*. These animals are provided with incisor teeth formed to produce a peculiar wound that bleeds very freely without giving pain. They differ from ordinary bats in locomotion, elevating the body on the legs and folded wings and walking thus on all fours, scarcely making themselves felt by the animal on which they have alighted. They have been proved to drink blood by lapping, and not by sucking it from the wound. (A.W.L.)

VANADINITE. The mineral vanadinite corresponds to the formula $(PbCl)Pb_4(VO_4)_3$, being composed of **lead chloride** and **lead vanadate** in the proportion of 90.2% of the former and 9.8% of the latter. It crystallizes in the **hexagonal** system, is usually prismatic, but the crystals are often skeletal or cavernous; it may be found in crusts. Its fracture is uneven; brittle; hardness, 2.75-3; specific gravity, 6.7-7.2; fresh fractures show a resinous luster; color, yellow, yellowish brown, reddish brown, and red; streak, white to yellowish; translucent to opaque. Vanadinite, by no means a common

mineral, occurs as an alteration product in lead deposits. It is found in the Urals, Austria, Spain, Scotland, Morocco, the Transvaal, Argentina, and Mexico. In the United States it occurs in Arizona, New Mexico, and South Dakota It is used as an ore of vanadium and to some extent of lead as well It is interesting to note that this mineral was first described as a chromate upon its discovery in Mexico in 1801. It was not until the discovery of the metal vanadium in 1830 that the true nature of this compound was known (E S C S.)

VANADIUM. Symbol V Atomic number. 23. Atomic weight 50 95 Density 5 69 Melting point· 1710° C

Vanadium is silver-white, and the hardest metal, oxidizes upon being exposed to air, and upon ignition forms the pentoxide, insoluble in **hydrochloric acid**, slowly dissolves in **hydrofluoric**, **nitric**, or **sulfuric acids** (hot, concentrated), or **aqua regia**, insoluble in **sodium** hydroxide solution Discovered by Del Rio in 1801 Subsequent investigations made by Sefstrom, Wohler, and Berzelius, all about 1830, and by Roscoe in 1868, are of great interest

Most of the vanadium of commerce is used in the form of ferrovanadium (30%-40% V) in the manufacture of special alloy steels to which vanadium (not usually exceeding 1%, and as low as 0 2%) imparts hardness and toughness, and increases the elastic limit and resistance to shock or impact

Vanadium occurs as **patronite**, containing vanadium pentasulfide, in Peru, as **carnotite**, potassium uranyl vanadate, in Colorado and Utah, as **vanadinite**, lead vanadate, in Arizona, New Mexico, South East Africa, and northern Rhodesia The sulfide ore is roasted to remove **sulfur**, and the residue fused with sodium carbonate forming sodium vanadate This last is extracted with water and excess of sulfuric acid is added, causing precipitation of vanadium pentoxide, which it later reduced by carbon or aluminum at high temperatures

Chlorides Vanadium dichloride (VCl_2), green crystalline solid, a strong reducing agent, vanadium trichloride (VCl_3), pink crystalline solid, vanadium tetrachloride (VCl_4), reddish-brown liquid, boiling point 148° C

Hydroxides Vanadium dihydroxide ($V(OH)_2$), brown precipitate by reaction of **sodium** hydroxide solution with hypovanadous acid (one of the most powerful of reducing agents) lavender solution; vanadous hydroxide ($V(OH)_3$), green precipitate by reaction of sodium hydroxide solution with vanadous salt green solution

Oxides Vanadium monoxide (VO), gray solid, vanadium trioxide (V_2O_3), black solid, vanadium dioxide (VO_2), dark blue solid; vanadium pentoxide (V_2O_5), orange to red solid The last is the most important oxide, formed by the ignition in air of vanadium sulfide, or other oxide, or vanadium; used as a catalyzer, e g, the reaction sulfur dioxide gas plus oxygen of air to form sulfur trioxide.

Sulfides. Vanadium monosulfide (VS); vanadium trisulfide (V_2S_3), most stable, vanadium pentasulfide (V_2S_5)

Vanadium is usually encountered as vanadate (vanadium of valence plus 5), which in acid solution is reduced by zinc metal successively to blue (vanadium of valence plus 4), green (vanadium of valence plus 2) The oxidation-reduction relations of vanadium element are among the most interesting of the metals

Common tests for vanadium are·

1 Inorganic and organic reducing agents convert the vanadates into blue vanadyl compounds.

2 Vanadic acid treated with hydrogen peroxide produces a reddish brown color insoluble in ether (difference from chromates) (R K S)

VAN DER WAALS' EQUATION. Characteristic Equations.

VANILLA. Bean. Orchidaceae Vanilla is a climbing **orchid** native to Central America and Mexico. Vanilla extract is obtained from the fruit. (R.M W)

VANILLIN. Aldehydes, Ketones, and Related Compounds.

VAN'T HOFF LAW. Equilibrium.

VAPOR CYCLE. A vapor cycle is so named from the fact that it uses the same **vapor** over and over again, passing it around a closed loop and subjecting it to various **thermodynamic** changes by means of which useful energy is produced from raw heat

In the process of conversion of the heat of a **fuel** into a useful form of energy there are three essentials: First, a heat absorber where the heat liberated by **combustion** of the fuel is absorbed by the working medium, second, a heat utilizer in which as much of the heat as is available is taken from the working medium and converted into a useful form of energy, third, the working medium itself passing back and forth between the first two—a carrier of heat energy The thermodynamic aspects of its passage from the heat absorber to the heat utilizer and back again constitute the vapor cycle (See **Rankine Cycle**, **Regenerative Cycle**, **Reheating**, **Mercury Vapor Cycle**) (F T M)

VAPOR LOCK. Volatility of **gasoline** makes for easier starting of an **engine** using it, but creates one undesirable feature, namely, vapor lock Vapor lock refers to a condition in which gasoline flowing in a pipe line from supply tank to engine spontaneously vaporizes, filling a bend in the line through which gasoline as a liquid might flow with the vapor, which can choke off the engine supply It also originates in the float chambers or jets of **carburetors** This condition is encountered in summer and/or in high altitudes, and where the feed line from the tank has certain conformation involving bends in which vapor may accumulate This fault occasionally occurs in automobile engines in certain parts of the country, where high temperatures are present on elevated plateaus It may be offset temporarily by cooling the supply line with water dashed against it. The fault also occurs on **airplanes**, where the supply line has been poorly laid out As aircraft engines operate at much higher altitudes than other types, and the gasoline employed is exceptionally volatile, the question of vapor lock should be carefully investigated in any layout of the gasoline supply line Also vapor lock is much more serious in an **aeronautical engine** because of the difficulty, or outright impossibility, of curing it until a forced landing has been made (F T M.)

VAPOR PRESSURE. The vapor pressure of a substance (solid or liquid) is the pressure exerted by its vapor when in **equilibrium** with the substance For pure substances it depends only on the temperature. The simplest way to measure the vapor pressure of a substance is to introduce a small amount of it into the closed end of a barometer tube and note the decrease in the height of the barometer (See table, page 1176)

The vapor pressure of a **solvent** is lowered on dissolving the solute in it This lowering for dilute solutions is proportional to the mole fraction of the solute (**Raoult's Law**) The lowering of the vapor pressure of the solution can be related to the lowering of the freezing point and the elevation of the boiling point These phenomena serve as a basis for **molecular weight** determinations. If both components of the solution are volatile, each lowers the vapor pressure of the other and the ratios of the two substances in the liquid and vapor phase are not necessarily the same. Use is made of this fact to separate the two substances by **distillation.** (See **Deliquescence** and **Efflorescence**) (R K S)

VAPOR PRESSURE OF SOME SUBSTANCES AT VARIOUS TEMPERATURES IN MILLIMETERS OF MERCURY EXCEPT AS STATED

	−20° C.	0° C.	+20° C	100° C.
Water	0 8 (Ice)	4 6	17 5	760
Ethyl alcohol	2 5	12 2	43 9	1690
Diethyl ether	37 6 (−30° C)	185 3	442 2	4860
Acetone	11 2 (−30° C)	89 1 (+5° C)	184 8	2790
Acetic acid			11 7	417
Carbon disulfide	46 5	127 3	298	3360
Carbon tetrachloride	9 8	32 9	91	1460
Benzene			77	760 (79 6° C)
Toluene			37 (30° C)	557
Aniline			2 4 (50° C)	45 7
Nitrobenzene			7 5 (80° C)	20 9
Ethylene glycol				39 (120° C)
Ammonia	1 88 atm	4 24 atm	8 46 atm	
Sulfur dioxide	0 63 atm	1 53 atm	3 23 atm	
Carbon dioxide	19 4 atm	34 4 atm	56 5 atm	
Oxygen	49 7 atm (−118° C)			
Nitrogen	33 5 atm (−147° C)			
Sulfur				0 010
Iodine		0 030	0 20	45 5
Mercury			0 0012	0 273
Naphthalene				19
Camphor				380 (180° C)

VAPOR PRESSURE THERMOMETER. Thermometry.

VAPORS. A substance in the gaseous state, but below its critical temperature, is called a vapor If a pure liquid partly filling a closed container is allowed to stand, the space above it becomes filled with the vapor of the liquid, which develops a pressure This **vapor pressure** increases up to a certain limit, depending upon the temperature, where it becomes constant, and the space is then said to be saturated

Such a body of vapor is not subject to the laws of gases If the space occupied by it is diminished without change of temperature, there is no increase in pressure, but instead part of the vapor condenses And if the temperature is raised, the pressure goes up not at a uniform but at an increasing rate, because of both the expansion of the liquid and the further **evaporation** from it The relation of vapor to liquid takes on a curious aspect as the **critical state** is approached, in which the vapor and the liquid have equal density

The **characteristic equations** applying to vapors are of various forms, differing, of course, from those for gases A typical empirical equation of the sort, proposed by Callendar to represent the behavior of steam, is

$$v = \frac{RT}{p} + f(T) + c,$$

in which R is the ideal gas constant, c is a constant to be obtained empirically, and $f(T)$ is a slowly varying function of the absolute temperature T (L D W)

VARIABLE. A symbol which represents any one of a set of numbers (or elements of any kind) is said to be a variable The elements of the set are called values of the variable, and the set of elements itself is called the range of the variable (L L S)

VARIABLE SPEED TRANSMISSION. Speed Changers.

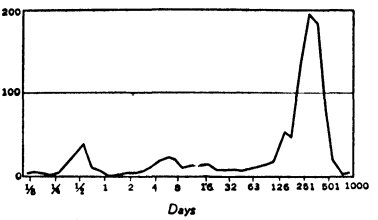
VARIABLE STARS. Any star whose light is known to fluctuate is called a variable star There is evidence that the ancients noticed certain temporary **stars**, now known as **novae**, and that the star **Algol** was recognized by them as a variable The first definite record that we have of observation of a variable star is in connection with observations of **Mira** during the late sixteenth and early seventeenth centuries In 1844, Argelander published the first catalogue of variable stars which contained eighteen entries The publication of this catalogue stirred up a great deal of interest in variable stars and they became objects of much search and study.

At the present time most variable stars are discovered from examination of photographic plates, taken at different times, of the same region of the sky At present over ten thousand variables are known, and it is estimated that at least 5% of all stars are at least slightly variable When a variable star is first observed it is assigned a serial number in order of discovery within the year, together with the year of discovery (e g, 256,1923 designates the two hundred and fifty-sixth variable discovered in 1923) After a sufficient number of observations have been taken to confirm the variability of the star and the fact that it is really a discovery, the star is assigned letters, in accordance with a system established by Bayer, followed by the genitive case of the **constellation** within which the object is located (e g, RZ Herculis) Novae are not included in this system of classification, being referred to by "nova" followed by the genitive case of the constellation and the year of discovery (e g, Nova Herculis 1934)

The observation of variable stars consists essentially in systematic **photometric** observations of the objects over long periods of time The methods employed are essentially those of stellar **photometry** and these will be found discussed elsewhere in this volume The observations are carried on not only by professional astronomers at many observatories all over the world, but also by an enthusiastic group of amateurs who have banded themselves together in societies for the purpose of carrying on this valuable work In the United States, the American Association of Variable Star Observers, commonly known as AAVSO, has its headquarters at the Harvard College Observatory, holds two general meetings each year, and its membership contributes thousands of observations annually Its membership is open to anyone who is interested in astronomical observing, whether or not he has any equipment other than eyesight and enthusiasm

When a sufficient number of observations of the magnitude of a variable have been obtained, a **light curve** is plotted and the study of the characteristics of the

object is undertaken Variable stars divide themselves into two natural groups the periodic and non-periodic variables In the accompanying figure the number of



Distribution of periods of variable stars (Russell, Dugan, and Stewart, *Astronomy*, Ginn & Co)

periodic variable stars within certain limits of period is plotted as ordinate against the logarithm of the period in days Examination of the figure indicates that there are three principal groups of periodic variables one group with periods of less than one day, a second with periods between three and fifty days, and a large group with periods between one hundred and twenty and seven hundred and fifty days Periodic variables with periods under fifty days are known as **Cepheids**, while those with periods greater than one hundred days are known as **long-period variables** The non-periodic variables are divided into two groups the novae and the **irregular variables** We sometimes find **eclipsing binaries** referred to as eclipsing variables, but they are not variables in the exact sense of the term, since the apparent variation in light is not due to any intrinsic variability within the stars themselves, but is due to changes in configuration of the objects as seen from the earth (W K G)

VARIATION. This term has a number of uses It is applied in connection with the compass, and this topic is discussed in the article on **compass correction** The term variation is also used in mathematics and biology, and these usages will be discussed in that order in this article

Variation is a simple and important type of mathematical relationship between variables, which is of very frequent occurrence in physical problems

If two **variables** x and y are related by the **power function** relationship $y = kx^n$, where k and n are **constants**, we say that y varies as x^n, or y varies as the n^{th} power of x, or that y is proportional to x^n The factor k is called the constant of variation, or the constant of proportionality, or the proportionality factor

Special cases are

(1) $(n = 1)$ If two variables are so related that their ratio is always constant, so that $y/x = k$ or $y = kx$ (k a constant), we say that y varies directly as x (or that y is proportional to x) The notation $y \propto ax$ is sometimes used to express the fact that y varies directly as x

(2) $(n = -1)$ If two variables are so related that their product is always constant, so that $xy = k$ or $y = k/x$ (k a constant), we say that y varies inversely as x (or that y is inversely proportional to x)

Other types of variation are defined as follows

If a variable z varies directly as the product of two variables x and y, so that $z = kxy$ (k constant), we say that z varies jointly as x and y

If a variable z varies jointly as x and the **reciprocal** of y, so that $z = kx/y$, we say that z varies directly as x and inversely as y

A common type of variation is one where a variable varies directly as the product of two variables and inversely as the square of another variable (as in the law of gravitation).

Instead of expressing variation statements by equations, we may express them as **proportions.** Thus, if y varies directly as x, we may write $y_1 : y_2 = x_1 : x_2$; and if y varies inversely as x, we may write $y_1 : y_2 = x_2 : x_1$

In biology, variation is the deviation of organisms from the mean development of their kind Very few individuals are even approximately identical in form, although some species show a much wider range of variation than others

The probable cause of variation is the interaction of diverse heritages with varying environmental conditions in the formation and maintenance of individuals The study of **heredity** has disclosed an intricate reproductive mechanism for the maintenance of diversity in the heritage as one source of variation, and environmental conditions have been found correlated with variation in many cases

As actual difference in living things variation is particularly interesting in the field of **evolution.** Here the heritability of variations is important, since evolutionary change sufficient to account for the origin of species can only be attained through a long succession of generations Characteristics due to the variable heritage are obviously heritable They are subject to change only through the process of **mutation**, as far as we know, hence this process becomes an important source of variations Efforts to determine the cause of mutations have shown that they may result from the incidence of unusual environmental conditions, such as x-rays, terrestrial radiation, and radium emanations, and from more usual factors such as heat and moisture Thus the most advanced information on the subject leads to the initial premise that variations are due to the intricacies of reaction between variable heritages and environments

The actual variation of existing species has been studied extensively and is the subject of an extensive literature Differences between individuals may be sexual, seasonal, or due to specialization within colonies These types of variation are often extreme, resulting in individuals of very different structure and appearance On a lesser scale the similar individuals of any species show incidental differences of no fundamental importance (L L S, A W L)

VARIATION OF LATITUDE. In the latter part of the eighteenth century the mathematician Euler predicted, from purely theoretical considerations, that the **latitude** of every point on the surface of the earth should be varying The amount of this variation depends upon the shape, the elasticity, and other physical characteristics of the earth, together with the attractions of external objects, such as the **moon**, for our rotating **planet** The first actual observations of variation of latitude were made in 1888, nearly a century after Euler's prediction, by the careful observations of the astronomer Kustner

The effect may be described by considering the motion of a wheel, the bearings of which have become so worn that the axle fits loosely in the hub When considering variation of latitude alone we consider the axis of the earth as fixed in space in spite of the fact that we know that it is actually slowly moving due to **precession** and nutation As the earth slips slightly about on this axis the position of the pole of rotation wanders about over a small area in the vicinity of the average position of the pole By definition the plane of the **equator** is perpendicular to the axis of rotation of the earth, and if this line moves, so also must the equator move Since latitude is measured from the equator, the motion of the equator must produce a variation of latitude

The actual amount of variation of latitude is a small quantity, the total area over which the pole moves being about the size of a baseball diamond Nevertheless, small as the effect may be, it is appreciable and the date should be very carefully specified whenever defining boundary lines by means of latitude.

During the past fifty years a great mass of observational material has been gathered, but as yet the problem has not been completely solved. At present an international campaign is under way in connection with which a number of stations all over the earth are constantly at work observing the latitudes of their localities by use of the **zenith telescope.** (W.K.G.)

VARICELLA. Chickenpox.

VARICOCELE. Enlargement and dilatation of the veins surrounding the spermatic cord in the male. When this condition is marked the knot of varicose veins forms a swelling in the upper scrotum. Surgical interference is not wise unless the condition causes severe symptoms.

Ovarian varicocele is a similar condition in the female of the veins in the ligaments near the ovary. (R.S.M.)

VARICOSE VEINS. An enlarged tortuous condition of the superficial veins of the body. This disorder is most often seen in the legs and thighs.

Varicose veins of the leg.

Varicose veins are directly caused by any disorder that destroys or weakens the **valves** in the **veins,** whether it be infection or increase in the venous pressure such as from a **tumor,** pregnant uterus or constriction of the leg as in tight circular garters or from constant standing, etc. A tendency toward varicose veins seems to be hereditary, and is probably due to the inheritance of weak valve structure in the veins, the basic cause of varicosities.

The symptoms caused by varicose veins are pain, cramps, or tired feeling in the legs, swelling of the ankles and legs when the condition is marked. Complicating the later stages of varicose veins are varicose ulcers and eczema. The ulcers are chronic and difficult to heal. They result from any break or injury to the skin of the leg and its inability to heal is due to the poor circulation in the leg. Treatment of the veins will usually heal the ulcers.

The eczema results from poor skin nutrition, due again to the poor circulation in the leg. It is treated by injection of the veins, which restores the normal circulation of the leg. Varicose veins are very subject to infection such as **phlebitis.**

Varicose veins were formerly treated by removal by surgical means. This method has been given up during the past ten years, and at present the veins are destroyed by the injection into them of chemical substances which act by completely shutting off the diseased veins. Since there is no adequate blood flow through varicose veins, the circulation in the leg is improved by destruction of these superficial veins. (R.S.M.)

VARIOLA. Smallpox.

VARIOLES. Variolite.

VARIOLITE. A fine-grained basic rock that contains **spherulites** made up of fibers of **feldspar** and **augite** in radial development.

The spherulites themselves are known as varioles, and the texture of such rocks is said to be variolitic. The term is derived from the Latin *variola,* smallpox, given to the rock because of resemblance of the pea-like or pustular forms of the varioles on weathered surfaces to smallpox pustules. (E.S.C.S.)

VASCULAR ELEMENTS. The vascular elements of a plant are the elements or cells which serve to conduct materials in the plant. The principal cells of the vascular system are the **xylem** and **phloem** cells. (R.M.W.)

VASCULAR SYSTEM. This is a complex system of cells or tissues composed mainly of **xylem** and **phloem** cells, and serving to conduct water, mineral salts, and foodstuffs through the plant. It also gives strength and support to the plant. It composes the bulk of the tissues of roots and stems of woody plants. (See **Circulatory System** for a discussion of the vascular system of animals.) (R.M.W.)

VASCULAR TISSUE. Blood, lymph, and related fluids of the body. These liquids are regarded as tissues because they consist of characteristic cells lying in an intercellular substance. The liquid condition of the intercellular substance is responsible for their fluidity. (A.W.L.)

VAS DEFERENS. Urogenital system.

VECTOR ADDITION. Let **a** and **b** be any two vectors (Figure 1). To add vector **b** to vector **a**, we place the origin of **b** at the terminus of **a**, then the vector **c** extending from the origin of **a** to the new terminus of **b** is defined as the sum (or resultant) of **a** and **b**, and is

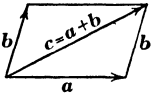


Figure 1.

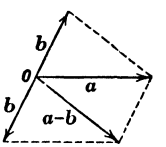


Figure 2.

denoted by $\mathbf{a}+\mathbf{b}$. This operation is often called composition of vectors.

Vector addition obeys the **commutative** and **associative** laws of algebra: $\mathbf{a}+\mathbf{b}=\mathbf{b}+\mathbf{a}$, $(\mathbf{a}+\mathbf{b})+\mathbf{c}=\mathbf{a}+(\mathbf{b}+\mathbf{c})$.

To subtract a vector **b** from a vector **a**, we take the negative of **b** and add $-\mathbf{b}$ to **a**. (Figure 2.)

The components of a vector **a** are any vectors whose sum is **a**. The components most frequently used are parallel to a set of rectangular coordinate axes; these are called rectangular components. The operation of finding components of a given vector is often called the decomposition of the vector.

In order to be able to express a vector in terms of its rectangular components in convenient form, we take unit vectors parallel to the X, Y, Z axes of a **rectangular coordinate** system and denote them by $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, $\hat{\mathbf{k}}$, respectively.

In terms of the unit vectors $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, $\hat{\mathbf{k}}$, we may express any given vector **r** with origin at the origin of the coordinate system by the form (Figure 3) $\mathbf{r}=x\hat{\mathbf{i}}+y\hat{\mathbf{j}}+z\hat{\mathbf{k}}$, where x, y, z are the rectangular coordinates of the terminus of **r**. Then $x\hat{\mathbf{i}}$, $y\hat{\mathbf{j}}$, $z\hat{\mathbf{k}}$ are the rectangular components of **r**.

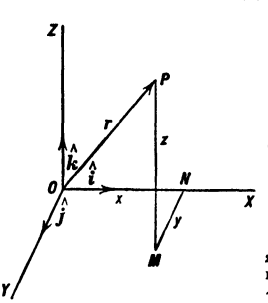


Figure 3. Vector components.

If $\mathbf{r}=x\hat{\mathbf{i}}+y\hat{\mathbf{j}}+z\hat{\mathbf{k}}$, then the magnitude of **r** is $r=\sqrt{x^2+y^2+z^2}$, and the direction of **r** is given by the direction cosine relation $\cos\alpha:\cos\beta:\cos\gamma=x:y:z$.

If two vectors **a** and **b** have rectangular components a_1, a_2, a_3 and b_1, b_2, b_3 in magnitude, then to add **a** and **b**, we have

$$\mathbf{a}+\mathbf{b}=(a_1+b_1)\hat{\mathbf{i}}+(a_2+b_2)\hat{\mathbf{j}}+(a_3+b_3)\hat{\mathbf{k}}.$$

Let a vector $\mathbf{a}$ have rectangular components a_1, a_2, a_3 (in magnitude) with respect to a first set of rectangular coordinate axes X, Y, Z, and components a_1', a_2', a_3' (in magnitude) with respect to any other set of rectangular axes, with the same origin Let the relations of the axes be given by the following scheme of direction cosines

	X	Y	Z
X'	l_1	l_2	l_3
Y'	m_1	m_2	m_3
Z'	n_1	n_2	n_3

where l_1, l_2, l_3 are the cosines of the angles which the X, Y, Z axes make with the X' axis, and similarly for the m's and n's Then the formulas for **transformation of coordinates** are

$$x' = l_1x + l_2y + l_3z, \qquad x = l_1x' + m_1y' + n_1z',$$
$$y' = m_1x + m_2y + m_3z, \qquad y = l_2v' + m_2y' + n_2z',$$
$$z' = n_1x + n_2y + n_3z, \qquad z = l_3x' + m_3y' + n_3z'$$

Then the vector components must transform in a similar way

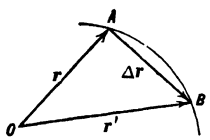
$$a'_1 = l_1a_1 + l_2a_2 + l_3a_3, \qquad a_1 = l_1a'_1 + m_1a'_2 + n_1a'_3,$$
$$a'_2 = m_1a_1 + m_2a_2 + m_3a_3, \qquad a_2 = l_2a'_1 + m_2a'_2 + n_2a'_3,$$
$$a'_3 = n_1a_1 + n_2a_2 + n_3a_3, \qquad a_3 = l_3a'_1 + m_3a'_2 + n_3a'_3$$

(L L S)

VECTOR ANALYSIS. The name Vector Analysis is usually applied to the study of the properties and applications of vectors It may be described also as the Algebra, the Geometry, and the Calculus of Vectors

The principal topics relating to Vector Analysis are **Vectors, Vector Addition, Vector Multiplication, Scalar Product of Two Vectors, Vector Product of Two Vectors, Triple Products of Vectors, Vector Geometry, Vector Derivatives, Vector Integrals, Line Integral of Vector Function, Surface Integral of Vector Function, Gradient of a Scalar Function, Divergence of a Vector Function, Curl of a Vector Function, Linear Vector Function, Dyadics.** (L L S)

VECTOR DERIVATIVES Let $\mathbf{r}$ be a **vector function** of a **scalar variable** t. If the origin of $\mathbf{r}$ be kept fixed and t is varied, the terminus of $\mathbf{r}$ will describe a curve Let A and B be two neighboring points on this curve, and let $\mathbf{r}$ and $\mathbf{r}'$ be their position vectors, then $\mathbf{r}' - \mathbf{r} = \Delta\mathbf{r}$ is a vector increment of $\mathbf{r}$, it is a vector having the direction of the secant AB, which approaches the **tangent to the curve** at A as B approaches A. Let Δt be the change (increment) in t corresponding to the increment $\Delta\mathbf{r}$ of $\mathbf{r}$ Form the ratio $\Delta\mathbf{r}/\Delta t$. If $\lim_{\Delta t \to 0} \frac{\Delta\mathbf{r}}{\Delta t}$ exists, it is called the **derivative** of $\mathbf{r}$ with respect to t, and is denoted by $\frac{d\mathbf{r}}{dt}$. It is a vector tangent to the curve described by the terminus of $\mathbf{r}$.



If $\mathbf{r} = x\hat{\mathbf{i}} + y\hat{\mathbf{j}} + z\hat{\mathbf{k}}$, and if x, y, z are functions of a **scalar variable** t, then

$$\frac{d\mathbf{r}}{dt} = \hat{\mathbf{i}}\frac{dx}{dt} + \hat{\mathbf{j}}\frac{dy}{dt} + \hat{\mathbf{k}}\frac{dz}{dt},$$
$$\frac{d^2\mathbf{r}}{dt^2} = \hat{\mathbf{i}}\frac{d^2x}{dt^2} + \hat{\mathbf{j}}\frac{d^2y}{dt^2} + \hat{\mathbf{k}}\frac{d^2z}{dt^2}.$$

If $\mathbf{r}$ is the position vector of a particle and if t is the time, then $\frac{d\mathbf{r}}{dt}$ will represent the vector velocity and $\frac{d^2\mathbf{r}}{dt^2}$ the vector acceleration of the particle.

If $\mathbf{r}$ is constant in magnitude but variable in direction, then $\frac{d\mathbf{r}}{dt}$ is perpendicular to $\mathbf{r}$.

Let $\mathbf{u}$, $\mathbf{v}$, $\mathbf{w}$ be vector functions of a scalar variable t.

Then the vector derivatives of various types of **products of vectors** are given by the following formulas·

$$\frac{d}{dt}(\mathbf{u} \quad \mathbf{v}) = \frac{d\mathbf{u}}{dt} \cdot \mathbf{v} + \mathbf{u} \quad \frac{d\mathbf{v}}{dt},$$
$$\frac{d}{dt}(\mathbf{u} \times \mathbf{v}) = \frac{d\mathbf{u}}{dt} \times \mathbf{v} + \mathbf{u} \times \frac{d\mathbf{v}}{dt},$$
$$\frac{d}{dt}[\mathbf{u} \quad (\mathbf{v} \times \mathbf{w})] = \frac{d\mathbf{u}}{dt} \quad (\mathbf{v} \times \mathbf{w}) + \mathbf{u} \quad \left(\frac{d\mathbf{v}}{dt} \times \mathbf{w}\right) + \mathbf{u} \cdot \left(\mathbf{v} \times \frac{d\mathbf{w}}{dt}\right),$$
$$\frac{d}{dt}[\mathbf{u} \times (\mathbf{v} \times \mathbf{w})] = \frac{d\mathbf{u}}{dt} \times (\mathbf{v} \times \mathbf{w}) + \mathbf{u} \times \left(\frac{d\mathbf{v}}{dt} \times \mathbf{w}\right) + \mathbf{u} \times \left(\mathbf{v} \times \frac{d\mathbf{w}}{dt}\right)$$

If we have given a vector function of several independent scalar variables, its **partial derivatives** may be defined in a manner similar to that for scalar functions of several variables

The symbolic vector expression

$$\hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}$$

is denoted by ∇ and is usually called "del" (occasionally "nabla") When applied directly to a scalar function of position, we obtain the **gradient** of the function, when applied by the **scalar product** process to a vector function of position, we obtain the **divergence** of the function, and when applied by the **vector product** process to a vector function of position, we obtain the **curl** of the function (L.L S)

VECTOR GEOMETRY. Let $\mathbf{r}$ be a **variable vector**, with origin at O and let s be a **scalar** variable. Then $\mathbf{r} = s\mathbf{a}$ is the equation of a straight line through O, parallel to $\mathbf{a}$, and $\mathbf{r} = \mathbf{b} + s\mathbf{a}$ is the equation of a line through the terminus of $\mathbf{b}$ and parallel to $\mathbf{a}$. The equation

$$\mathbf{r} = \mathbf{a} + s(\mathbf{b} - \mathbf{a}) = s\mathbf{b} + (1 - s)\mathbf{a}$$

is the equation of a line through the ends of two vectors $\mathbf{a}$ and $\mathbf{b}$. If we have given three vectors, $\mathbf{a}$, $\mathbf{b}$, and $\mathbf{c}$, with the same origin, they terminate in the same straight line if

$$x\mathbf{a} + y\mathbf{b} + z\mathbf{c} = 0 \text{ and } x + y + z = 0$$

The equation of a straight line through the end of $\mathbf{b}$ and parallel to $\mathbf{a}$ may also be written $\mathbf{a} \times (\mathbf{r} - \mathbf{b}) = 0$

Let $\mathbf{r}$ be a variable vector, and let s and t be scalar variables Then the equation of a plane through the end of $\mathbf{c}$ and parallel to $\mathbf{a}$ and $\mathbf{b}$ is $\mathbf{r} = \mathbf{c} + s\mathbf{a} + t\mathbf{b}$ The equation of a plane through the ends of three noncoplanar vectors $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$ is $\mathbf{r} = s\mathbf{a} + t\mathbf{b} + (1 - s - t)\mathbf{c}$. The condition that four vectors $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$, $\mathbf{d}$ with the same origin terminate in the same plane is

$$x\mathbf{a} + y\mathbf{b} + z\mathbf{c} + w\mathbf{d} = o \text{ and } x + y + z + w = o$$

The equation of a plane perpendicular to a and through the end of $\mathbf{b}$ may be written $\mathbf{a}\ (\mathbf{r} - \mathbf{b}) = 0$ The equation of a plane through the end of $\mathbf{b}$ and parallel to $\mathbf{c}$ and $\mathbf{d}$ may be written $(\mathbf{c} \times \mathbf{d})\ (\mathbf{r} - \mathbf{b}) = 0$ The equation of a plane through the ends of three vectors $\mathbf{a}$, $\mathbf{b}$, $\mathbf{c}$ with the same origin is $(\mathbf{r} - \mathbf{a})\ (\mathbf{a} - \mathbf{b}) \times (\mathbf{b} - \mathbf{c}) = 0$, or $(\mathbf{a} \times \mathbf{b} + \mathbf{b} \times \mathbf{c} + \mathbf{c} \times \mathbf{a})\ (\mathbf{r} - \mathbf{a}) = 0$.

The vector to a point of division of the segment joining the ends of $\mathbf{a}$ and $\mathbf{b}$ is $\mathbf{r} = \mathbf{a} + s(\mathbf{b} - \mathbf{a})$, where s is the ratio of the partial segment AP to the total segment AB, where A and B are the ends of $\mathbf{a}$ and $\mathbf{b}$

If r is a variable vector, the equation of a circle (or of a sphere), with center at the origin of $\mathbf{r}$, is $\mathbf{r} = \mathbf{a}$ or $\mathbf{r}\ \mathbf{r} = \mathbf{a}\ \mathbf{a}$ (written $\mathbf{r}^2 = \mathbf{a}^2$). If the center of the circle is at the end of $\mathbf{c}$, the equation of the circle is $(\mathbf{r} - \mathbf{c})^2 = \mathbf{a}^2$ or $\mathbf{r}^2 - 2\mathbf{r}\ \mathbf{c} = \mathbf{a}^2 - \mathbf{c}^2 =$ constant. If the origin is on the circumference of the circle, $\mathbf{c} = \mathbf{a}$, and the equation of the circle is $\mathbf{r}^2 - 2\mathbf{r}\ \mathbf{a} = 0$ (L L S.)

VECTORIAL ANGLE. Polar Coordinates in a Plane.

VECTOR INTEGRALS. Vector integration, as an operation, may be defined as in the case of a scalar function, as the **inverse operation** to vector differentiation.

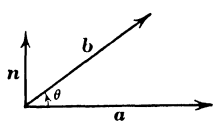
Corresponding to ordinary **definite integrals** of functions of one variable, and to **double integrals** of functions of two variables, we have vector integrals of the following types **line integrals of vector functions** and **surface integrals of vector functions.** (L L S)

VECTOR MULTIPLICATION. There are two distinct kinds of products of two **vectors**· the **scalar product** and the **vector product.**

Combining these two types of products, we get two kinds of **triple products of vectors,** and also several products of four vectors, giving rise to **reciprocal systems of vectors.** (L L S)

VECTOR PRODUCT OF TWO VECTORS. The vector product (or cross product) of two **vectors** is defined as a vector perpendicular to their plane in the sense of advance of a right-handed screw rotated from the first to the second of these vectors through the smaller angle between them, and having a magnitude equal to the product of the magnitudes of the two vectors by the sine of the angle between them

The vector product is represented in magnitude by the area of the parallelogram of which the two given vectors are adjacent sides



The vector product of **a** by **b** is denoted by $\mathbf{a} \times \mathbf{b}$ in the Gibbs notation, by $[\mathbf{a}, \mathbf{b}]$ in another common form of notation, and by V **ab** in the Hamiltonian notation

We have

$$\mathbf{a} \times \mathbf{b} = (ab \sin \theta)\hat{\mathbf{n}},$$

where θ is the angle between **a** and **b**, and $\hat{\mathbf{n}}$ is the unit normal vector to **a** and **b**

The vector product $\mathbf{a} \times \mathbf{b}$ does not obey the **commutative law,** but we have

$$\mathbf{a} \times \mathbf{b} = -\mathbf{b} \times \mathbf{a}.$$

It is, however, **distributive**

$$(\mathbf{a} + \mathbf{b}) \times \mathbf{c} = \mathbf{a} \times \mathbf{c} + \mathbf{b} \times \mathbf{c}.$$

If **a** is parallel to **b**, then $\mathbf{a} \times \mathbf{b} = 0$, and conversely It follows that $\mathbf{a} \times \mathbf{a} = 0$ for any vector **a**

For the unit vectors $\hat{\mathbf{i}}, \hat{\mathbf{j}}, \hat{\mathbf{k}}$, we have

$$\hat{\mathbf{i}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}} \times \hat{\mathbf{k}} = 0,$$
$$\hat{\mathbf{i}} \times \hat{\mathbf{j}} = \hat{\mathbf{k}}, \quad \hat{\mathbf{j}} \times \hat{\mathbf{k}} = \hat{\mathbf{i}}, \quad \hat{\mathbf{k}} \times \hat{\mathbf{i}} = \hat{\mathbf{j}}$$

If $\mathbf{a} = a_1\hat{\mathbf{i}} + a_2\hat{\mathbf{j}} + a_3\hat{\mathbf{k}}$, $\mathbf{b} = b_1\hat{\mathbf{i}} + b_2\hat{\mathbf{j}} + b_3\hat{\mathbf{k}}$, then $\mathbf{a} \times \mathbf{b}$

$$= (a_2b_3 - a_3b_2)\hat{\mathbf{i}} + (a_3b_1 - a_1b_3)\hat{\mathbf{j}} + (a_1b_2 - a_2b_1)\hat{\mathbf{k}}$$
$$= \begin{vmatrix} \hat{\mathbf{i}} & \hat{\mathbf{j}} & \hat{\mathbf{k}} \\ a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \end{vmatrix}.$$

(L L S)

VECTOR PRODUCTS. Vector Multiplication.

VECTORS. Line-segments, as AB and BA, in which opposite senses are distinguished, are called directed line-segments

A directed line-segment is also called a vector A vector then has magnitude (length), direction and sense

A physical quantity which has the three attributes of magnitude, direction and sense may be called a vector quantity Examples of vector quantities are displacement of a particle, velocity and acceleration of a particle, force acting on a body, etc

If a vector is a directed line-segment AB, in which the sense is from A to B, we call A the origin and B the terminus of the vector and sometimes denote it by the symbol $\overrightarrow{AB}$

A vector is frequently denoted by a single letter, printed in bold-face type, as **a.**

A scalar is a number

By a scalar quantity we shall mean a physical quantity whose measure is completely expressed by a scalar or number, it has only magnitude Examples of scalar quantities are temperature, weight, potential, etc

Scalars are denoted by light-face type

The magnitude (or length) of a vector **a** is often denoted by a or by $|\mathbf{a}|$ The unit vector having the same direction and sense as **a** but of unit length is sometimes denoted by $\hat{\mathbf{a}}$

To multiply a vector **a** by a positive scalar m, we multiply the magnitude of **a** by m, leaving the direction and sense unchanged

The negative of a vector **a** is the vector of the same magnitude and direction but of opposite sense

There is great diversity of notation in vector analysis, particularly with regard to products of vectors (L L S)

VEERY. Aves, Passeriformes A **thrush,** *Hylocichla fuscescens,* of eastern North America, also called Wilson's thrush (A W L)

VEGA. Vega (α **Lyrae**) is the second brightest star visible in northern latitudes It is visible during some portion of every clear night throughout the year, and dominates the summer skies Because of its distinctly bluish tinge it is one of the most beautiful stars of the northern skies and references to it are found in all of the ancient literatures At one time Vega was the pole star and, because of **precession,** the pole will be close to Vega about 11,500 years hence Lockyear claims that the temples at Denderah in Egypt were oriented to this star as early as 7000 B C

Vega is of interest astronomically for it is the brightest star in the general vicinity of the **solar apex** or the point on the celestial sphere toward which the **sun** is moving, carrying all other members of the **solar system** along with it (W K G)

VEGETABLE IVORY. Vegetable ivory is obtained from the fruits of various **palms** of the genus *Phytelephas,* known as ivory palms These plants, natives of the wet forests of tropical America, have short thick stems and erect, **pinnate** leaves of very large size The plants are **dioecious.** The staminate (See **Stamen**) flowers are borne on an elongate fleshy **spadix,** while the pistillate (See **Pistil**) flowers occur in groups of six or seven Each flower gives rise to a berry, the six or seven berries of a group being united This fruit has a hard outer layer, covered with woody protuberances, and contains several seeds During development these seeds contain a milky-white fluid, which hardens as the seed matures, and which is the endosperm of the seed It becomes almost as hard as ivory, and is used in making billiard balls, buttons, and a variety of small articles (R M W)

VEIN. For the use of this term in anatomy, see **Circulatory System.** For its use in botany, see **Leaf.** In geology the term vein is understood to refer to small or large fissures which have been filled with mineral matter by deposition from aqueous solutions, including "liquors" and gaseous emanations from magmas Lode means essentially the same thing as vein, being an old Cornish mining term referring to the formations which would "lead" or direct the miner to the desired minerals (E S C S)

VELAMEN. Root.

VELARIUM. A flange of thin tissue projecting from the margin of a jellyfish over the concave surface of the body Unlike a true **velum** it contains neither muscles nor a nerve ring This structure is well developed in the order Cubomedusae (**Scyphozoa**) and increases the resemblance of these animals to the **hydrozoan** medusae Also called the pseudovelum (A W L)

VELIGER. A form of **larva** found in the phylum **Mollusca.** Some mollusks hatch as a **trochophore** and later develop into a second free-swimming larval stage, the veliger. In this stage a ciliated (**cilia**) ring called the **velum** is developed and the foot becomes larger. The shell becomes coiled in the veliger stage of some **gasteropods.** (A.W.L.)

VELOCITY. The time rate of change of position. (Unless angular velocity is specified, this term is understood to refer to linear motion, which may be emphasized by the expression "linear velocity.") Strictly, the velocity of a moving point must specify both the speed and the direction of the motion, and is therefore a **vector;** though the term is sometimes carelessly used as merely synonymous with speed. The velocity is the time rate of the distance s from a fixed origin O, expressed as the vector derivative of s with respect to the time, ds/dt (Figure 1); while the speed is the magnitude of the velocity and is not a vector. If the direction of motion is constant, so that the motion is in a straight line (but not necessarily with constant speed), and if the line of motion is clearly understood, it is convenient to treat the distance s and the velocity ds/dt as scalars with appropriate algebraic signs (Figure 2); otherwise they must be regarded as vectors. If the velocity is variable, account must be taken of the **acceleration.** Examples of both curved and rectilinear motion are treated under **kinematics.** (L.D.W.)

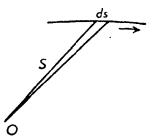


Figure 1.

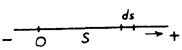


Figure 2.

VELOCITY CURVE. A plot of **radial velocity** of a star as ordinates against time as abscissae is known as the velocity curve for the star. The method of formation of a mean velocity curve is similar to that described for the determination of a mean **light curve.** The use of the velocity curve for determining the **orbit** of a **spectroscopic binary** is discussed elsewhere. (W.K.G.)

VELUM. 1. In **hydrozoan** medusae, a thin flange of tissue projecting from the margin of the body over its concave surface, leaving a restricted circular opening. The velum contains a nerve ring and muscles. It aids in locomotion by the contraction of the body to force jets of water from the concave subumbrellar surface. 2. In the **veliger** larva of **mollusks,** a ciliated (**cilia**) organ adjacent to the mouth. It is formed of the postoral ciliated ring of the trochophore larva together with the preoral ring, and serves as an organ of locomotion and to bring food to the mouth. 3. The double ciliated ring surrounding the oral end of the body of a **rotifer.** (A.W.L.)

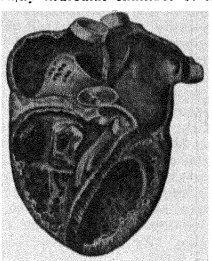
VELVET ANT. Insecta, Hymenoptera. A **wasp** of the family Mutillidae. The females of these insects are wingless and consequently are antlike in form, but they differ in the absence of the dorsal prominence on the slender waist that characterizes the ants. They are densely hairy insects, usually brightly banded with some shade of red or yellow, black, and sometimes white. The males differ in other details than the presence of wings, hence it is difficult to associate the sexes unless they are taken together. Velvet ants are parasitic in the nests of other insects and some have been reported as parasites on the tsetse fly. (A.W.L.)

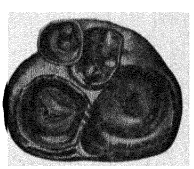
VENA CAVA. A main venous trunk returning blood to the **heart** in **vertebrates.** Above the fishes the paired condition of the venous system is modified, and in the **reptiles,** birds (**Aves**), and **mammals** the posterior parts of the body are drained by the tributaries of a single trunk vein, the posterior vena cava. In the mammals the paired condition of the anterior venous system also disappears, giving rise to an anterior vena cava. Owing to the erect posture of man these vessels are also known as the superior and inferior venae cavae. The name is also applied to a venous trunk in the **cephalopod** mollusks. It drains the head and subdivides to form the **branchial veins** to the gills. (A.W.L.)

VENDACE. Pisces, Teleostei. A fresh-water fish related to the salmon, found in lakes of Ireland. (A.W.L.)

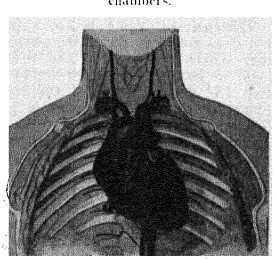
VENEER. **Wood.**

VENTRICLE. 1. A strongly muscular chamber of the **heart** from which **blood** is pumped to various parts of the body. In the **mollusks** it is a single chamber and in the vertebrates it is single in the more primitive forms, including fishes, amphibians, and some reptiles. In the reptiles its subdivision is begun, and in the crocodilians right and left ventricles appear. This division is complete in the birds and mammals.

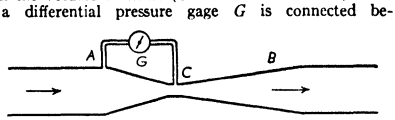



Cavities of the heart, showing valves between the heart chambers.

2. A cavity of the vertebrate **brain.** The first and second ventricles are in the cerebral hemispheres. The third is formed of the persisting median cavity of the first primitive brain vesicle. The fourth ventricle is the cavity of the third primary vesicle, and all other remnants of the original cavities become narrowed passages. The term is applied to some minor diverticula of these divisions. (A.W.L.)


Heart and main vessels. (Lungs removed.)

VENTURI METER. A device for measuring the rate of flow of fluids through pipes, usually of fairly large diameter. It consists in a short constriction of the pipe, toward which the diameter tapers from both directions, somewhat like an hour-glass. Its operation depends upon the fact that when the pipe is completely filled, the pressure in the constricted portion, where the speed is greater, is distinctly less than that on either side of it, and the pressure difference increases in a definite way with the volume of flow. (See **Bernoulli's Law.**) Thus if a differential pressure gage G is connected be-



Venturi meter. Pressure at C is less than at A by an amount depending upon rate of flow.

tween the point *A* and the constriction *C* (see figure), its dial may be graduated to show the flow in feet per second or in gallons per minute In large water-works stations the gage is often self-recording, showing the variations of flow during the day (See **Flow Meter.**) (L D W)

VENUS. (Cf Tables of planetary data, page 865) Venus may be called the earth's twin **planet,** for in size, density, and general constitution, if not in all physical characteristics, Venus is much like the earth This planet is one of the most conspicuous objects in the sky and may easily be viewed in full daylight with the naked eye, provided attention is directed to the proper point in the heavens For this reason Venus is frequently used by navigators for obtaining a **Sumner line** in the daytime to use in conjunction with an observation of the sun

Venus, like **Mercury,** has its orbit between the earth and the sun and never appears very far away from the sun Since at maximum elongation Venus appears either in the eastern sky at sunrise, or in the western sky at sunset, this is the planet that is most commonly referred to as the morning or evening "star" Like Mercury the ancient astronomers had two names for it, calling it Phosphorus as the morning star, and Hesperus as the evening As Venus passes about in its apparent path from inferior conjunction back to inferior conjunction again it goes through a series of **phases** exactly as does the moon In fact, this change in phase of Venus was one of the tests proposed by the anti-**Copernicians** prior to the invention of the telescope At inferior conjunction Venus is closer to the earth than any other astronomical object except the moon (and an occasional asteriod or comet), having a distance of only 26,000,000 miles Since at superior conjunction the planet has a distance of nearly 160,000,000 miles the changes in apparent diameter are very great and, as a matter of fact, Venus appears the brightest to us (i e, has the largest apparent area) when in the crescent phase similar in shape to the moon when about five days old

Telescopically Venus is not a particularly interesting object except in so far as the phase changes are interesting There are very few and very faint surface markings, in fact, the markings are so faint and so illusive that the determination of the rotation period of the planet by direct observation is practically impossible The application of the spectroscope, by applying the **Doppler-Fizeau principle** to the spectral lines, indicates that the rotation period is considerably longer than that of the earth, thirty days being a fair compromise between various discordant results

The high reflecting power of the planet, together with a value for **surface gravity** comparable with the value for the earth, lead to the conclusion that Venus has a dense **atmosphere.** A tremendous amount of research has been applied to the problem of the constitution of the atmosphere of Venus Delicate and exacting tests have failed to indicate the presence of either water vapor or oxygen in the atmosphere of Venus, although there is considerable evidence of the existence of carbon dioxide The absence of water vapor precludes the possibility of any large bodies of water on the planet and makes the existence of any forms of life such as we know them on the earth highly, improbable

Comparatively little is known concerning the surface conditions of Venus because the dense atmosphere of the planet prevents observations being made of the surface Measurements of the surface temperature of the planet indicate a range of from 333° K (140° F) on the sunlit portions, down to 253° K. (−4° F) for the dark regions

At rare intervals Venus passes through inferior conjunction at a time when the sun is close to the node of its apparent path At such times the planet will transit the disk of the sun and, since the planet will then be quite close to the earth, the transits may be used for the determination of **solar parallax.** The last transits occurred in 1872 and 1882 and the next ones will come in 2004 and 2012 (W K G.)

VENUS' FLY-TRAP. *Dionaea muscipula* **Insectivorous plants.**

VENUS' GIRDLE. Ctenophora, Cestida A transparent marine animal of ribbonlike form The longitudinal axis of the body lies across the width of the ribbon, hence the body is short and is greatly elongated on one transverse axis and very short on another (A.W L)

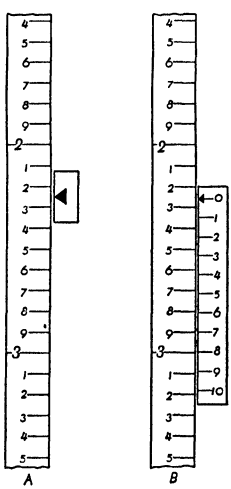
VERATRINE. Alkaloids.

VERDET CONSTANT. Faraday Effect.

VERMIFUGE. A **drug** used to expel worms or intestinal **parasites.** (R S M)

VERNAL EQUINOX. The point of intersection of the **ecliptic** and the equator where the sun apparently passes from south to north of the earth's equator is known as the vernal equinox The direction of the vernal equinox is the fundamental direction in the equatorial and ecliptic systems of **spherical coordinates** from which right ascension and celestial longitude are measured The sun is in the direction of the vernal equinox on approximately March 21st and this date indicates the beginning of the spring season in the northern hemisphere On the ancient **calendars** the passage of the sun through the vernal equinox indicated the beginning of the new year Some two thousand years ago the vernal equinox was in the **constellation** of **Aries** and was frequently referred to as the first of Aries Astrologers frequently use this same terminology for the position of the sun on March 21st in spite of the fact that, due to **precession,** the vernal equinox has shifted into the constellation of **Pisces** (W K G)

VERNIER. A vernier is an auxiliary scale which permits an observer to read the smallest main scale subdivision with greater accuracy For example, when, as



Vernier scale.

in Figure *A*, two pieces, one bearing the main scale, and the other an index point (either of these may be the movable one) register in the position shown, it is necessary to estimate within the smallest subdivision on the

scale. It is doubtful whether this could be uniformly estimated with accuracy. Figure *B* shows a vernier replacing the index point. A vernier scale for decimal subdivision is shown for the sake of simplicity, although other scales may have verniers, i.e., circular scales reading in degrees and minutes. In the vernier shown, ten equal units on the vernier occupy the same length as nine on the main scale. It is the property of this manner of subdivision that the point of coincidence of graduations on the main and vernier scales is read on the vernier as the fractional subdivision at the index point (the zero of the vernier). Thus in the illustration the index would be read 227. (F.T.M.)

Vertebral column. (From Cunningham, *Textbook of Anatomy*, Oxford Press.)

VERONAL (Barbital, Di-ethylbarbituric Acid). A sedative whose compounds and derivatives are much used in medicine where sleep or quieting of the nerves is desired. There are many derivatives of veronal on the market under proprietary names as "Luminal," "Medinal," "Amytal," "Dial," "Phanodorm," "Allonal," "Alurate," "Evipal," etc. The advantage of these derivatives over veronal is in their comparatively low toxicity. (See **Purine and Related Compounds.**) (R.S.M.)

VERTEBRA. One of the thirty-two bones making up the **spinal column.** There are seven cervical, twelve dorsal, five lumbar, five sacral and four coccygeal vertebrae. (R.S.M.)

VERTEBRATA. Animals with a bony or cartilaginous skeleton enclosed within the body. A subphylum of the phylum **Chordata.**

The vertebrates are distinguished from the lower chordates by the greater complexity of the **nervous system,** including a well-developed **brain,** as well as by the replacement of the **notochord** by a spinal column in most forms.

The group is divided into six classes:

Class **Cyclostomata.** The **hag-fishes** and **lampreys,** or round-mouthed eels. A group with a persistent notochord and without hinged jaws.

Class **Pisces.** The fishes. Animals of aquatic habit, relatively few species leaving the water at all. They breathe by gills.

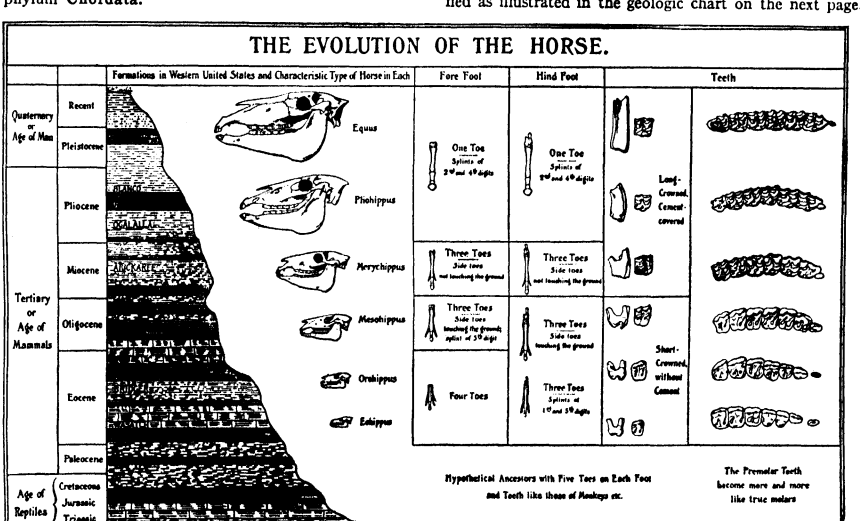
Class **Amphibia.** **Frogs, salamanders** and related forms. Moist-skinned animals, usually with an aquatic larval stage in which gills appear. Some are permanently aquatic and some exclusively terrestrial.

Class **Reptilia.** **Lizards, snakes, turtles, crocodiles,** etc. Never with gills, even though aquatic. Skin scaly.

Class **Aves.** The birds. Skin clothed with feathers and scales. Mostly flying species.

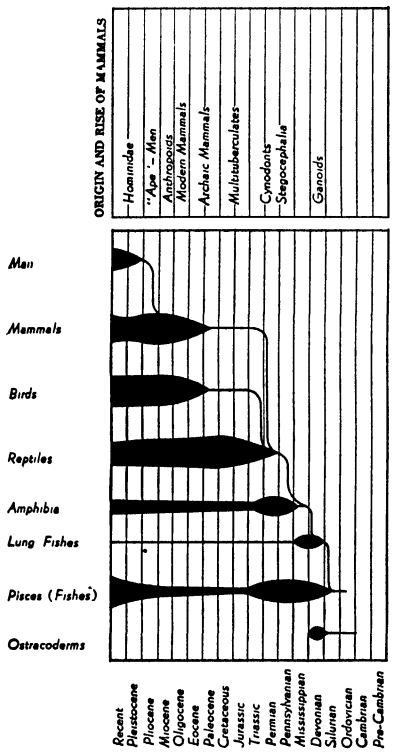
Class **Mammalia.** Skin clothed with hair in most species. Young nourished with milk secreted by the mother. (A.W.L.)

VERTEBRATE PALEONTOLOGY. The study, description and geologic use of vertebrate **fossils** in relation to paleobiological and stratigraphic problems. The science of vertebrate paleontology is primarily founded upon vertebrate zoölogy, and especially comparative osteology. Since thousands of vertebrate fossils, ranging in age from the late **Palezoic** to the **Pleistocene** have been figured and described, it is not possible to list them all in a general science encyclopedia. Also there is no single reference work in existence which covers the entire subject. For detailed information one must consult special bibliographies which list the generic and specific references in a large number of special papers and monographs. The chart below presents various data relating to the evolution of the horse. From the paleontological point of view the vertebrates may be classified as illustrated in the geologic chart on the next page.



Evolution of the horse. (Courtesy of American Museum of Natural History.)

Further information regarding the geologic and paleontologic terms used on these charts will be found elsewhere in this encyclopedia. (R M F)



Geologic range of the vertebrates (Field, *Geology Manual*, Part II, Princeton University Press)

VERTICAL CIRCLE. Any great circle on the **celestial sphere** which passes through the **zenith** and **nadir** is known as a vertical circle Since the zenith and nadir are poles of the **horizon,** a vertical circle must be perpendicular to the horizon. The vertical circle which cuts the horizon at the north and south points is known as the local **meridian,** while that vertical circle which cuts the horizon at the east and west points is known as the prime vertical (W K G)

VESSELS. A vessel is a linear series of water-conducting cells formed in the **xylem** of **angiosperms** by the dissolution of the end walls of the cells in the linear row The lateral walls are thickened and contain many bordered **pits,** usually of small size. There is no **cytoplasm** in a vessel. It is particularly adapted for the conduction of water in the stem.

For development, see **cambium.** (R.M.W.)

VESUVIANITE. The mineral **vesuvianite is a very complex silicate of calcium and aluminum with fluorine** which may also contain varying amounts of **boron, iron, lithium, magnesium, manganese, potassium, sodium** and **titanium.** A suggested formula is $Ca_6Al(OH,F)Al_2(SiO_4)_5$ Its **tetragonal** crystals are usually short, somewhat stoutish, prisms, sometimes pyramids, but columnar to massive varieties are common. It is essentially without cleavage, fracture, uneven, brittle; hardness, 6 5, specific gravity, 3 3-3.5, luster, vitreous to greasy or resinous, color, commonly some shade of brown or green, but may be reddish, bluish or yellowish, may be transparent, but is usually translucent It has been used as a gem but is not a particularly desirable stone This mineral was formerly called idocrase, having been named by Hauy from the Greek words meaning *form* and *mixture* because it resembled crystals of other species, scarcely a valid distinction. Werner gave it the name vesuvianite from Mt Vesuvius where it was first found in blocks of limestone appearing as inclusions in the **lava** Vesuvianite is not a constituent of the **igneous rocks,** but rather a contact **metamorphic** mineral resulting from the alteration of impure **limestones** and **dolomites.** It is usually associated with **diopside, wollastonite, epidote, grossularite, garnet,** etc There are many localities worthy of mention among which are The Urals, Czechoslovakia, Rumania, Trentino and Monzoni in Italy, as well as at Mt Vesuvius and Mt Somma, Switzerland, Mexico and Japan In the United States vesuvianite is found in Androscoggin and York Counties in Maine, Orange County, New York, Sussex County, New Jersey, Garland County, Arkansas, and Riverside and Tulare Counties in California (E S C S)

VIBRACULUM A modified form of individual in the **bryozoan** colony These colonies contain the complex polypides and two reduced forms whose functions appear to be the protection of the entire group against the lodging of **sessile** animals These forms are the **avicularium** and the vibraculum The latter is no more than a bristle or filament that moves back and forth, sweeping across the surface of the colony Numerous vibraculata sometimes act synchronously in this movement (A W L)

VIBRATIONS AND WAVES. These terms are used in very broad senses and apply to a large variety of phenomena and processes "Vibration" commonly refers to a to-and-fro motion, but we shall have to extend the meaning to include any periodic physical process, such, for example, as a cyclic variation in electric or magnetic field intensity When an elastic body is deformed and released, it is in general set into oscillation such that the displacement of any particle from its equilibrium position is a more or less complicated harmonic function of the time (See **Harmonic Motion** and **Harmonic Analysis**) The vibration may or may not be symmetrical with respect to the neutral position, in any case the maximum displacement is called the amplitude of the vibration By analogy, the same terms and the same analysis are applied to vibrations of any type

If a vibratory disturbance occurs at any point in a medium having sufficient continuity to transmit displacements from one part to another, a train of waves is propagated outward from the seat of the disturbance The speed of propagation depends upon the closeness of coupling between adjacent particles of medium and the consequent magnitude of the restoring forces, and upon whatever reaction of the medium corresponds to mechanical inertia In some cases also the speed varies with the frequency, as with light in a material medium In any case the wave length, viz, the distance traversed during a complete vibration period, is related to the frequency of vibration and the speed of propagation by the simple equation $v = n\lambda$ in which v is the speed, n the frequency, and λ the wave length. Thus, if sound waves of frequency 250 vibrations per second are traveling with a speed of 1000 feet per second, the wave length is 4 feet In case the vibrations are of complex character and the different components travel with different speeds, the resulting "wave group," traveling with its characteristic **group velocity,** may be very sharply defined and may

thus constitute a "wave packet," resembling a single pulse or unrepeated wave (See **Interference.**)

The theorem of Fourier states that any vibration or wave train, however complex, can be resolved into simple harmonic components of various amplitudes and frequencies and in various phases Of these components, the one of lowest frequency (and in the case of elastic vibrations, usually of greatest amplitude) is the "fundamental"; the others are "overtones"

The character of a wave process may be described mathematically by means of a "wave equation" which specifies the condition at any point of the wave field in terms of the position and of the time, or graphically by one or more "wave form" curves, of which the ordinates represent the periodically variable displacements at any point, and the abscissas the time See **Wave Propagation**

In applied dynamics vibrations might be classified as natural and artificial An outstanding example of the former is the earthquake Almost any rotating machinery furnishes examples of the latter Civilized man comes into contact with artificial vibrations constantly, but only occasionally with those of a natural type Sometimes vibration can be an asset, witness the use of vibrators to jar a **pattern** loose from molding sand, vibrators in therapeutical work, and a few others In the main vibration is a nuisance, possibly destructive, indicative of wear and inefficiency, liable to produce weakening of a structure, and fatiguing physically and mentally Man-made vibrations are much more likely to be encountered in damaging amounts in cities than in rural areas There is considerably more machinery in and about the cities Most of the streets are hard-paved They carry a high average density of traffic, and further, there are subways, elevated railroads, and a concentration of commercial vehicles which produce all sorts of disturbances on the crust of the earth In a region of large modern buildings these vibrations might enter the structural steel skeleton of the building below ground level, and be felt throughout the whole structure Concrete in monolithic construction transmits vibrations exceptionally well This condition has reached such proportions that a cessation of vibration, or a very effective damping of it, is of definite financial value, and hence the economic incentive to attack vibration from an engineering standpoint is provided By the use of suitable vibration absorbing materials, and with proper isolation of machines having vibration, or, better still, the more scientific balancing of rotating apparatus, much has been done to reduce vibration to a point where it is not objectionable This work has appeared in many different fields, as is brought out by illustrations of vibration control taken at random In the automotive field, the number of cylinders of engines have been increased so that there will be a smoother flow of power due to overlapping power impulses, vibration dampers have been designed and applied to crankshafts, and engines have been mounted in resilient supports like rubber. The widespread use of pneumatic tires has helped more than anything in reducing vibration from passing vehicles The spring suspension of many pieces of rotating machinery, which were once rigidly bolted to their foundations, is a further example Most domestic refrigerators will be found to have the rotating refrigerating unit flexibly supported so that a minimum of vibration will be transmitted Buildings are insulated partially from vibration if the problem is considered at the time of laying down the foundations, but not much can be done about it once the building is finished.

The amplitude of vibration is the distance traversed by the particle in vibration in its excursions. Vibrations arising from rotation machinery have usually a constant amplitude and frequency Earthquakes, city traffic, and others, usually have variable amplitude A particular case of vibration is harmonic vibration, which is vibratory motion of simple harmonic nature. See **Mechanics, Balancing, Critical Speed.** (L D W, F T M)

VIBRATION SPECTRUM. **Molecular Spectra.**

VICUNA, VICUGNA, VICUNIA. Mammalia, Artiodactyla. A wild South American animal, *Lama vicunia*, related to the guanaco and the domestic llama and alpaca The vicuna is the smaller of the two wild species. It lives in the mountains of Ecuador, Peru, and Bolivia (A W L)

VINCENT'S ANGINA. An infection of the mouth, particularly the gums, by two organisms, a bacillus and a spirochete (See **Bacteria.**) During the War it was common and was known as "trench mouth" It may be transmitted from person to person by contact with each other or a contaminated object Its occurrence is favored by decayed teeth and poor hygiene of the mouth The disease is obstinate, difficult to eradicate and may recur if care is not taken to prevent it

Treatment is by **arsenical** preparations especially by the use of arsphenamine or neoarsphenamine as in syphilis It is applied locally to the affected areas besides being given intravenously (R S M)

VINE **Stem.**

VINEGAR EEL. Nemathelminthes, Nematoda A minute roundworm, *Anguillula aceti*, found in the "mother" of vinegar It reaches a length of two millimeters The worms have been found in other situations, including the human bladder (A W L)

VINEGARONE **Whip scorpion.** (A W L)

VIOSTEROL. A general name for preparations of **ergosterol** that have been irradiated with **ultra-violet light.** This substance is very powerful in **vitamin** D, the vitamin that determines bone growth and strength The strength of the viosterol preparation is described as ten D, 250 D, etc, to indicate the vitamin D potency as compared with the vitamin D potency of cod-liver oil Ergosterol is related to cholesterol, and in animal or plant life is believed to be the precursor of vitamin D It is changed to vitamin D by the action of the ultra-violet rays of the sun (R S M)

VIPER Reptilia, Sauria A poisonous **snake** with a pair of long tubular fangs near the front of the upper jaw Most species of vipers are also characterized by the relatively short and thick body and the broad triangular head The group includes the typical vipers of the Old World and the **pit vipers** of North and South America

The Old World vipers include a number of Asiatic, European, and African species bearing the name viper and in addition the two species known as the asp and eja The Egyptian horned viper is sometimes known as the cerastes from the name of the genus to which it belongs. The African puff-adder is a viper, named from its habit of inflating the body when disturbed. This name has unfortunately been borrowed for an entirely harmless snake of the eastern states, related to the hog-nosed snake It is variously known as the puffing or spreading adder or blowing viper When disturbed it flattens its body and makes an impressive bluff, but it is quite harmless

Many of the Old World vipers are dangerous. Their poison is similar in nature to that of the pit vipers (A W L)

VIREO. Aves, Passeriformes *Vireo.* A small quietly colored bird (**Aves**) of a family related to the warblers The vireos are mostly gray to olive gray above and white below Some species show traces of contrasting black or yellow They build beautiful cupped nests, suspended in the crotch of a twig (A W L.)

VIRGO. (Cf map, page 306) Virgo, the sixth sign of the **zodiac**, is one of the earliest named among the constellations In every known literature we find references to this constellation and always connected in some manner with a maiden and the harvest Among the Egyptians, Virgo was associated with Isis and was said to have formed the milky way by dropping innumerable wheat heads in the sky

Astronomically, the constellation is famous for the large number of **nebulae** found in it Sir William Herschel found no less than 323 of these objects in this part of the sky and more recent observations have raised the number to over 500 A large number of variable stars are also to be found in the constellation. The brightest star in the constellation is the well-known star **Spica.**

Since Virgo is a feminine sign, it is generally considered **astrologically** as unfortunate, although those born under this sign are supposed to be thrifty and ingenious (W K G)

VIRTUAL WORK PRINCIPLE. Equilibrium of Forces; Least Energy Principle.

VIRULENCE. This term is used in describing pathogenic organisms It is indicative of the disease-inciting power of these organisms. Variations in virulence occur not only among different species of microorganisms but also among organisms of the same species **Bacteria** gain or lose their virulence according to environmental conditions outside and within the body This accounts for the presence of **epidemics** at certain times and the rise and fall and severity of epidemics. (R S M)

VIRUS. An ultra-microscopic substance that causes many diseases A filterable virus is so small that it will pass through the pores of a porcelain filter It cannot be seen by the strongest microscope now made These substances are known to exist for the reason that they can be killed by heat, and can cause disease in subjects Viruses have been obtained for experimentation by means of extremely powerful **centrifuges.** The centrifuges must be capable of many thousand revolutions per minute and must be specially built

Some of the diseases caused by viruses are the common cold, **dengue,** poliomyelitis (infantile paralysis), **rabies, smallpox, chicken pox, measles,** etc (R S M)

VIRUS DISEASES. Many diseases, both plant and animal, are called virus diseases The organisms causing these diseases are too small to be seen even with the aid of microscopes of the highest power These organisms, usually called viruses, can pass through filters of extreme fineness

Virus diseases attack herbaceous plants more frequently than they do woody plants, and often cause serious damage, especially to such cultivated plants as **tobacco, potato** and **sugar-cane.** The number of virus diseases is great, but the host range for any one virus usually rather strictly limited Virus diseases are classified by the effects they produce rather than by their properties These effects vary greatly with the different diseases Leaves of the Tobacco plant when infected with tobacco mosaic disease become spotted with light areas, and are rather stunted Mosaic disease of the cucumber causes the leaves to become irregularly mottled and somewhat wrinkled. Virus diseases may not be fatal but do greatly reduce the vigor of the plant and also diminish the value of the crop produced by such plants.

These diseases are transmitted from plant to plant through wounds Very commonly sucking insects serve as carriers, transferring the virus, which seems able to exist within the insect body, to another plant which becomes infected through the insect bite Once within the plant the virus spreads rapidly In some forms the virus seems to be carried into the seed and to infect the new plant when the later develops from the seed.

A great deal of experimental work has been done on virus diseases, which has shown among other things that they are remarkably tolerant to substances which would destroy other organisms, to high temperatures, and prolonged desiccation

Despite much research, however, the essential nature of the viruses remains unknown Whether they are living organisms or not is questioned. Recent work suggests that they are complex chemical substances which may be on the border line between the vital and the inorganic world (R M W)

VISCACHA. Mammalia, Rodentia. *Viscaccia.* A large stoutly built burrowing animal of the South American pampas, related to the chinchillas The contrast between these animals has been likened to that between our related squirrels and woodchucks, the one gracefully built and the other a clumsy burrowing form (A W L)

VISCERA. Organs lying more or less freely in the cavities of the body Usually applied to the **heart** and **lungs** as thoracic viscera and to the **stomach, intestines, spleen,** liver and **pancreas,** and some of the **reproductive** organs as abdominal viscera The singular form, viscus, is rarely met. (A W.L.)

VISCERAL ARCH. The column of tissues persisting between adjacent **gill slits** in the wall of the vertebrate **pharynx.** The arch is lined with endodermal tissue and covered outside with ectodermal It contains a bony or cartilaginous support belonging to the **visceral skeleton** and an **aortic arch** In the fishes the gills are supported by these arches (A W L)

VISCERAL CLEFT. Gill slit.

VISCERAL MASS. A compact mass of tissue containing some of the internal organs of the **mollusks.** It forms the main part of the body. (A W L)

VISCERAL SKELETON. A portion of the vertebrate skeleton supporting the walls of the **pharynx** and forming the jaws and hyoid apparatus. In the primitive condition it consists of a series of bony or cartilaginous arches extending from the ventral wall of the pharynx upward in the **visceral arches.** Seven pairs of these structures persist in the fishes The most anterior of the visceral arches forms part of the upper and all of the lower jaw, supported by skeletal structures derived from this source The skeleton of the second arches and variable derivatives of those following constitute a hyoid apparatus supporting the base of the tongue Other components of the visceral skeleton become the cartilages of the larynx and upper part of the trachea

One of the most remarkable transformations of this part of the skeleton is the migration of small bones of the first and second arches into the middle **ear** as the hammer, anvil, and stirrup which bridge the cavity in the mammals (A W L)

VISCOMETER. Viscosity.

VISCOSITY. A property of fluids, either liquid or gaseous, which may be briefly described as a resistance to flow When a solid is subjected to shear, a **stress** develops in it, increasing with the shear until a condition of static equilibrium is reached by virtue of the **elasticity** of the solid On the other hand, when a fluid starts to flow, while there is likewise a **shearing** stress, the opposing reaction is of the nature of an internal friction, and the equilibrium attained when the flow becomes steady is brought about by the viscosity of the fluid opposing the shearing motion. As one layer of the fluid moves past an adjacent layer, the passage of molecules across the boundary both ways results in the transmission of energy from the faster to the slower, and

hence tends to check the relative motion This reaction is proportional to the rate of shear, thus.

$$\text{shearing stress} = \eta \times \text{rate of shear.}$$

The constant η is called the viscosity coefficient of the fluid For liquids, it decreases, in general, with rise of temperature, with gases, it increases Thus, molasses becomes more fluid but air becomes less so, at a higher temperature

When a fluid flows through a capillary tube because of a pressure difference Δp at the opposite ends, the volume per unit time is given by Poiseuille's law

$$\frac{V}{t} = \frac{\pi r^4 \Delta p}{8 \eta l},$$

in which r is the radius and l the length of the capillary The viscosity coefficient may thus be measured, since it is easy to measure r, l, and Δp and to observe the rate of flow V/t Several types of viscometer depend upon this principle

Stokes derived an expression for the force necessary to keep a small sphere of radius r moving at a uniform speed v through a given fluid $f = 6\pi vr$, an expression very useful in studying drops or other spherical particles falling freely in the air (L D W)

VISCOSITY MANOMETER. Pressure Gages.

VISIBILITY FACTOR. Photometry.

VISION. The formation of mental images of the shape and color of objects through the reception of light rays reflected from their surfaces to sensory organs known as **eyes.** While some organs included in this category are supposed to be merely sensitive to light and capable of perceiving its intensity and the direction of its source, others are either known or supposed to form sharply defined images like our own

The compound eyes of **arthropods** are supposed to form fairly definite images by a process known as **mosaic vision.** The interpretation of such organs is necessarily theoretical since they are conspicuously different from our own Their action is certainly very different from that of the camera eye of man

For from the optical standpoint, the human eye is merely a **camera,** with the retina substituted for a photographic plate The optical system, however, extends continuously from the cornea back to the retina, instead of being localized in an objective It consists of four transparent media. cornea, aqueous humor, "crystalline" lens, and vitreous humor, bounded by curved interfaces The crystalline lens is of non-uniform refractive index, and is flexible like rubber, so that its shape and focal length can be controlled by a set of muscles, it is in this way that the focusing or "accommodation" is accomplished The lens casts a sharp inverted image on the sensitive **retina.** Each rod or cone affected by the light sends an impulse to the visual centers in the brain Here the mental image resulting from the total stimulation of the retina is formed.

The normal human eye forms clear images of objects eighteen feet away or more without effort Closer objects require accommodation by the contraction of the ciliary muscle, which permits the lens to become more convex For this reason close vision is more tiring than distant Cephalopods and fishes on the contrary must accommodate for distant vision The change is accomplished by the contraction of muscles which draw the retina and lens closer together In amphibians and reptiles the lens is moved farther from the retina for close vision

In the human eye a blind spot occurs at the point of entrance of the optic nerve where only nerve fibers exist. A depression in the retina at the axis of the eyeball, called the fovea, is the point of most acute vision. Here very few nerve fibers intervene between the nerve endings (rods and cones) and the source of light Certain areas of the retina are also different in their sensitiveness to light of various lengths Although color vision is conditioned by a number of variations in stimuli, the retina has certain normally characteristic visual fields Red and green are perceived by a limited central area and blue and yellow by this area and a surrounding extension The marginal field perceives only black and white and the grays

The perception of size, shape, and distance depends partly on experience and partly on comparison with other known objects in view The relative distances of objects are determined by stereoscopic vision through the mental association of slightly different images formed by the two eyes Animals whose eyes are directed outward from the sides of the head are incapable of this type of vision The same principle is used in stereoscopic photography Two pictures made simultaneously from slightly separated points of view are examined through the stereoscope so that each eye sees one member of the pair The difference in images may also be noted by closing or covering one eye at a time while looking at some object See **Binocular Vision.**

Defects of vision in man include various forms of color-blindness, due to hereditary abnormality of the cones in the retina, and malformations of the eyeball that interfere with the formation of sharp images When a normal eye is relaxed the image focuses directly on the retina, such an eye is called emmetropic If the ball is slightly elongated the rays focus slightly in front of the retina during relaxation and the individual is said to be short-sighted or myopic In the opposite condition light rays come to a focus behind the retina of the short eye, which is said to be long-sighted or hyperopic

The commonest form of color-blindness is the red-green type. The condition varies but in general red and green register as different degrees of yellow A more extreme form called monochromatic color-blindness results in the perception of all colors as shades of gray See **Color.**

Other adjustments of vision related to the intensity of illumination have been recorded They involve various structural adaptations of the eyes to secure maximum stimulation for dim light and the familiar contractile iris to cut down the amount of light entering the eye. (A W L, R S M)

VISUAL BINARIES. A visual **binary star** is one for which the angular separation between the two components is great enough to permit the system to be observed as a **double star** in a telescope. The **resolving power** of the **telescope** employed is an important factor in the detection of a visual binary and as telescopes of larger and larger aperture are built there will be an ever increasing number of visual binaries discovered Also, the brightness of the objects is an important factor in the detection of the double character of a star, it being easier to see as separate objects two faint stars separated by a small angular distance, than two bright stars separated by the same angular distance Adopting certain arbitrary definitions as to what shall be considered a visual binary, Aitken estimates that about one star out of every eighteen is a visual binary

Visual binary stars are studied from observations taken either with a **filar micrometer** or a **stellar interferometer.** The brighter star of the pair is known as the primary and the fainter as the secondary **The position angle** of the secondary with respect to the primary is measured, together with the angular distance between the two components The time of the observation is also recorded After a sufficient number of observations have been obtained they are plotted in polar **coordinates,** using the primary star as origin Through these plotted points the most probable ellipse is drawn, the only restriction on the ellipse being that the **Keplerian Law of Areas** must be satisfied The ellipse thus drawn is known as the apparent ellipse.

This apparent ellipse is the projection of the actual elliptical **orbit.** of the secondary with reference to the

primary, on the plane perpendicular to the line of sight of the observer. From this projected ellipse the complete **elements** of the orbit may be computed, the semi-major axis, a, being expressed in **angular units** unless the **stellar parallax** of the system is known. (W.K.O.)

VITAMIN. One of a group of substances which are present in varying amounts in certain animal and plant tissues. Vitamins are necessary for normal nutrition, growth and function of the body Their absence or partial deficiency produces various characteristic diseases and disturbances of body function and growth.

Biological, rather than chemical, methods were responsible for the discovery of vitamins, and for much of the knowledge that has been obtained about them. To such methods is due the knowledge concerning the necessity of the supply of vitamins to the organism, as well as much of the other knowledge about the properties of vitamins, which is very briefly summarized in the accompanying table

VITAMINS * (ALEXANDER)

Designation	Properties	Main Efforts of Deprivation	Good Food Sources	Chemical Nature
A—Anti-ophthalmic	Fat-soluble Oxidizable	Xerophthalmia Night-blindness Stunted growth	Fish oils, liver, fresh vegetables, egg-yolk, butter, cream	$C_{27}H_{30}O$, derived from various carotenes which serve as precursors (P. Karrer)
B (B_1)—Anti-neuritic	Water-soluble Relatively heatable, especially in alkaline solution	Beri-beri (in man) Polyneuritis (in rats) Loss of appetite	Wheat, eggs, yeast, milk, fruit, vegetables	$C_{12}H_{16}N_4OS \cdot 2$ HCl (hydrochloride of base) (R. R Williams)
C—Anti-scorbutic	Water—soluble Oxidizable Hurt by heat	Scurvy Fatigue Soft gums	Citrus fruits, peppers, spinach, water-cress	$C_6H_8O_6$, ascorbic or cevitamic acid (A Szent-Györgyi)
D—Anti-rachitic	Fat—soluble Resists heat well, oxidation fairly well	Rickets	Fish liver oils, eggs, milk Sunlight for irradiation	$C_{28}H_{43}OH$, ergosterol, one precursor, transformed into the vitamin on irradiation, presumably by intramolecular rearrangement (A Windaus)
E—Anti-sterility	Fat—soluble Resists heat, but not oxidation	Sterility (in rats) Organic degeneration in male; lack of placental formation in female	Wheat, milk, eggs, meat, lettuce, water-cress	
G(B_2)†—Anti-pellagric	Water—soluble Relatively heat-stable	Pellagra Skin, digestive nervous troubles	Eggs, milk, and vegetables, yeast, liver	$C_{17}H_{20}O_6N_4$, lactoflavine (R Kuhn)

* Thanks are due to Prof B Harrow (C C N Y) for critical suggestions

† This is a group of substances of which only lactoflavine has been identified A certain amount of unsaturated fatty acids (linolic, linolenic) appear to be food essentials, and are by some termed Vitamin F

In this country extreme deficiency states of a particular vitamin are not as common as they are in other parts of the world. But milder states of deficiency diseases are common, especially **rickets** and **pellagra.** Deficiency in diet is not the only factor involved as disturbances in assimilation from one cause or another can produce a similar deficiency state In sickness from the infection itself and also from the impairment of appetite that accompanies a chronic illness, subnormal amounts of the vitamins may be present This is also seen in certain restricted diets for certain disorders, as in some reducing diets In pregnancy, lactation, infancy and childhood, a diet rich in vitamins is essential.

Vitamin A is a fat-soluble vitamin necessary to growth, that also augments the general resistance of the body to infection Its deficiency, when marked, produces certain eye disturbances and diseases. Night-blindness associated with faulty nutrition is due to lack of Vitamin A This disorder is common Deficiency will produce xerophthalmia, xerosis, and keratomalacia Several varieties of **dermatitis,** formation of stones in the urinary tract, may be in part caused by deficiency of this vitamin

Vitamin A is stored in the **liver,** and the amount stored depends upon the character of the diet, and the ability of the individual to absorb the vitamin during digestion. It is particularly necessary in infancy, childbirth, and during pregnancy.

Vitamin A occurs widely in plants, and is evidently connected with the life processes of the plant It is found in green leaves—usually the thinner and greener the leaf the more vitamins—followed in decreasing richness by growing shoots, by some roots, and by germs of seeds Its content is usually negligible in the starch-reserve parts of the plant, such as the **endosperms** of seeds In the fleshy parts of roots and tubers notable differences occur, as illustrated by the experimental demonstrations of Steenbock, that yellow Indian corn is richer in vitamin A than white Indian corn, sweet potatoes than Irish potatoes, and carrots than parsnips and beets Carotene ($C_{40}H_{56}$), the yellow coloring matter of carrots, is transformed in the liver into vitamin A The concentration of vitamin A is greatest in milk and butter, in cod liver oil (unsaponifiable portion) and in egg yolk, liver, kidney, oysters

Vitamin B (B_1) is a water soluble vitamin that is necessary to life and growth Its deficiency, when marked, gives the picture seen in **beri-beri,** multiple **neuritis, edema,** and heart weakness. Supplying the vitamin in large amounts cures the disease. In alcoholics, who develop multiple neuritis, the cause is substitution of alcohol for a greater portion of a normal diet, with insufficient intake of this particular vitamin. Those Asiatic races, whose chief diet is polished rice, are subject to beri-beri to a remarkable degree. Rice polishings, wheat germs, and yeast are sources of Vitamin B, but the minute amount present may be realized from the experimental recovery of about one part by weight of vitamin B from 50,000 parts by weight of rice polish-

ings. Vitamin B has been isolated, and may be obtained on the market in pure form.

Vitamin C (Ascorbic acid) is a water soluble vitamin that prevents and cures **scurvy**. It has been isolated, and is administered medically either by mouth or by hypodermic injection in those cases where there is faulty assimilation from the intestinal tract

Besides being curative and preventative of scurvy, vitamin C plays an important part in many vital processes, some of which are not clearly understood It is concerned in the so-called intracellular, cement substance of the body Lack of vitamin C, and the resultant disturbance in this substance cause hemorrhage from the fine capillary blood vessels, with hemorrhage into body tissues, or externally, from the mucous membrane During infectious processes, extra large amounts of vitamin C are required Healing of wounds in some cases appears to be hastened with an increase in vitamin C intake

Vitamin C is found in fresh, uncooked foods and fruit juices, especially those of citrus fruits, and in tomatoes, raw cabbage, and raw onions Formation of Vitamin C is connected with the life processes of the plant, and the vitamin is found most abundantly in fresh, green leaves, growing shoots and juicy stems, roots, tubers and fruits Notable differences occur, as illustrated by the experimental demonstration that lemon juice contains more vitamin C than lime juice, and the Swedish yellow more than the common white turnip The relation between the vitamin C content and the amount of a given food consumed must be considered, thus, potatoes, although not high in vitamin C, are often consumed in such quantity that they furnish adequate amounts of this vitamin Vitamin D is a fat soluble vitamin which is necessary for the absorption of **calcium** and **phosphorus** and is concerned directly in **metabolism** of the bone structure of the body It is a specific in the prevention and treatment of infantile **rickets**, spasmophilia and osteomalacia It is required for formation and maintenance of the structure of the teeth Large amounts are especially required during periods of growth

Vitamin D is found in cod liver oil and many other fish oils (particularly halibut liver oil), in milk, egg yolk, etc Sunlight is also specific due to the formation of vitamin D from cholesterol of the body Food materials that contain cholesterol, when irradiated by ultraviolet light furnish vitamin D Ergosterol is a source ("Viosterol" is irradiated ergosterol)

Vitamin E is a fat soluble vitamin essential for reproductive processes It is also known as the anti-sterility vitamin. It is present in seeds and green leaves, in many vegetable oils, and most readily in the unsaponifiable portion of the oil from wheat germ The manner in which this vitamin acts is not clearly understood, but it has been successfully used in certain types of sterility and habitual abortion associated with faulty diet.

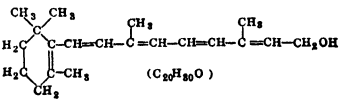
Vitamin G (B_2) is a water soluble vitamin, the portion of the vitamin B complex that is relatively unaffected by heat With vitamin B_1, vitamin G occurs in yeast, milk, cheese, and grain cereals, leafy green vegetables, carrots, turnips, tomatoes, potatoes, and beans Much of the earlier research was done with both these vitamins (They were originally thought to be one.) The most striking difference between these vitamins lies in the fact that vitamin G, when markedly deficient, causes pellagra The best source of vitamin G is liver (and liver extract) This is administered in pellagra, and in pernicious **anemia**. In the latter disease the spinal cord symptoms causing weakness and paralysis are improved and arrested by the use of vitamin G

It appears quite likely that there are other vitamins, but research in this direction has not progressed to the point where definite statements can be made about them Thus, the term vitamin F is applied by some to a substance which apparently consists of unsaturated fatty acids, and may be necessary to health

For tables showing vitamin content of foods, see **Foods**.

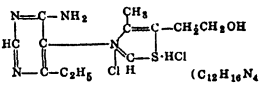
MOST PROBABLE STRUCTURAL CONFIGURATIONS OF THE KNOWN VITAMINS * (Alexander)

Vitamin A:



($C_{20}H_{30}O$)

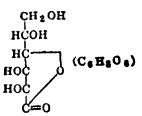
Vitamin B (B_1):



($C_{12}H_{16}N_4OS \cdot 2HCl$)

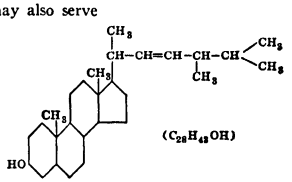
Formula is given as the hydrochloride of the base

Vitamin C (Ascorbic or Cevitamic acid)



($C_6H_8O_6$)

Vitamin D—Formula is that of ergosterol, which after irradiation presumably involving a molecular rearrangement is transformed into vitamin D Certain other sterols may also serve

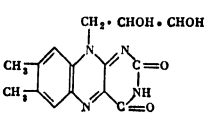


($C_{28}H_{43}OH$)

Some doubt as to exact position of the —OH group

Vitamin E—Structural formula not yet elucidated Probably a higher alcohol, tocopherol (Evans)

Vitamin G (B_2) (Lactoflavin)



($C_{17}H_{20}O_6N_4$)

(R K.S., R S M)

* Data kindly supplied by Doctor L E Booher (Columbia University), and Dr R E Gruber (Merck & Co)

VITELLARIUM. A yolk-forming organ The term is applied in the flatworms (**Platyhelminthes**) to a long series of glandular bodies associated with the **oviducts**. They form both the yolk and the shells of the eggs. The same name designates a portion of the ovary of rotifers. This organ is divided into a germarium where the egg cells are produced and the larger vitellarium. (A W L)

VITRAIN. A term proposed by M. Stopes, in 1919, for a glassy variety of **coal** which occurs in bituminous coal as bright narrow and easily friable bands which may be distinguished from **clarain**, especially with the aid of the microscope. (R M F)

VITRELLA. A crystal cell of the group between the cornea and the retinula in the compound **eye** of **arthropods**. (A W L)

VITRIOL. Term applied to **sulfates.** Oil of vitriol, concentrated **sulfuric acid;** blue vitriol, **copper** sulfate crystals, green vitriol, **ferrous** sulfate crystals, white vitriol, **zinc** sulfate crystals. (R.K S)

VITROPHYRE. A vitrophyre is a volcanic glass carrying sporadic distinct crystals of **feldspar** and other minerals, in short, a **porphyritic** glass. (E S C S)

VIVIANITE. The mineral vivianite is a hydrous **iron phosphate,** $Fe_3P_2O_8$ $8H_2O$, its **monoclinic** crystals are usually prismatic or bladelike but may be in massive forms Vivianite has one perfect **cleavage,** hardness 1 5–2, specific gravity, 2 58–2 68, luster, pearly on cleavage faces, otherwise vitreous, colorless, when freshly exposed, but becoming blue or brownish with the alteration of the ferrous to ferric iron, transparent to translucent Vivianite is an associate of **pyrrhotite, pyrite** and **copper** and **tin** ores It is found also in clay beds forming the so-called "blue iron earth" which is common and of wide distribution in peat bogs Vivianite is found in Rumania, Bavaria, Cornwall in England, Australia, Bolivia, Greenland and elsewhere in Europe In the United States it occurs in New Jersey, Delaware and Colorado. This mineral was named by Werner after the English mineralogist J G Vivian, its discoverer (E S C S)

VIVIPARITY. A reproductive process involving the internal nourishing of the young by the body of the mother during the early stages of development and their birth when sufficiently advanced to carry on essential processes of life It contrasts with oviparity, in which reproduction is accomplished by the formation and discharge of eggs, and ovoviviparity, in which the eggs hatch in the body of the mother, but there are no special adaptations for the direct prenatal nourishing of the young

Both viviparity and ovoviviparity necessitate internal **insemination.** They are not limited to particular groups of animals but occur in many forms of invertebrates and vertebrates, including roundworms, rotifers, insects, fishes, reptiles and mammals Although most of the forms below the mammals are probable ovoviviparous, there is good evidence for the interpretation of some of the parasitic flies as truly viviparous, since the larvae are produced just prior to their transformation into pupae True viviparity is at its maximum, however, in the mammals, but even here a transition occurs from the oviparous monotremes to the true mammals, including man The young are nourished prior to birth by interchange with the blood stream of the mother through the **placenta.** (A W L)

VIVISECTION. The dissection of living animals The practice of vivisection has aroused so much emotional opposition that it has been widely publicized in the daily press In the strict sense, scientists do dissect living animals to learn of processes taking place in their bodies more accurately than is possible without this procedure. Such studies are conducted, however, with the greatest possible humanity Animals are anesthetized for operative procedures and are killed painlessly at the end of experimental study If the destruction of life is to be regarded as cruelty, then our use of domestic animals as food is on a par with vivisection

The study of processes and relations within the body of the animal while it is still a living organism has been of incalculable benefit to medicine and has been directly responsible for the saving of many human lives As an example among recent discoveries, the functions of the adrenal cortex were discovered through experiments with cats from which the glands had been removed The animals were kept alive by administering extracts of the adrenal cortex of other species, and the final perfection of these extracts so that they could be administered safely to human beings provided the first alleviation for Addison's disease (A W L)

VOGESITE. A term proposed by Rosenbusch, in 1887, for a **syenitic lamporphyric igneous rock** in which the characteristic minerals are generally **hornblende** or **augite** and **oligoclase** or **andesine** feldspar (R M.F)

VOLATILE. Coal, Proximate Analysis.

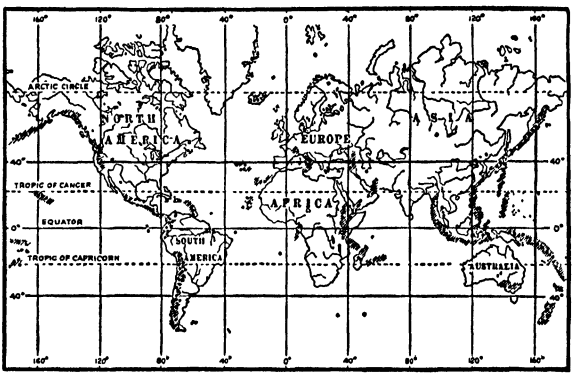
VOLATILE OILS. The volatile oils are distinguished from the **fixed oils** by the fact that a drop of one of these oils does not leave a spot on paper Members of certain plant families, such as the **Mint Family,** contain a larger percentage of such oils than do other families. But volatile oils are in no sense restricted to any small group, nor are they found only in certain tissues Sometimes, certain parts may be principally used for the oil, as the seeds of the **Carrot Family**

Various methods are used in extracting the oil from the plant tissue Many are distilled with water or steam, the oil being carried over with the distillate In others, as for example oil of bitter almonds, the oil develops in the tissues only after **fermentation.** It is then obtained by **distillation.** Another method, and one especially used for more delicate and valuable oils, is called "enfleurage" In this method the flowers containing the oil are spread as a thin layer over a layer of lard or olive oil The latter absorbs the delicate oil in the flowers, after which distillation may separate the volatile oil from the other

Volatile oils are much used as perfumes, flavorings, drugs and solvents Attar of Roses, or Rose oil, from **Roses,** is one of the most valuable Jasmin oil, from *Jasminum grandiflora* (Oleaceae) petals is somewhat less valuable It is obtained by absorbing the oil from the petals of the plant in olive oil Geranium oil, from several species of *Pelargonium,* cultivated mainly in Southern France and Spain, is much used to adulterate rose oil Bay oil, from the leaves of *Pimenta acris* (Myrtaceae), a native of the West Indies, is much used in perfumes, toilet preparations and Bay rum From the leaves and flowers of many members of the Mint Family fragrant perfume oils are obtained *Lavendula vera,* used by the Romans to scent their baths, gives lavender oil, an expensive perfume oil, while *L spica* yields Spike oil, a cheaper oil than lavender Dried lavender plants are frequently used in bedding and clothing to impart to them a delicate fragrance Another mint, *Rosmarinus officinalis,* yields oil of rosemary Certain grasses also yield fragrant oils Among these are *Cymbopogon citratus,* a native of India and Ceylon, from which is obtained lemon grass oil, used as an adulterant for lemon oil, as well as for its own fragrance, and *Cymbopogon nardus,* from which citronella oil is obtained The latter is used as a repellent for mosquitoes and other insects These two grasses are cultivated to a limited extent for their oils Verbena oil is a valuable product from *Verbena triphylla* and other species (Verbenaceae) Neroli oil is obtained from the flowers of the orange tree (Rutaceae), this oil is used in cologne and in liquors From another member of this family comes **Bergamot oil.** The Laurel Family (Lauraceae) has many members which yield volatile oils From *Cinnamomum zeylanicum* come cinnamon oil and cinnamon leaf oil, used not only in perfumes but also in medicines and as a flavoring The green leaves of *Cinnamomum cassia,* a native of the East Indies and India, give cassia oil, an expensive and consequently much adulterated oil used in perfumes and medicines The bark and roots of *Sassafras officinale,* a tree native in southern United States, yield sassafras oil, used in making cheaper perfumes. From *Cananga adorata* (Annonaceae) comes oil of cananga, called also Ylang ylang, "Flowers of Flowers," a very expensive oil The tree is a native of southeastern Asia. Various species of Iris, particularly *Iris germanica,* yield Orris root and Orris oil, the dry powdered rhizome being used The powder has an odor suggestive of violets, and is used in compounding medicines, sachets and tooth powders. Southern Italy leads in the production of orris root.

Among volatile oils are many primarily used in flavoring and as drugs Many of these come from members of the Mint Family One of them is oil of peppermint from the leaves and stems of *Mentha piperata* The states of Michigan, Indiana, and New York grow much of the native crop, but are far behind Japan in production Oil of peppermint is mostly menthol, and is used in flavoring chewing gum, tooth pastes, and as a medicine and perfume It is commonly adulterated From *Mentha spicata*, or Spearmint, comes oil of spearmint, used as a drug, as a flavoring in cooking, and in preparing mint sauce, in chewing gums and in cheaper perfumes The principal producing regions are New York, Michigan, India and Russia Clove oil is obtained from the flower buds of the Clove tree, *Eugenia aromatica* It is used as a drug and for flavoring and in perfumes *Artemisia absinthum*, one of the **Composite Family**, yields oil of wormwood, used in medicine, as a worm repellant, and in the preparation of absinthe Oil of anise seed is obtained from the seeds of *Pimpinella anisum*, a member of the **Carrot Family** indigenous to Egypt and now widely cultivated The oil is used in perfumes, as a drug, and in liquors Anise seed oil is also used to make a trail which will be followed by foxhounds Many other members of the **Carrot Family** have aromatic oils in the seeds Star annis, so named because of the star-shaped fruit, from *Illicum verum* (Magnoliaceae), is a similar oil Camphor oil is obtained from the **Camphor** Tree, *Cinnamomum Camphora* Lemon oil comes from the skin of the lemons, *Citrus Limonium* Bitter almond oil is extracted from *Prunus amygdalus*, of the **Rose Family.** Juniper oil is obtained from *Juniperus communis*, a Conifer It is used in medicine, also in varnish making, and in gin Among leguminous plants the genus *Eucalyptus*, especially *E globulus*, yields from the leaves oils known as eucalyptus oils, used in making perfumes, as antiseptics, in scented soaps and toilet preparations, also in concentrating ores by the flotation process The trees are natives of Australia, and have been introduced into California.

Oil of turpentine, also called spirits of turpentine, is obtained by the distillation of exudates of *Pinus ponderosa* and *P taeda* (Coniferae) It is used as a solvent in making paints and varnishes, and also in medicine Venetian turpentine, obtained from the European Larch, *Larix europea*, is a similar product (R M W)



Map showing the distribution of active and recently extinct volcanoes. (Tarr's *New Physical Geography*, The Macmillan Company)

VOLCANIC BOMB. Lapilli.

VOLCANITE A term proposed by Hobbs, in 1893, for a volcanic rock from the Lipari Islands largely composed of the minerals **anorthoclase** and **augite.** (R M F)

VOLCANO. A volcano is a conical mountain built up around a vent in the crust of the earth It is formed of lava and fragmental material which has flowed out in a highly heated and liquid state, or from matter ejected by explosive eruptions, or both It is convenient to classify volcanoes as of three types· 1 The explosive type from which solid fragmental material and gases are erupted This material may consist of blocky pieces, often ejected in a partly fluid condition, *lapilli*, or dust, the latter often incorrectly called ash 2 The effusive type, characterized by quiet eruptions of liquid lava with little or no explosive violence. Such lavas are very fluid and frequently flow for many miles. 3 The intermediate type which may at times erupt explosively with accompanying flows of lava Typical highly explosive eruptions have been: that of Krakatoa in the Straits of Sunda, Dutch East Indies, which in 1883 blew up about a cubic mile of rock which rose as dust over fifteen miles in the atmosphere, and that of Mt Pelée on the Island of Martinique, West Indies, which occurred in 1902. The latter eruption was without lava and consisted of a great cloud of incandescent gases and dust, which destroyed the city of St. Pierre and almost its entire population of about 28,000 inhabitants Mauna Loa and Kilauea in the Hawaiian Islands are examples of the effusive type of volcano and Mt Vesuvius is an excellent example of the intermediate type Most of the active Alaskan volcanoes are of the intermediate type as were doubtless the now extinct volcanoes of the northwestern part of the United States which include Mt Shasta, Mt Rainier, Mt Hood, Mt Baker, and others

The explosive type may be recognized by the steep cone (often seen with the intermediate type as well), the effusive type of volcano with its long lava flows builds a low cone of great areal extent as compared with its height (E S C S)

VOLE. Mammalia, Rodentia The meadow or field mice, constituting the genus *Microtus* The genus is limited to the northern hemisphere and in Asia does not extend south of the Himalayas Voles are characterized by rootless molar teeth formed of two rows of alternating triangular prisms About twenty species occur in North America (A W L)

VOLT. The volt, which is the practical unit of **electromotive force** and **electric potential,** may be defined in different ways, some of which are equivalent, while others give rise to slightly different values Perhaps the simplest definition of the "absolute volt" is, that electromotive force or potential difference against which one watt of power is necessary to maintain an electric current of one (absolute) **ampere;** or against which one joule of energy is necessary to transfer an electric charge of one (absolute) **coulomb.** The "international volt," on the other hand, is defined in terms of the international ampere and international **ohm** in accordance with **Ohm's law** (one volt maintains a current of one ampere through a one-ohm resistance) The international volt exceeds the absolute volt by about 46 parts in 100,000 (See also **Standard Cell.**) One may get a fair idea of the magnitude of one volt by noting that the electromotive force of a three-cell automobile battery is about 6 volts, and that of the ordinary electric light supply is 110 volts. (L D W)

VOLTAGE REGULATION. Automatic voltage regulators are relied upon for maintenance of constant **generator** voltage Alternator voltage regulators have, for all practical purposes, become limited to three distinct types, the vibrating, the direct acting, and the rheostatic Direct-current regulators are usually rheostatic

In the vibrating voltage regulator system the voltage is maintained by varying the **alternator** field strength indirectly through control of the **exciter** field The basic idea is the short-circuiting of the exciter shunt field rheostat by rapidly vibrating contacts which open and close the short circuit path several times per second The main contacts in this type of regulator are acted on by two sets of control magnets, one connected across the exciter bus and tending to move the main contacts farther apart as the exciter voltage rises, and the other acted upon by alternating current potential and current coils Suitable springs and counterweights allow adjustment to be made When the main contact closes it energizes the relay magnet, thus closing the relay contact, short circuiting the exciter rheostat, raising the exciter voltage, and consequently, the alternator voltage The use of the exciter voltage as one of the main control circuits prevents the alternator voltage "overshooting"

Compensating current winding of the alternating current **solenoid** is provided with a dial switch to give any amount of compensation required for the feeder circuit in which the current transformer is located The vibrating-type regulator may be applied to direct-current as well as alternating-current systems The exciters should be selected with characteristics known to function satisfactorily with the type of regulators used The regulators may be operated in parallel, also one regulator may control more than one generator through the use of special exciter rheostats Successful operation of individually regulated exciters in parallel depends upon control of the wattless current which may circulate between the alternators as a result of momentary differences in excitation Control of this feature is worked out on the basis of alternator power factor

In direct-acting regulators, an induction motor principle furnishes the actuating impulse The torque produced is counteracted by a spring (and the exciter field rheostat is an integral part of the regulator) The rheostat arm has pure rolling motion, hence very little effort is required for the voltage regulating motion A damping mechanism consists of a disk and magnets

Unlike the first two types, the rheostatic regulator can be used in plants where the excitation is taken normally from a constant-potential bus The rheostatic regulator does what an operator would do, except that it does it more quickly and provides instantaneous correction to standard voltage Rheostatic regulators should be used in the case of large slow speed exciters, the magnitude of whose field current would prove embarrassing to the vibrating type regulator It is also applied where exciter field control would give too slow a response to the control impulse (F T M)

VOLTAMETER. Coulombmeter.

VOLT-AMPERE. Alternating Currents.

VOLTA'S LAW. Contact Potential Difference.

VOLTMETERS. The usual instruments of this class differ from **ammeters** used on the same type of service in only one essential respect: they are of very high resistance Therefore, when connected across the terminals between which the voltage is to be measured, they take very little current and cause but a very slight drop in the potential difference The current through the voltmeter is proportional to the voltage, and the scale may therefore be graduated to read directly in volts Instruments are made which, with the proper change in connections, serve either as voltmeters or ammeters, the scale having two graduations For high voltages, the voltmeter is placed in series with a large resistance, called a multiplier, so that the potential difference between its terminals is a known fraction of the voltage under test

There are electrostatic voltmeters which may be used to measure electrostatic potentials of thousands of volts. A common form resembles a gold-leaf **electrometer** of large size, but with a brass pointer swinging on a scale in place of the gold-leaf The "sphere gap" (See **Spark**) may also be used for approximate high-voltage measurements (L D W)

VOLUME INTEGRAL. Triple Integral.

VOLUMES BY DOUBLE INTEGRALS. Consider the solid bounded below by a region S in the XY-plane, with boundary $x=a$, $x=b$, the X-axis and a curve $y=\phi(x)$, bounded above by a surface $z=f(x,y)$, and laterally by planes $x=a$, $x=b$, $y=0$ and the cylindrical surface formed by parallels to the Z-axis through the points of the curve $y=\phi(x)$ The volume of this solid is given by the double integral

$$V=\int_a^b\left(\int_0^{\phi(x)} z\,dy\right)dx=\int_a^b\left(\int_0^{\phi(x)} f(x,y)\,dy\right)dx$$

(L L S)

VOLUMES BY PARALLEL SECTIONS. If the plane perpendicular to the X-axis at a distance x from the origin cuts from a given solid a section whose area is $A(x)$, then the volume of that part of the solid between $x=a$ and $x=b$ is given by

$$V=\int_a^b A(x)dx \qquad \text{(L L S)}$$

VOLUMES BY TRIPLE INTEGRALS. A volume in general may be found by the **triple integral**

$$V=\int_{x_1}^{x_2}\left[\int_{y_1}^{y_2}\left(\int_{z_1}^{z_2} dz\right)dy\right]dx,$$

where the limits of the successive integrations are determined by the boundary of the given solid (L L S)

VOLUMETRIC ANALYSIS. Analytical chemistry.

VOLUMETRIC EFFICIENCY. Volumetric efficiency is a term applicable to a **piston** and **cylinder** mechanism in which an outward stroke of the piston induces a **vacuum** which draws a gas into the cylinder This efficiency is of special importance in the **internal combustion engine,** and no complete explanation of engine action is possible without invoking it Volumetric efficiency may be defined as the weight of gas actually drawn in on an induction stroke, divided by the weight which would occupy the piston displacement under standard conditions of atmospheric pressure and 60° F If an engine revolved very slowly, and the induction passages were large and unobstructed, the cylinder might be filled with a gas at practically atmospheric pressure, but still the volumetric efficiency could be less than 100% by the heating of this fresh charge through contact with warm manifold and cylinder walls Since internal combustion engines rotate at speeds from 300 to 3,000 revolutions per minute, a definite pressure decrement must be expected as necessary to overcome inertia and friction in order to get the cylinder filled with gas in so short an interval of time Of course, the above refers to normal operation, as it is possible to obtain volumetric efficiencies higher than 100% by **supercharging.**

From the above it will be realized that volumetric efficiency has little in common with **thermal efficiency,** but depends on such factors as the rotative speed of the engine, the fraction of the cycle which is given over to induction, the shape of the ports and valves, and the

temperature of the gas. The latter is affected by heating in manifolds, carburetor air heaters, or cylinders, though this may be partially offset by some refrigeration obtained in the vaporization action of the carburetor. (F.T.M.)

VOLUTE PUMP. A volute is a spiral or scroll. A volute **centrifugal pump** has a spiral casing surrounding the impeller, so that as water is discharged uniformly around the periphery of the impeller it will be collected in a chamber of increasing cross-sectional area. In this way the discharge from the rim of the rotating impeller is delivered to the discharge outlet without the necessity of the water velocity near the outlet being higher than average. (F.T.M.)

VOMER. A bone of the vertebrate skull. In mammals it is a thin vertical plate in the posterior part of the nasal septum. (A.W.L.)

VOMITING. The expulsion of the stomach contents through the mouth. Vomiting is caused by irritation of the stomach or gastrointestinal tract, or by stimulation of the vomiting center in the brain by **drugs,** pressure (as by a brain tumor or intracranial pressure) and by **toxins** of **bacteria.** (R.S.M.)

VUG. A rock cavity lined, but incompletely filled, with mineral matter so that a part of the available space remains empty. (E.S.C.S.)

VULTURE. Aves, Falconiformes. A large flesh-eating bird (**Aves**) with a hooked beak but with claws less strongly developed than those of the eagles, hawks, and owls. They feed largely on carrion, but many species are also known to attack living animals.

The Old World vultures belong to a family distinct from the New World species. The latter differ in having the nostrils confluent, so that the beak is perforated transversely. With the exception of the lammergeier, an Old World species, all vultures have the head and neck almost bare of feathers and sometimes brightly colored.

The turkey vultures or turkey buzzards, *Cathartes aura,* of North America are our most widely distributed representatives of the group, and the condor of South America is probably most widely known for its enormous size. It has been recorded with a length of four and a wingspread of nine feet. The California vulture or condor, *Gymnogyps californianus,* of the southwestern states and Lower California has also been recorded with a maximum length of four or more feet, and its wingspread is said

Turkey buzzard, *Cathartes aura septentrionales.* Black with brown edging to feathers. Skin of head and neck bare and red.

to reach almost eleven feet. Although their habits are repulsive, all of these birds are magnificent fliers, soaring for long periods without flapping a wing. (A.W.L.)

VULVA. The structures in the female corresponding to the external genital organs in the male. They comprise the two labia majora and the parts lying between them. They are as follows:

The larger labia are two large fatty folds of skin lying between the thighs. Posteriorly they end at the **anus,** anteriorly they end in the *mons Veneris,* a fatty prominent elevation over the pubic bone. They correspond to the **scrotum** in the male. The lesser labia are two smaller similar folds of skin within the fold of the larger labia. Anteriorly they are prolonged over the **clitoris** to form the foreskin or **prepuce.** Just below the clitoris within the labial folds is the opening of the **urethra,** just above the **vagina.** Opening into the area about the vagina are the ducts of several glands whose special purpose is for lubrication. (R.S.M.)

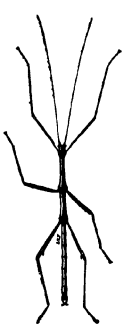
W

WACKE. An old English term for a dark, greenish brown clay, a decomposition product of **basalts** and **tuffs.** (R.M.F.)

WAD. The mineral wad, sometimes called bog manganese, occurs in amorphous masses, and consists of mixtures of **manganese** oxides, MnO_2 and MnO and oxides of other metals such as **copper, lead, cobalt, iron,** etc. It is bluish to brownish black, usually soft enough to soil the fingers and often porous and light. It is not a distinct mineral species. (E.S.C.S.)

WAGTAIL. Aves, Passeriformes. Slender insect-eating birds (**Aves**) of the Old World, related to the larks and pipits. There are numerous species in both hemispheres. (A.W.L.)

WALKING-STICK. Insecta, Orthoptera. A slender wingless insect related to the **grasshoppers.** The walking-sticks are elongate in every part and closely resemble the twigs or stalks of the vegetation on which they live. Together with winged species found in the warmer regions of the world they make up the family Phasmidae. Some of the winged species resemble leaves. (A.W.L.)


Walking-stick.

WALLABY. Mammalia, Marsupialia. A **kangaroo** of the smaller species. The distinction between kangaroos and wallabies is not a scientific one, the large species being called kangaroos and the smaller species wallabies, with a transition in the larger wallabies which are also known as brush kangaroos. Wallabies, like their large relatives, have powerful hind legs and small forelegs, and are bipedal in locomotion. They vary from the hare wallaby (*Lagorchestes*), less than two feet long, to the red-necked wallaby whose body is 3½ feet long, exclusive of the tail. The spur-tailed wallabies (*Onychogale*) are peculiar in having the tail tipped with a horny spur. (A.W.L.)

WALLAROO. Mammalia, Marsupialia. A stoutly built **kangaroo,** *Macropus robustus.* It is one of the large species, thickly furred and gray in color. (A.W.L.)

WALNUT. Wood.

WALRUS. Mammalia, Carnivora. A giant marine animal related to the seals but constituting a distinct family. Adults reach a length of more than twelve feet and a weight of a ton to 3000 pounds. The feet of the walrus are adapted for swimming but they are used for clumsy locomotion on land, as in the seals. In early life the body is covered with thick light brown fur but after middle age this vestiture tends to disappear. The muzzle bears a number of very thick bristles.

Walruses have the canine teeth of the upper jaw prolonged as tusks. The ivory of these tusks is used extensively by the Eskimos.

These animals are confined to the Arctic seas and are commonly regarded as constituting an Atlantic (*Odobaenus rosmarus*) and a Pacific (*O. obesus*) species, the latter with longer tusks. (A.W.L.)

WANDEROO, WANDERU. Mammalia, Primates. The purple-faced monkey of Ceylon, one of the **langurs.** The name has also been applied incorrectly to the lion-tailed monkey of western India, belonging to the **macaques.** (A.W.L.)

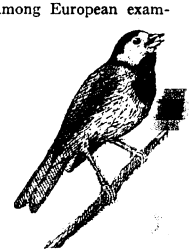
WAPITI. Mammalia, Artiodactyla. The American **elk,** *Cervus canadensis,* a member of the red deer group. It is a large species, attaining a height of more than five feet at the shoulder, with gracefully branched antlers four to five and one-half feet long. The species once ranged entirely across the continent but is now restricted to the western mountains. (A.W.L.)

WARBLE FLY. Insecta, Diptera. *Hypoderma.* **A bot fly** whose **larva** migrates through the connective tissues of cattle to complete their development in small abscesses called warbles opening through the skin of the animal's back. The adult flies attach their eggs to the hairs of cattle and the newly hatched larva enters the skin by way of the hair follicle. During its development it migrates extensively before reaching its final position under the skin of the back. The perforations leading into the warbles damage the best part of the hide, and the insect is sometimes a source of economic loss as a cause of illness in cattle. The maggots can be pressed out of the warbles when they once become evident or can be destroyed by smearing an ointment over the openings in the skin. A mixture of one ounce of iodoform (See **Iodine**) to five of vaseline has been recommended for this purpose. (A.W.L.)

WARBLER. Aves, Passeriformes. A small bird (**Aves**) related to the thrushes. The warblers of the Old World are an extensive family (Sylviidae) represented in North America only by the kinglets and gnatcatchers. The birds commonly called warblers in America are more accurately distinguished as wood warblers and make up the family Mniotiltidae, more closely related to the vireos.

Both groups include species whose common names do not indicate their association. Among European examples are the whitethroat, the hedge sparrow, the firecrest, and among the American warblers are the **oven bird,** water thrushes, **chats,** and **redstarts.**

Many of these birds are beautiful. Their numerous species are a delight to bird lovers during the spring migration in the United States, and in the fall, due to the great variation of patterns and colors between the sexes and the immature individuals, they are as much a puzzle as a pleasure. (A.W.L.)


Hooded warbler, *Wilsonia citrina.* Olive green above, yellow below. The male has a black hood covering the top of the head and running around the neck to the throat, giving the effect of a yellow mask across the face.

WARMOUTH. Pisces, Teleostei. A species of **sunfish,** *Chaenobryttus gulosus,* also called the red-eyed bream. It is an olive-green fish, marked with red and blue especially in northern waters. Maximum length ten inches. The species ranges from the Great Lakes to Florida and Texas and is common in quiet waters in the South. (A.W.L.)

WART. An elevated **benign tumor** of the skin. They are believed to be caused by irritation, injury, or a specific type of infection. They are cured by excision, cauterization (by heat or chemical) and X-ray or radium. Many warts will spontaneously disappear without treatment. (R.S.M.)

WART-HOG. Mammalia, Artiodactyla. A very ugly pig of Africa. It has a large head bearing excrescences which add the prefix to its name. The broad muzzle also bears strong upturned tusks. Two species are recognized, one, *Phachochoerus africanus*, ranging from Abyssinia southward through eastern Africa and the other, *P. aethiopicus*, confined to the southeastern portion of the continent. (A.W.L.)

WASHING SODA. Sodium.

WASP. Insecta, Hymenoptera. An **insect** related to the ants and bees. Some species are solitary and some social. Most species have four membranous wings, the front wings much larger than the hinder pair and both with few veins, joined to form closed cells. Some wasps burrow, some build nests of mud, and some use a coarse paper made by chewing wood from weathered surfaces. The last species are more commonly called hornets. Wasps are well known for their ability to sting; the more commonly known species inflict painful wounds because of their large size.

Wasp.

From the scientific point of view the term wasp is almost without value, since it applies to many different groups of insects. The members of one superfamily, the Vespoidea, include the spider wasps, the cuckoo wasps, the velvet ants, the true ants, the true wasps, and the potter wasps, each making up a different family, while the hornets and yellow-jackets, most familiar of wasps, are only one family of the group. Scientifically another superfamily, Sphecoidea, is made up entirely of insects called wasps according to some writers, but includes the bees according to others. The wasps of this division are represented by the giant cicada-killer, the largest of North American wasps, and the thread-waisted wasps.

Wasps have been extensively studied because of their complex behavior in making and provisioning nests for their young. In the works of the Peckhams and the Raus some remarkable and interesting records are preserved. (A.W.L.)

WASSERMANN REACTION. One of the most important tests used in the diagnosis of **syphilis.** The test is made on the patient's blood or spinal fluid. A positive reaction is graded as one, two, three or four plus, indicating the intensity of the reaction. It is rare for the reaction to be positive early in syphilis. Usually eight or nine weeks must elapse before the reaction is positive. At times the blood will be negative and a Wassermann test of the spinal fluid will indicate the presence of the disease. A positive reaction practically always indicates the presence of an active syphilis. The Kalm precipitation test is almost as reliable as the Wassermann test and is much simpler. A positive Wassermann reaction is also seen in **yaws** and frequently in **leprosy.** (R.S.M.)

WATER. Water (H_2O) is a colorless (blue in thick layers), odorless, tasteless liquid, melting point 0° C. (one of the standard temperature points), boiling point 100° C. at 760 mm. pressure (another standard temperature point). At 770.0 mm. pressure, the boiling point is 100.366° C.; at 750.0 mm., 99.360° C.; at 740.0 mm., 99.255° C.; at 730.0 mm., 98.877° C.; at 380 mm., 81.7° C.; at 76 mm., 46.1° C.; at 1520 mm., 120.6° C.; at 7600 mm., 180.5° C. Density, 1.000000 gram per milliliter (or 0.000073 gram per cubic centimeter) at 3.98° C. (one of the standard density points). At 0° C., the density is 0.99987 gram per milliliter; at 8° C., 0.99988; at 15° C., 0.99913; at 16° C., 0.99897; at 17.5° C., 0.99871; at 20° C., 0.99823; at 25° C., 0.99707; at 40° C., 0.99224; at 50° C., 0.99807; at 75° C., 0.97489; at 100° C., 0.95838; at 120° C., 0.9434. **Critical temperature** 374° C., **critical pressure** 217.7 atmospheres, **critical density** 0.4 gram per cubic centimeter. **Viscosity,** 0.01792 poise (dyne-second per square centimeter) at 0° C. (specific viscosity 1.000). At 20° C., the viscosity is 0.01005 poise (specific viscosity 0.561), at 50° C., 0.00549 (specific viscosity 0.307), at 75° C., 0.00380 (specific viscosity 0.212), at 100° C., 0.00284 (specific viscosity 0.158). **Surface Tension** against air, at 0° C., 75.6 dynes per centimeter; at 10° C., 74.22; at 20° C., 72.75; at 30° C., 71.18; at 60° C., 66.18; at 100° C., 58.9. **Specific heat,** 1.00000 at 15° C. (standard of specific heat). At 0° C., the specific heat is 1.00874; at 25° C., 0.99765, at 35° C., 0.99743 (minimum); at 50° C., 0.99829; at 65° C., 1.00001; at 80° C., 1.00239; at 100° C., 1.00645; at 120° C., 1.016; at 180° C., 1.04. Electrical **conductivity** 0.04×10^{-6} reciprocal ohms at 18° C. (Kohlraush and Heydweiller, 1902), of pure water in **equilibrium** with air 0.8×10^{-6}, or ordinary distilled water about 5×10^{-6}. **Dielectric constant** (specific inductive capacity), 81.07 at 18° C. (compare ethyl alcohol 25.8 at 20° C., carbon disulfide 2.6 at 20° C.).

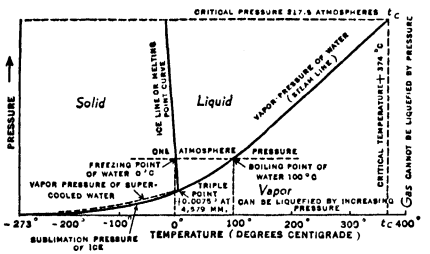
The chemical composition of water has been the subject of intensive studies from the early years of the science of chemistry. E. W. Morley, of Western Reserve University, Cleveland, Ohio, in 1895, reported the weight ratio of **oxygen** to **hydrogen** in water as 7.9395 to 1.00000, and the volume ratio, 1.00000 to 2.00288. F. P. Burt and E. C. Edgar, of England, in 1916, considered, on the basis of their experiments, 7.9387 to 1.00000 the most exact weight ratio. The present value accepted by the International Union of Chemistry, Committee on Atomic Weights, is 8.0000 to 1.0078. Liquid water consists of dihydrol ($(H_2O)_2$) mainly, and some trihydrol ($(H_2O)_3$), at 0° C., probably 63% of the former and 37% of the latter; steam at 100° C. is monohydrol (H_2O); ice is possibly trihydrol. This phenomenon may account for the abnormally high **heat of vaporization** (and condensation), which is 585 calories (15° C.) per gram of water at 20° C., and 540 at 100° C. (compare butane 88, **ethyl alcohol** 204, **acetone** 125, **acetic acid** 97, **carbon tetrachloride** 46), and high **heat of fusion** (and solidification), which is 80 calories (15° C.) per gram of water (compare **benzene** 30, ethyl alcohol 25, acetone 21, **acetic acid** 44, carbon tetrachloride 4).

For water as **catalyzer** see **Reactions Involving Water.**

Pure water, especially when free from dissolved gases, may be heated above 100° C., even to 180° C., without boiling, but on further heating boiling with explosive violence may occur. Steam at 100° C. occupies a volume 1700 times greater than water at 100° C. Pure water, when not agitated, may be cooled somewhat below 0° C. without freezing, but on further cooling congeals with increase of volume (density of ice 0.917) exerting great force, when confined, but if in intimate contact with water at atmospheric pressure the temperature is 0° C. Vapor pressure of ice and of water 4.579 mm. at 1 atmosphere pressure, 0° C. Triple point, ice-water-water vapor, + 0.007° C. in vacuum. When water is compressed to say 20,000 atmospheres and then cooled, other varieties of ice, all denser than water, are formed (ice

II 12 percent denser than water ice, III 3 percent denser. Six varieties of ice are known).

Pure water may be obtained (1) by distillation and condensation of water, (2) by partial freezing of water



Pressure-temperature diagram for water.

followed by separation of the pure ice and melting, (3) by burning of hydrogen or reduction of heated oxides by hydrogen and collecting the product. Hydrogen containing organic substances, e.g., **hydrocarbons,** when burned in air or heated with **copper** oxide, form water.

"Heavy water," deuterium oxide (D_2O, molecular weight 20, that of ordinary water 18), is found in the residual water of **electrolytic** cells that have been operated a long time, ordinary water being more rapidly decomposed than heavy water. The physical constants of deuterium oxide are: melting point 3.8° C., boiling point 101.42° C., density at 25° C. 1.1056, temperature of maximum density 11.6° C., solubility of sodium chloride 15 percent less than in ordinary water.

Water occupies a distinct position among liquids in the matter of dissolving gases, liquids and solids. While there are other liquids that exceed it in solvent power in specific cases, no other shows such a wide range and general intensity of solvent power. Many chemical reactions take place in water as the solvent medium, and many of these occur instantaneously. See **Solutions and Solubility.**

Water of the ocean, containing dissolved salts, covers 73 percent of the surface of the earth; water of lakes (fresh and salt) and rivers forms an important portion of the land surface; water vapor of the atmosphere is a constituent affecting climate and plant growth; snow and ice of mountain tops serve upon melting as regional water supplies, and of the polar regions determine ocean currents and climate; and underground water is an industrial and agricultural source of water supply. The effect of water in changing the earth's surface is mainly due (1) to the disintegration of rocks when ice forms in the interstices, (2) to the mechanical carrying of particles of various sizes from higher to lower levels, (3) to the solution of parts of the rocks, (4) to its beneficial effect on plant growth. Water stands alone in its importance to plant and animal life, and to industry.

Rôle of water. The rôle of water in our universe is on a par with, if not surpassing, that of any known substance. The scope is briefly as follows:

In nature
- Geochemical
  - The hydrosphere (See below)
  - Water as vapor, liquid, ice and snow
  - Water at rest and in motion
- Biochemical
  - Water and plant organisms
  - Water and animal organisms

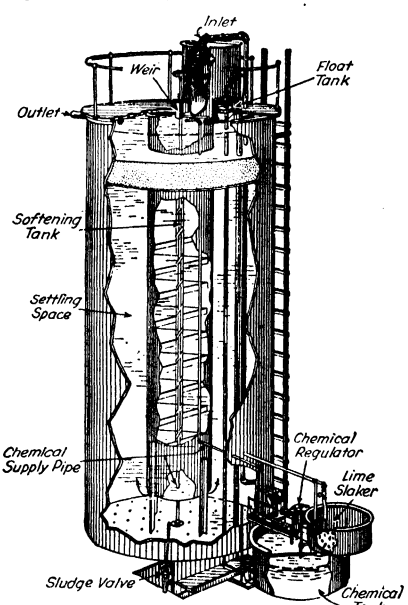
In industry
- As solvent, and medium of reaction (See **Solutions**)
- Humidity
- Extinguisher of fires by lowering the temperature
- Drying and wetting

In living
- Beverages, foods and their preparation (See **Foods**)
- Washing, cleansing and sanitation

In science
- Standard of reference for many data (See above)
- **Deliquescence and water absorption**
- **Efflorescence and loss of water**
- Drying and desiccation
- **Reactions involving water**
  1. Consumption of water
  2. Production of water
  3. Water as catalyzer

Natural waters may be contaminated with (1) insoluble suspended material. This settles out upon standing, or may be filtered, (2) soluble inorganic matter, (3) soluble organic matter. This may impart color or acidity. The latter may be readily neutralized by addition of a base. The former may be removed by precipitation of gelatinous **aluminum** hydroxide (aluminum sulfate or alum plus sodium carbonate), a process which also removes practically all the bacteria which may be present.

In ocean and salt lake waters the principal content is **sodium** chloride, with small amounts of **calcium, magnesium, potassium,** and **sulfate, carbonate;** in fresh lake, river and underground water the content is variable in amount over a wide range, some surface waters in contact with igneous rocks are practically pure water except for dissolved air, others are notable for their high



Typical lime-soda water softener--continuous type.

calcium content in **limestone** regions, usually containing calcium and magnesium as hydrogen carbonate and chloride, respectively ($Ca(HCO_3)_2$, $MgCl_2$). When the hydrogen carbonates are boiled calcium carbonate ($CaCO_3$) is precipitated and can be separated. In order to separate dissolved calcium and magnesium, treatment with calcium hydroxide and sodium carbonate has long been practiced. Other treatments include passage of the water over artificial sodium zeolites, addition of trisodium phosphate.

The cycle of water in nature is evaporation from the oceans, then condensation upon cooling by contact with colder bodies of land, e g , mountains, or cold currents of air from the polar regions This may fall as rain or snow, which are practically pure water, except for dissolved air. Rain runs off the surface into lakes or rivers or seeps into the earth Snow and ice form a storage source of water which is liberated when and as the temperature rises Underground water gradually evaporates through porous soil, flows to lower levels, or remains as a storage source Plants and animals enter the cycle to use such water as is necessary and available, and returning to the atmosphere or the surface of the earth such as is not retained Animal waste and animal remains furnish a food source for **bacteria** which in some cases are hazardous to animal life Such water is purified (1) by **filtration** through sand filters, usually accompanied by precipitation of **aluminum** hydroxide, (2) by disinfection, most frequently by chlorine or a hypochlorite, and, in many cases (3) by treatment with activated **carbon** to remove odors Industry enters the cycle (1) to use the water for power, usually hydroelectric, (2) to generate steam, in which case the purity or impurity of the water used is an important consideration in connection with steam boiler practice, (3) to use the water for cleansing purposes, in cases where soap is used the extent to which **calcium** or **magnesium** ("hardness") is present represents loss of soap, (4) to use the water for dissolving or separating solids, liquids, gases The effluents from such applications represent a wide range of impurities, e g , from coal-gas works, wood-pulp mills, tanneries, packing-house plants These effluents, along with those from domestic sewage, present a serious problem in sanitation Rivers complete the cycle of water in nature by returning to the oceans the excess of water plus such natural, industrial, and domestic additions of insoluble and soluble materials as are contained

Volume and Mass of Hydrosphere

Data of Kossinna (1921), accepted by Clarke (1924)

Volume of hydrosphere, including the oceans, the mediterranean seas, the border seas, and the gulfs

1,370,323,000 cubic kilometers or 327,672,000 cubic miles

Mass of hydrosphere, described as above

$1{,}411\ 4 \times 10^{15}$ metric tons

Density of sea water of normal salinity (35 parts per 1,000) at 0° C.

1 028 (1 03, Clarke)

Mass of salt in hydrosphere.

$49\ 4 \times 10^{15}$ metric tons

The hydrosphere is estimated to be 7 percent of the total mass of the earth

ANALYSES OF SEA WATERS

Dissolved Solids		Analyses of Dissolved Solids					
		Chloride	Sodium	Potassium	Sulfate	Calcium	Magnesium
Atlantic Ocean	3 30 to 3 74%	55 3%	30 6%	1 1%	7 7%	1 2%	3 7%
Great Salt Lake, Utah	14 99 to 23 04	56 0	33 2	1 6	6 6	0 2	2 5
Owens Lake, Cal	7 2	25 7	37 4	2 2	10 0	0 02	0 01
Dead Sea	19 22 to 26 00	65 8	11 7	1 9	0 3	4 7	13 3
Baltic Sea	0 3 to 0 8						
White Sea	2 6 to 3 0						
Black Sea	1 8 to 2 2						
Red Sea	5 1 to 5 9						

ANALYSES OF RIVER WATERS

Parts per Million, Average

Place	Silica	Calcium	Magnesium	Sodium plus Potassium	Sulfate	Chloride	Total Dissolved Solids
Mississippi							
Minneapolis, Minn , 1 yr (1906–07)	15	40	14	10	18	2	200
Memphis, Tenn , 1 yr (1908)	24	36	12	19	43	9	202
New Orleans, La , 1 yr (1905–06)	11	32	8	13	24	10	166
Ohio (calculated from tributaries)	12	18	5	8	17	7	
Missouri							
Kansas City, Kans , 1 yr (1906–07)	37	62	18	44	135	13	426 (1909)
Lake Superior (Aver of 11 anal)	13	22	5	6	4	2	60
St Lawrence (Aver of 11 anal)	5	24	5	5	9	6	134
Penobscot							
Bangor, Me , 3 yr (1909–12)	2	4	1		6	2	62
Hudson							
Hudson, N. Y , 1 yr (1906–07)	11	21	4	8	16	4	108
Rio Grande							
Laredo, Tex , 1 yr (1905–06)	29	104	23	119	228	164	791
Colorado							
Yuma, Ariz , 1 yr. (1893)	19	66	13	194	231	183	706
San Joaquin							
Lathrop, Cal , 1 yr (1906)	16	18	8	27	26	30	161

(*Continued on next page.*)

ANALYSES OF RIVER WATERS—*Continued*

PARTS PER MILLION, AVERAGE

Place	Silica	Calcium	Magnesium	Sodium plus Potassium	Sulfate	Chloride	Total Dissolved Solids
Sacramento							
Sacramento, Cal , 1 yr (1906)	19	15	7	15	13	9	124
Columbia							
Cascade Locks, Wash (Bonneville, Ore) 1 yr (1911–12)	14	17	4	9	12	3	97
Willamette							
Salem, Ore , 1 yr (1911–12)	15	5	1	4	4	2	51
Thames, England, 1906–13						17	227
Rhone, France	2	26	4	4	27	1	64
Rhine, Cologne	0 2	26	6	3	13	4	52
Elbe						123	414
Danube							
Budapest	1	27	7	1	14	1	51
Nile, Egypt							
Cairo	17	13	7	16	4	3	60
Amazon							
Obidos	29	15	1	9	2	7	63

TURBIDITY OF RIVER WATERS

PARTS PER MILLION, AVERAGE

Place	Turbidity	Place	Turbidity
Mississippi		Columbia	
Minneapolis, Minn 1 yr (1906–07)	10	Cascade Locks, Wash (Bonneville, Ore), 1 yr (1911–12)	27
Memphis, Tenn , 1 yr (1908)	556	Willamette	
Hudson		Salem, Ore , 1 yr (1911–12)	8
Hudson, N. Y , 1 yr (1906–07)	13		

CHEMICAL DENUDATION IN THE UNITED STATES

Drainage Area	Area Drained (Square miles)	Dissolved Solids to Ocean (Short tons per square mile per annum)
North Atlantic	159,400	130
South Atlantic	123,900	94
Eastern Gulf of Mexico	142,100	117
Western Gulf of Mexico	315,700	36
Mississippi River	1,265,000	108
Laurentian Basin (U S A)	175,000	116
Colorado River of Arizona	230,000	51
South Pacific . .	72,700	177
North Pacific	270,000	100
Sum	2,753,800	Average 98
Great Basin	334,700	
Total	3,088,500	

TOTAL DENUDATION OF THE COLUMBIA RIVER BASIN

Above Cascade Locks, Wash (Bonneville, Ore)
Observations, Aug , 1911, to Aug , 1912

Drainage Area· Columbia River above Cascade Locks, Wash

Area Drained 175,200 Square miles
Mean Discharge: Minimum 60,600 Second-feet, Jan. 1, 1912
Maximum 624,900 Second-feet, June 10, 1912
Dissolved Matter: 17,000,000 Short tons in 1 year
Suspended Matter· 7,000.000 Short tons in 1 year

CHEMICAL DENUDATION OF THE LAND SURFACE OF THE EARTH BY CONTINENTS

	Land Surface Million square miles	Dissolved Solids to Ocean	
		Metric tons per square mile	Million metric tons per annum
North America	6	79	474
South America	4	50	200
Europe	3	100	300
Asia	7	84	588
Africa	8	44	352
Total	28	Aver 68 4	Total 1,914

AVERAGE HARDNESS OF WATER FROM PUBLIC SUPPLY SYSTEMS IN THE UNITED STATES IN 1923

State	Average Hardness as Calcium Carbonate in Parts per Million	Population Served Thousand	% of Total Population of State	State	Average Hardness as Calcium Carbonate in Parts per Million	Population Served Thousand	% of Total Population of State
Alabama	53	283	12	Missouri	148	1,245	37
Arizona	221	49	15	Montana	91	66	12
Arkansas	149	94	5	Nebraska	239	247	19
California	172	1,800	52	Nevada	74	16	21
Colorado	144	330	35	New Hampshire	9 7	107	24
Connecticut	25	826	60	New Jersey	48	1,983	63
Delaware	51	114	51	New Mexico	126	22	6
District of Columbia	80	438	100	New York	47	7,576	73
Florida	296	204	21	North Carolina	22	157	6
Georgia	27	421	15	North Dakota	141	36	6
Idaho	91	36	8	Ohio	153	2,767	48
Illinois	156	3,435	53	Oklahoma	400	194	10
Supplied from Lake Michigan	131	2,824	44	Oregon	9 6	276	35
Not supplied from Lake Michigan	274	611	9	Pennsylvania	69	3,556	41
Indiana	264	873	30	Rhode Island	12	475	79
Iowa	298	412	17	South Carolina	31	105	6
Kansas	316	223	13	South Dakota	503	40	6
Kentucky	90	387	16	Tennessee	57	416	18
Louisiana	54	431	24	Texas	136	841	18
Maine	18	127	17	Utah	158	151	34
Maryland	53	792	55	Vermont	39	38	11
Massachusetts	14	2,668	69	Virginia	45	489	21
Michigan	134	1,722	47	Washington	41	570	42
Minnesota	158	714	30	West Virginia	76	174	12
Mississippi	14	46	3	Wisconsin	145	760	29
				Wyoming	119	25	13
				United States	99	38,757	37

PERCENTAGE OF POPULATION OF THE UNITED STATES SERVED BY PUBLIC WATER SUPPLY

Data for 1930, Except As Stated

State	Percentage of Population Served by Public Water Supply
Massachusetts	97 0
New Jersey	94 7
New York	90 0
Rhode Island (1933)	89 4
Connecticut.	89 0
California	84 6
New Hampshire	82 8
Nevada (1933)	81 5
Followed by 8 other states, making a total of 16 above the average.	
Average United States	63 1

State	Percentage of Population Served by Public Water Supply
Followed by 25 other states, and the following states, making a total of 32 below the average	
Kentucky	34
Alabama	31
North Carolina	31
Arkansas	25
South Carolina	24
North Dakota	22
Mississippi	18

SANITARY CHEMICAL ANALYSIS OF RIVER WATERS

DATA IN PARTS PER MILLION

	Color	Oxygen Consumed	Free Ammonia	Albumin-oid Ammonia	Nitrites	Nitrates	Chlorine	Hardness by Soap	Residue on Evaporation Total
Mississippi River									
At Minneapolis	40	7 60	9 072	0 240			2 0	164 0	197 0
At New Orleans	13	0 9	0 006	0 245	0 00	0 12	9 3	84 0	573 0
Missouri River									
At Omaha		71	0 062		0 004	0 18	10 0		1,325 0
At St Louis, high stage, 26 3 ft	36	41 5	0 048	1 480	0 006	1 36	4 0	92	
At St Louis, low stage, 5 6 ft	25	13 1	0 040	0 720	0 006	0 40	15	155	
Ohio River									
At Cincinnati, max		46 0	0 074	0 868	0 030	1 34		57 0	2,556 (223 diss)
At Cincinnati, min		13 0	0 008	0 106	0 000	0 37		11 0	91 0 (67 diss)

AVERAGE CONSUMPTION OF WATER IN VARIOUS CITIES

City	Gallons Per Capita Per Day	City	Gallons Per Capita Per Day
London (1924)	43	Tokio (1913)	32
Paris (1913)	38	Sydney (1913)	50
Madrid (1913)	84	Toronto (1913)	118
Rome (1913)	120	New York City	115
Berlin (1913)	35	Chicago	235
Cairo (1913)	25	Baltimore	130
Calcutta (1913)	62	Milwaukee	85

The consumption of water in European cities is usually about 20 to 50 gallons per capita per day, but in the cities of the United States is much larger, from 75 to 150 In the United States, the consumption of water is distributed about 35% domestic, 40% industrial, and the remainder for municipal use plus waste

SEASONAL EVAPORATION OF WATER AT VARIOUS PLACES

DATA IN INCHES OF WATER EVAPORATED

	Berkeley, California, 1905	Minidoka Dam, Idaho, 1909–10	Boston, Massachusetts, 1875–90	Nebraska Interstate Canal, 1909–10	Lee Bridge, England, 1860–73
Jan	1 0	2 2	1 0	2 0	0 8
Feb	1 4	2 5	1 0	2 2	0 6
Mar	2 1	4 0	1 7	3 5	1 1
Apr	3 1	7 0	3 0	6 0	2 1
May	4 7	11 2	4 5	8 5	2 8
June	5 7	12 3	5 5	11 0	3 1
July	5 5	15 0	6 0	14 7	3 4
Aug	5 1	13 5	5 5	12 7	2 8
Sept	4 6	11 0	4 1	10 0	1 6
Oct	4 3	8 5	3 2	7 6	1 1
Nov	2 7	5 8	2 2	5 2	0 7
Dec	1 3	3 5	1 5	3 0	0 6
1 year	41 6	96 5	39 2	86 4	20 7

(R K S)

WATER BEAR. Bear animalcule **Tardigrada.**

"WATER BLOOM." **Algae.**

WATER BOATMAN. Insecta, Hemiptera An aquatic bug of the family Corixidae These insects are flattened, broad at the head and tapering bluntly at the opposite end of the body. The fringed posterior legs project like a pair of oars and are used in swimming Water boatmen breathe air but they are able to descend to considerable depths, carrying a film of air on the ventral surface of the body They feed on ooze containing plant matter and minute animals. (A W L)

WATER BUCK. Mammalia, Artiodactyla *Kobus* A large antelope of southern and eastern Africa It frequents rocky hills in the vicinity of rivers The horns are more than two feet long, slightly curved and ringed almost to the tips (A W L.)

WATER DEER. Mammalia, Artiodactyla *Hydropotes* A small **deer** found along the margins of the Yangtse Kiang river in China The male has long curved tusks in the upper jaw and neither sex has antlers The species is also remarkable in producing three to six young at a time (A W L)

WATER DOG. Amphibia, Urodela The **mud puppy.**

WATER FLEA. Crustacea, Cladocera Minute aquatic **crustaceans** of compact form, usually transversely compressed and provided with a bivalve **carapace.** They are superficially like fleas in form (A W L)

WATER GAP. Gap.

WATER HAMMER. Sudden stoppage of water flow in a pressure conduit caused by the closing of **valves** can, if the rate of closure be rapid enough, cause the conduit to be subjected to a sharp, hammer-like blow from a steep front pressure **wave** Water moving in a pipe line has considerable mass To decelerate a mass requires a force equal to the mass times the deceleration (negative **acceleration**) If the rate of deceleration is large, the force will be large Hence if a valve or gate is suddenly closed, the water has high deceleration, and a large force is set up Due to the elastic nature of conduit material, this force is expanded, slightly stretching the pipe When the inertia force has disappeared, the pipe regains its original girth and produces secondary pressure waves A calculation shows that the power required to decelerate water in a five foot pipe 2,000 feet long is 1400 H P This calculation was based on an assumption of 10 feet per second water velocity, and 5 seconds was the time taken to close the valve, and it should acquaint one with the magnitude of power behind the water hammer To cushion all or parts of the water conduit against the destructive effect of water hammer forces, relief valves, bursting plates, and surge tanks have been used Water hammer may also be caused by the sudden collapse of steam bubbles upon entering cold water, as when the steam is turned into a cold radiator partly filled with water (F T M)

WATER HEATING. Feed Water Heating, Heating.

WATER HYACINTH. *Eichhornia crassipes* Pontederiaceae This plant occurs widespread in tropical and subtropical regions, where it often becomes a troublesome weed In Florida it sometimes forms floating masses so dense as to become a serious hindrance to river navigation Very noticeable are the leaves, the **petioles** of which are swollen in bladder-like enlargements containing many air-spaces These cause the plant to remain floating at the surface of the water Because of the broad shining green blades the plants are easily blown about on the surface by the wind The dark-colored roots form a dense mass beneath the water surface The root cap at the tip of each rootlet is a very conspicuous structure The flowers are showy and pale lavender in color They are trimorphic, there being three different lengths of **styles.** The plant is frequently found in cultivation in northern regions, where, however, it is not hardy (R M W)

WATER LEVEL REGULATOR. Feed Water Regulator.

WATER-LILIES Nymphaeaceae. The water-lilies form a small family of water or marsh plants The leaves may be submerged or floating or carried well above the surface of the water on stiff petioles, as in the Lotus. The flowers are usually large and solitary The principal genera are *Cabomba, Nuphar, Nymphaea,* or *Castalia,* and *Nelumbium*

Cabomba is a genus of tropical American water-lilies having two types of leaves, some are submerged and much-divided into linear segments, while others are entire and floating with the petiole centrally attached The small flowers are borne on long **peduncles,** and have their parts in threes These plants are frequently used in aquaria, both for ornament and to oxygenate the water

Nuphar is a genus of yellow-flowered plants occurring in the northern hemisphere *Nuphar advena* is the common yellow water-lily or spatterdock of the marshes

Nymphaea or *Castalia* contains the showy-flowered water-lilies so frequently grown in artificial ponds Northern hardy forms are white- or sometimes pink-flowered and fragrant Many tropical species have red, yellow, blue, or pink flowers of great beauty These flowers float on the surface of the water, as do the large cleft leaves The fruit is a berry containing many seeds, each enveloped in a spongy **aril.** The fruit ripens under water, the mature seeds floating upward from the fruit and drifting about, by means of the air bubbles contained in the aril Eventually each seed sinks to the bottom.

Nelumbium is a genus which contains but two species, *N lutea,* a native of the southern half of North America, and *N speciosum,* of Asia and the East Indian Islands The American species is pale yellow-flowered, the flowers and also the large peltate leaves standing well above the surface of the water The Asiatic species is the Sacred Lotus, which has showy fragrant pink flowers of great beauty The fruit of the lotus is a curious obconical receptacle in the top of which are embedded the many carpels At maturity the receptacle is very light and dry, so that when broken from its stalk it floats on the water, carrying the seeds about until it breaks apart The seeds of the lotus are used as food by many peoples, especially in Asia

Victoria regia, the giant water-lily of the Amazon, is related to *Nymphaea* It is a plant of tremendous size, the floating leaf with its upturned rim often having a diameter of six feet or more The flowers are likewise very large The seeds are used as food in the Amazon valley, where the plant is native (R M W)

WATER MEASURER. Insecta, Hemiptera A long slender **bug** that creeps slowly on the surface of water Also called the marsh treaders These are not the common insects that skate rapidly on the water, although they are closely related The water measurers make up the family Hydrometridae, and the other insects are water striders of the family Gerridae (A W L)

WATERMELON. *Citrullus vulgaris* Gourd Family.

WATER MOLDS. Phycomycetes.

WATER PENNY Insecta, Coleoptera A small flattened oval insect found chiefly on the underside of rocks in running water Water pennies are the **larvae** of **beetles** of the family Psephenidae They resemble crustaceans and were originally described as such (A W L)

WATER PHEASANT Aves, Charadriiformes A large and beautiful water bird (**Aves**) of India and Ceylon Its nest floats on the water or is anchored to water plants Related to the jacana (A W L)

WATER PRESSURE Head.

WATER PROPELLER. A water propeller is a very short section of an endless screw used for propulsion of power-driven vessels Although when first developed, a short section of an actual endless screw was used, the modern propeller uses only segments of the screw which are arranged radially on a hub, there being usually two, three, or four blades, depending on the type of vessel The water propeller depends largely upon push exerted on the water by its astern face, and in this respect is unlike the air propeller, in which thrust is developed by vacuum on its forward face For this reason, also, and because of the greater density of water as compared

to air, the water propeller has a relatively small diameter and large blade area This means that the disk area, i e, the area of the circle swept by the tips of the blade, is largely occupied by blade Water propellers are usually made of cast iron or manganese bronze, the latter being more suitable than iron for salt water The propeller is securely attached to a propeller shaft, which passes through the hull at the stern, and from there is connected to the engine by couplings, and possibly also by universal joints The propeller shaft is given a slight slant downwards to the rear, and leaves the hull through a stuffing box which reduces water leakage to small value The pitch of the propeller is the distance it would advance in a complete turn, considering it a screw revolving in a solid medium In use, it does not actually advance this distance, the difference being **slip** This slip averages about 15% for a properly selected propeller In any application of the water propeller, it is important to select the propeller with due regard to the speed and power of the engine The weight and size of the boat are of much less importance If a propeller is improperly selected, it will either permit the engine to race, churning the water and producing little thrust, or it will hold the engine speed below rated, and prevent development of its full output (F T M)

WATER PURIFICATION. Water purification may consist of the removal of suspended or **colloidal** matter, or it may go further than this and include chemical treatment for the removal of dissolved salts, or for the neutralization of an acid condition Ordinarily, drinking water purification is of the first type It is carried out in the three steps of **sedimentation, coagulation,** and **filtration** The raw water is first admitted to a sedimentation basin, where such suspended matter as will settle under the influence of gravity is deposited from the water Such basins must have considerable volume, and be arranged for easy and thorough cleaning of the sediment Sometimes sedimentation is sufficient, but often water is further treated with a coagulant When coagulation is also used, the sedimentation does not have to be so thorough, as coagulation can be depended upon to remove a greater amount of sediment in a shorter time This is done by treating the water with a compound which coagulates and forms a flocculent precipitate Alum (See **Aluminum**) is an example of a coagulating agent The floc may be removed by settling or by filtering Filtration of the raw water is sometimes the only purification practiced, especially when the raw water supply is exceptionally good A certain amount of sterilization of the water is frequently practiced through the addition of chlorine Chlorination processes have been improved so that chlorinated water does not taste or smell badly, especially if the water is aerated in spray ponds as the final step in the purification process (See **Filter**) (F T M)

WATER SCORPION Insecta, Hemiptera Moderately large water **bugs** of oval or slender and elongate form, with a long breathing tube at the end of the body The front legs are adapted for catching small prey (A W L)

WATER STRIDER. Insecta, Hemiptera A moderately large **bug** whose two posterior pairs of legs are modified for locomotion on the surface film of water The claws are set back from the tip of the leg and the hairs of the dense covering are turned under so that the tip of the leg rests on their curved surfaces These bugs are common on streams and ponds The members of one genus, *Halobates*, are the only truly marine insects They are found in tropical waters, often far from land, and their eggs have been found attached to floating feathers (A W L)

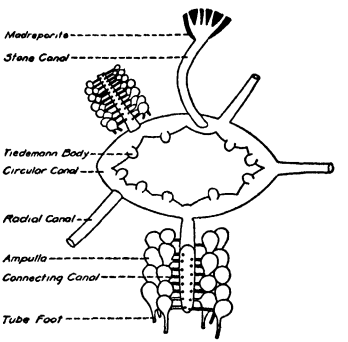
WATER TABLE. Ground water.

WATER TANK. Tank.

WATER VAPOR. Steam and Vapors.

WATER VASCULAR SYSTEM. A tubular system of **echinoderms** through which **sea** water is circulated It is formed from the **coelom** and is associated chiefly with locomotion, respiration, and the securing of food

In the starfishes (**Asteroidea**) the madreporite on the surface of the disk is a round perforated plate



Water vascular system of the starfish (Drawn by W J Moore)

leading into this system of tubes Directly below it the **stone canal** extends into the disk and joins a ring canal encircling the axis of the body From the ring canal a radial canal passes out along the axis of each ray, and various appendages arise from all of these canals The appendages of the ring canal are a series of Polian vesicles and a series of minute Tiedemann's bodies (or vesicles) The former are saccular reservoirs and the latter glandular bodies The radial canals bear transverse branches with a small vesicular ampulla inwardly and a slender **tube foot**, cupped at the end, extending out through an opening in the hard wall of the animal and projecting in the ambulacral groove on the under surface of the ray These tube feet grip by suction and adhesion

The madreporite of sea cucumbers projects into the cavity of the body, several madreporites and stone canals may also occur The body cavity is in communication with the exterior by way of the branching respiratory trees that arise from the cloaca A similar condition exists in the crinoids, which have several stone canals opening by single pores into the cloaca, and other pores from the **cloaca** to the surrounding water. (A W L)

WATER WALL. Water walls are installed on most modern **boilers** that are designed to operate at high rating They are also often added to old boilers which, by the further installation of high-capacity **combustion** equipment, **economizers,** and **air preheaters,** may be operated at greatly increased capacity When **pulverized coal** was first used refractory walls were standard, but pulverized coal could be burned by 10% to 20% excess air whereas 50% was considered good in the existing stoker-fired furnaces The results of the higher furnace temperatures accompanying pulverized coal were destruction of **refractories** and slagging of walls and tubes The **furnace** temperature was above the softening point of the ash and particles of it flying about in a sticky or molten state adhered to the first cool surface they touched. Unless the advantages gained from the reduction of flue-gas loss were to be sacrificed, furnace designs had to be changed. This led to the introduction of water-cooled furnaces in which the combustion space was partially or completely surrounded by tubes carrying water which, by absorbing radiant heat directly as soon as it was evolved from the combining molecules of

fuel and oxygen, prevented the attainment of destructively high furnace temperature

Besides plain-tube water walls there are walls with cast-iron blocks fitted over and protecting the tubes. The blocks are flat on the furnace side, thus presenting a flat unbroken water-cooled surface to the heat In others thin refractory blocks cover all or a portion of the water-cooled surface The purpose of refractory covering is to maintain a furnace temperature sufficient to prevent incomplete combustion at low ratings Radiant heat is absorbed so rapidly that steam forms a large part of the tube contents near the top This requires connections to give the best of circulation to the water walls (F T M)

WATT. A metric unit of **power**, equivalent to 10^7 **ergs** (one joule) of work per second The watt is especially convenient in electrodynamics, because the practical electrical units are so chosen that the product of the current (**amperes**) by the electromotive force (**volts**) at any instant equals the power in watts One **horsepower** is equal to about 746 watts, so that the **kilowatt** (1000 watts) is approximately 1 34 horsepower. (L D W)

WATT-HOUR METER. Integrating Meters.

WATTMETERS. A wattmeter has two coils, one fixed, the other capable of turning in the field of the first, both coils being without iron cores The fixed coil is connected in series with the main circuit, so as to carry the whole current (or, with d-c instruments, a known fraction of it, as determined by a shunt) The movable coil, which is of high resistance, is connected across the terminals of the "load," that is, that portion of the circuit in which the power is to be measured, and the small current in the coil is therefore proportional to the voltage between these terminals This coil turns against a hairspring, and since the torque is proportional to the product of the currents in the two coils, it is proportional to the product of the main current by the terminal voltage, that is, to the required power The scale may therefore be graduated directly in watts The wattmeter may be replaced by an ammeter (in series with the load) together with a voltmeter (across the load terminals) To obtain the power it is merely necessary to multiply their readings together, except that in the case of **alternating currents** with reactance in the load, this product must also be multiplied by a "power factor" equal to the cosine of the phase angle (L D W)

WAVE FILTER. Electric Oscillations and Electric Waves.

WAVELLITE. The mineral wavellite is a hydrous **phosphate** of **aluminum**, formula $(Al\ OH)_3(PO)_4\ 5H_2O$. It is **orthorhombic** but crystals are of rare occurrence as it is ordinarily found in crusts or radial aggregates, sometimes fibrous Its hardness is 3 5–4; specific gravity, 2 3–2 4, may be of various colors, gray, blue, green, yellow, black, or colorless It has a vitreous luster, and is translucent This mineral is of secondary origin, probably formed by waters bearing phosphoric acid which have acted on aluminum minerals Wavellite is found in Saxony, Bavaria, Devonshire, from whence it was originally described, and in the United States in Chester and Cumberland Counties, Pennsylvania; and Montgomery and Garland Counties, Arkansas. It was named after its discoverer, Dr Wavel (E S C S)

WAVE MECHANICS. Wave mechanics is a more or less direct outgrowth of the **quantum theory**, and an integral part of **quantum mechanics.** The fact that radiant energy (light, x-rays, etc) is certainly emitted by atoms or molecules and is as certainly done up in parcels, called **quanta**, the magnitude of each of which is definitely associated with a vibration or wave frequency of some kind (See **Planck's Law**), leads one to inquire what there is about an atom or the electrons in it that has to do with vibrations or waves The now famous **Davisson-Germer experiment** gave most conclusive evidence that electrons actually do have wave characteristics even when flying freely through space (or at least when they strike and rebound from something like a crystal), and that, again, the energy of their motion is expressible in terms of a wave or vibration frequency Even whole atoms are reflected by crystals as if they were waves, as shown by the experiments of Ellett, Olson, and Zahl

Such facts have given rise to the idea that perhaps all physical processes are, in the last analysis, wave processes, with frequencies or wave lengths appropriate to the quanta into which the energy divides itself Indeed it seems not impossible that the very atoms of which matter is composed are complex wave patterns, and that when an atom changes from one "quantum state" to another, it is because this wave pattern changes to one of different frequency (A useful analogy is found in a metal plate clamped at the center and covered with sand, when stroked with a violin bow it shows a complex wave pattern) Instead of being particles which revolve in orbits like planets, the electrons in the atom, according to this conception, become wave trains reverberating like sound in a closed room, and setting up stationary **interference** patterns corresponding to the stationary quantum states It is of such boldly revolutionary concepts that the new wave mechanics is built The mathematical formulation of the theory has been developed largely by de Broglie and Schroedinger (L D W)

WAVEMETER. Frequency Meters and Wavemeters

WAVE PROPAGATION In the propagation of a train of waves, each particle of the medium undergoes some sort of periodic variation, represented by the departure of some periodic variable from a neutral or zero value This variable may be a position (geometrical co-ordinate), a pressure or other stress, a magnetic intensity, an electric intensity, a temperature, etc Let the departure of the variable from its zero or equilibrium value at any instant be represented by d If the variation is harmonic, it may, for any one particle of the medium, be represented by the equation $d = a \cos 2\pi\nu t$, in which a is the amplitude and ν the frequency of the periodic variation, and t is the time reckoned from an instant when d is at its maximum value (See **Harmonic Motion**) But if we consider different particles, we must also provide for differences in phase, by adding an adjustable phase term

$$d = a \cos (2\pi\nu t + \Delta) \qquad (1)$$

Now if a train of waves is moving in a homogeneous medium in the direction, let us say, of the X-axis, this phase term Δ is a linear function of x, so that, if we could arrest the process for a moment and examine conditions along the X-axis, the phase of d would be found to differ by equal amounts at equal intervals of distance This linear function has the form

$$\Delta = \Delta_0 - \frac{2\pi\nu}{V} x,$$

in which Δ_0 is the value of Δ at the origin, and V is the speed of the wave propagation Also, the amplitude a is in general some function of x, called a "wave function", let it be represented by $\psi(x)$ Substituting these expressions in (1), we obtain the simple harmonic "wave equation"

$$d = \psi(x) \cdot \cos\left[2\pi\nu\left(t - \frac{x}{V}\right) + \Delta_0\right]. \qquad (2)$$

According to Fourier's theorem of **harmonic analysis**, any periodic variable can be expressed as the sum of a number of simple harmonic variables, so that any wave

equation in one dimension (x) may be written by equating d to a series of terms similar to (2) but with different values of $\psi(x)$, ν, Δ_0, and sometimes also of V. (See **Group Velocity** and **Vibrations and Waves.**) (L.D.W.)

WAVES. Vibrations and Waves; Wave Propagation.

WAXES. Esters.

WAX MOTH. Insecta, Lepidoptera. A small **moth** whose **larva** lives in the combs of bee hives, spinning silken tunnels as it burrows through them. Although it eats the wax of which the combs are built and will attack the pure wax in stored comb foundation, careful studies have shown that it does not thrive on a pure wax diet. The other materials in old combs are a necessary source of nitrogen, without which the **caterpillar** may live but cannot grow and develop normally.

The moth does not become a serious pest in strong colonies of bees but it is sometimes a cause of serious damage in weak colonies and stored combs. It may be killed by fumigating stored supplies with **carbon disulfide.** This fumigant is highly explosive and must be used with due precautions to prevent ignition. The vapor is heavier than air and may collect in dangerous quantities in low places, but fortunately its disagreeable odor makes it easy to detect. (A.W.L.)

WAXWING. Aves, Passeriformes. A bird (**Aves**) of the northern hemisphere, smoothly gray and brown, with limited yellow shading and black marks, and red tips of horny material on some of the wing feathers. The name waxwing refers to these tips. The head bears a sharp crest. One species, the cedar waxwing or cedar bird, *Bombycilla cedrorum,* is peculiar to the United States. The Bohemian waxwing, *B garrula,* nests in northern latitudes in Europe and North America and is occasional through the northern half of the states. A third species, the Japanese waxwing, *B. japonica,* breeds in eastern Asia. (A.W.L.)

Cedar waxwing, *Ampelis cedrorum.* Soft cinnamon-brown. A yellow band across the end of the tail. A crest on the head. The end of each secondary feather in the wing has a red tip like a drop of sealing-wax, whence the name of the bird.

WEAKFISH. Pisces, Teleostei. A food fish, *Cynoscion regalis,* belonging to the **drum** family. It attains a length of 2½ feet and is found from Cape Cod to Florida. Also called the squeteague. Two related species of more southern distribution are the white and the spotted weakfish. (A.W.L.)

WEASEL. Mammalia, Carnivora. A small carnivorous animal, slim and short-legged, related to the minks, ferrets, and martens. Several species of weasels occur in Eurasia and a dozen North American species have been described. The common or long-tailed weasel, *Mustela noveboracensis,* ranges from Illinois to Carolina and northward into Canada. It is brown above and yellowish below in the summer, becoming white in winter, with a black-tipped tail, in the northern part of its range. The winter phase has also been called **ermine.** The name long-tailed weasel applies also to another species, *M. longicauda,* found only on the plains from Kansas northward. The short-tailed weasel, *M. cicognanii,* resembles the common species but is white below in summer; it ranges from the northern states to Alaska. Other species are of limited distribution or are not commonly known. (A.W.L.)

WEATHERING. The processes by which the atmospheric agencies, commonly associated with the weather, mechanically disintegrate or chemically decompose the rocks at or near the earth's surface. Mechanical weathering includes the effects produced by changes of temperature, the action of frost, abrasive action of the wind, etc.; chemical weathering includes the solvent action of water, the union of atmospheric **oxygen** with rock materials—oxidation, union with atmospheric **carbon dioxide**—carbonation, and the chemical combination of substances with water—hydration. (E.S.C.S.)

WEAVER. Pisces, Teleostei. Marine fishes (**Pisces**) with poisonous spines on the dorsal fins and **opercula.** They are found in European and South American waters. The greater weaver, *Trachinus draco,* or stingbull of British seas is an excellent food fish. (A.W.L.)

WEAVER BIRD. Aves, Passeriformes. A bird (**Aves**) of a large group found in Africa, Australia, and tropical Asia. They build remarkable nests, weaving their materials intricately and sometimes in complex forms. Some species are gregarious, building large nests for the entire colony. Many species of weavers are brilliantly colored. The group includes the ox birds, whydah birds, bishop birds, munias, and weaver finches. (A.W.L.)

WEBWORM. Insecta, Lepidoptera. A **caterpillar** that surrounds the site of its work on plants with a mixture of silk and debris. Several insects belonging to different families are known as webworms. The burrowing webworms (Acrolophidae) eat the roots of **grass** and may damage **corn** when planted on sod ground. The sod webworms work at the base of the stem and damage **grasses, cereals,** and other plants. They belong to the subfamily Crambinae of the family Pyralidae, which also contains the cabbage and garden webworms, members of a different subfamily, Pyraustinae. The former affects cabbage and related plants and the latter attacks corn, cotton, and various species of garden plants. The European corn borer is closely related to the last two species.

Cultural methods are the most important in controlling these pests. They vary according to the species, the crop, and the conditions. (A.W.L.)

WEDGE. Machines.

WEDGE PHOTOMETER. In the many forms of **bench photometer,** the illuminations or luminous flux densities from the two sources to be compared are made equal by regulating the relative distances. In photometers of the wedge type, the same object is accomplished by pushing into the beam from the brighter source a graduated wedge of absorbing material until its intensity is cut down to equality with that from the other source. The scale reading on the wedge indicates the ratio in which the flux density has been reduced, and hence the luminous intensity ratio of the two sources. It is highly important that the absorbing wedge shall be "neutral," that is, not selective as to wave length, in its absorption; otherwise there will be an alteration of color as well as of total intensity.

This same principle may be applied to **stellar photometry.** By means of a complicated system of diaphragms, lenses, and color screens, an "artificial star" image may be formed and reflected into the eyepiece of a telescope close beside the image of a star whose **stellar magnitude** is desired. The source of light for this artificial star is usually a small incandescent lamp whose brightness is maintained as nearly constant as is possible by using a storage battery of large capacity. In the path of the light from this lamp is placed the neutral optical wedge so that the brightness of the artificial star may be varied, with the amount of variation proportional to the position of the wedge. In determining magnitude with this instrument the observer sets the telescope on a star whose brightness is desired

and adjusts the wedge until the artificial star and the star image formed by the telescope have the same apparent brightness The telescope is then turned to a star of known magnitude, e g , a star of the north polar sequence, and the wedge readjusted. The difference in wedge positions on the two stars may be converted into the difference of magnitude between the stars by means of a calibration curve previously obtained for the instruments and the observer (L D W , W K C)

WEEDS. Any plant growing where it is not wanted and seeming to have no usefulness may be called a weed. Many plants become weeds when introduced to new regions, where they can grow rapidly Cultivated land, in which competition with other plants is very much reduced, is such a region Here small plants such as purslane, which would be choked out in competition with other plants, can spread rapidly Attempted eradication by hoeing often fails to remove such plants, because of the ease with which they put out roots and become reestablished Other plants become weeds when introduced into countries in which they do not naturally occur and where they meet with little competition from native plants The common white daisy, introduced into America in colonial times as a garden flower, grows rapidly in hay fields and by its presence greatly reduces the value of the crop Another weed causing even greater loss in such situations is the common hawkweed or devil's paintbrush The prickly pear cactus, introduced into Australia and into Mediterranean countries, has become a troublesome weed In the western plains the Russian thistle, *Salsola Kali*, becomes a pest which, however, may be of value at times because of its great drought-resisting ability When young the plants are fairly good forage When mature they are utterly worthless, breaking loose from their roots and rolling about as tumbleweeds, scattering seeds far and wide Other plants such as dandelion and plantain, because of the coarse unsightly habit of their leaves, become weeds when they get into lawns

Various means are used to control weeds Whenever possible they may be kept down or eliminated by thorough hoeing, which prevents them from getting established In other cases the tops may be prevented from forming, thus gradually starving the plants by preventing **photosynthesis.** Sometimes they may be smothered out by covering them with paper or other materials This method is successfully used in the pineapple fields of the Hawaiian Islands Recently some success has been obtained by using certain sprays, such as iron sulfate solution, which sticks to the broad leaves of such plants as kale or mustard, but does not materially harm the grain among which the weeds are growing Partial success has also resulted from spraying poison ivy, where the latter has become an obnoxious and unwanted weed (R M W)

WEEVIL. Insecta, Coleoptera A **snout beetle,** member of a large division of the order known as the Rhynchophora These insects, with some exceptions, have the head prolonged into a snout which bears the small mandibles at its tip The snout is most conspicuous in the nut weevils, where it exceeds the length of the body and is very slender Some of the weevils are important pests, notably the cotton boll weevil and the granary weevil The former lives as a **larva** in the squares and bolls of the cotton plant, preventing the normal development of seeds and lint, and the latter is found chiefly in stored grains (A W L)

WEIGHING METHODS. The use of a **balance** for measuring masses is something more than the mere placing of equal weights on the two pans The chief reasons are that the refinement required often goes beyond the smallest weights in any set, and that the arms of a balance are never exactly equal in length

The former condition is commonly met by the use of a "rider," a small weight (usually 1 milligram) sliding along a scale on the beam The most approved procedure, however, makes use of the known sensibility of the balance, expressed in divisions of the pointer scale per unit excess weight on one pan. The arm inequality may be allowed for by the substitution method, in which the object to be weighed is first counterpoised, or nearly so, and then replaced by known weights on the same pan, the small difference in pointer reading being noted and the difference in weight computed from it

Both difficulties can be met at once by the method of "double weighing" The object is first placed on the left pan and weights nearly equal to it on the right, the resulting pointer reading being r_1 The object and weights are now interchanged, with pointer reading r_2 Then if the sensibility of the balance is s, and if the weights used total a value w, the weight of the object is given by

$$W = w + \frac{r_1 - r_2}{2s}$$

The sensibility is, in general, a function of the load, and before precise weighing is attempted, a table or a graph should be prepared from which s can be obtained from the value of w When the pointer is used, it should not be allowed to come to rest, but its equilibrium position should be deduced from the extremes of its small oscillation (See **Damping**)

It is of course presumed in any case that the errors of the weights themselves have been accurately determined Due allowance must also be made in precise weighing, for the buoyancy of the air, or rather for the difference of the buoyant force on the object to be weighed and that on the weights in the opposite pan If the weights are mainly of brass (density 8 4 g /cm^3), the corrected or "vacuum" weight of an object of volume V (cm^3), weighed in air of density ρ (g /cm^3), is

$$W_0 = \left(1 - \frac{\rho}{8\ 4}\right) W + V\rho,$$

where W is the uncorrected result of the weighing Under ordinary laboratory conditions, the value of ρ is approximately 0 00119 g /cm^3, giving 0 99986 as the coefficient of W in the above formula (L D W)

WEIGHT. Gravitation and Gravity; Weighing Methods, Errors

WEIL'S DISEASE (Infectious jaundice, epidemic jaundice) An acute infectious disease occurring in epidemic usually caused by a form of spirochete (*Spirochaeta icterohaemorrhagiae*) There is some evidence that a non-spirochaetal form occurs This spirochaete is present in rats and they may be the primary source of infection

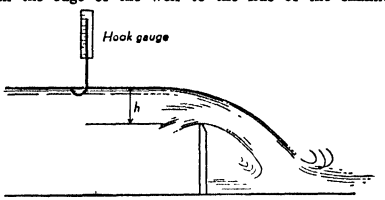
The disease is characterized by a sudden onset of fever, chill, gastrointestinal symptoms, **jaundice,** and enlargement of the **spleen**

Immune serum, vaccination and **bismuth** have been used in the treatment with some success, although the main treatment is symptomatic (R S M)

WEIR. A weir is any **dam** or **bulkhead** over which water flows, or it may be a bulkhead containing a notch through which water flows, the notch at no time becoming completely submerged A weir is usually employed to measure the volume in a flow of water This it accomplishes through the fact that a discharge through a weir bears a certain definite relationship to the **head** of water over its crest, and this head is comparatively easy to measure Uses of a weir, then, are for the precise measurement of a large flow of water, or of one where peculiar conditions eliminate other methods of volume measurement The weir is frequently used for measuring the flow of small streams, and the discharge from all sorts of hydraulic apparatus It also is used for measuring hot water When used with water which is not at atmospheric pressure and temperature, the

general weir formulae do not apply, and the weir must be calibrated by a primary meter

There are many different forms of weirs, such as sharp crested and flat crested, rectangular and V-notch, trapezoidal, broad crested and submerged Also the distance from the crest to the bottom of the channel and from the edge of the weir to the side of the channel



Sharp crested weir

distinguishes a weir If the edge of the channel is also the edge of the weir, it is said to have no end contraction, and this type is recommended, since no corrections for end contraction need be made The crest, however, should be high enough over the bottom that a standard crest contraction exists The figure shows a cross-section through a trapezoidal weir, with sharp edged crest This type is better than the flat crest, as results may be duplicated with greater accuracy The height of water over the crest should be measured at least 2½ crest heads upstream, so that the water surface contraction will not be included in the reading of head The head is measured by a hook gauge, which is a hook submerged in the water and raised until the point just touches the surface To the stem of the hook is attached a scale, so that the head may be read Where it is possible to flood the weir, and then shut off the water supply, the hook gauge can be used to give a zero reading, since the water will stand back of the weir at exactly the crest elevation Where this is not possible, a surveyor's level can be employed to give the elevation of the crest in comparison with some reference point on the hook gauge support

If the flow is highly variable, it is better to use a triangular notch weir than rectangular, because at small discharges the head does not become so minute Both 90° and 60° V-notch weirs are used A trapezoidal shaped notch whose sides slope four on one theoretically gives the discharge without "end contraction" corrections, because the decrease of flow resulting from end contractions is compensated for by the flow through the small triangles on either side of the weir The bottom width is used as crest length in the regular rectangular weir formula This is known as the Cipolletti weir

Weirs having flat or rounded crests can be used to measure discharge of water, and often the overflow section of a dam can be used in this way The discharge is proportional to the length of crest, and to the 3/2 power of the head over the crest, but the factor of proportionality must be established by experiments with models which duplicate hydrodynamically the proposed weir

The most common formula for the discharge of water through a suppressed rectangular weir is the Francis formula

$$Q = 3.33Lh^{3/2}$$

Q is the discharge, cubic feet per second, L is the crest length in feet, and h the crest head in feet Specific weir installations may call for corrections to this formula for end contractions or velocity of approach, or both Furthermore, if the crest is very close to the bottom of the channel of approach, a correction for suppression of crest contraction is used The discharge through V-notch weirs is given by the following formula:

$$Q = Ch^{5/2}$$

Q and h have the meanings given above, and C is a constant depending upon the angle of the notch. It is approximately 2.5 for a 90° notch (F.T.M.)

WELDING. Welding is a method of joining metals by means of fusion Metals having similar composition may be united in one homogeneous piece by fusing together the edges in contact, or by additional molten metal of the proper characteristics deposited where it will form a fused joint with each piece. In any machine or structure there are numerous cases of permanent junctions needed to be made between the component parts Before the advent of welding, these were made by riveting and bolting In a number of instances within comparatively recent years, structures have been built with welded joints at a lower cost than was possible formerly Typical of such practice might be mentioned the welding of joints in pipe lines, eliminating flanges, couplings, and cumbersome fittings Moreover, bridges and buildings of structural steel have been fabricated by arc welding, replacing the older riveted connections Where lightness is as important as strength, welding is especially suitable because of the elimination of the weight of rivets and bolts, and often of the flanges which gave them seat Furthermore, many complicated machine parts, which at one time could be produced only by casting, are now built up from structural steel shapes by welding To the above illustrations may be added the aircraft structures, where, especially in the fuselage tubing, welding has become standard practice Machinery frames and bases, tanks, and steel frames are welded Even high-temperature and pressure vessels, such as boiler drums, are now accepted if welded in conformance with standard procedures

Welding can be practiced on castings, on rolled and forged metals, and on thin gauge sheet metals, although naturally the technique employed varies with the thickness of section being welded Steel, iron, aluminum, duraluminum may be welded. The principal methods for welding are gas welding, arc welding, and resistance welding The first of these is illustrated by the oxy-acetylene or oxyhydrogen welding, and the last two are electrical methods The electrical methods are adaptable to factory production and their use for field research or isolated welding jobs is entirely dependent upon the availability of electric power Portable internal combustion engine generator sets have been developed for field work, such as the welding of a pipe line, but for the most part non-production welding is of the gas type Most of this is of the oxygen-acetylene form, as the oxyhydrogen welding is rather specialized, being used mainly for aluminum welding

The ordinary gas welding outfit consists of a supply of **acetylene** and **oxygen**, a method for regulating and controlling these gases, mixing them, and delivering the proper mixture from a welding tip Oxygen is supplied in the seamless steel cylinders which have become the standard container for this purpose The amount of oxygen contained when the cylinder is freshly charged at a very high pressure (2000 pounds per square inch) is considerable Acetylene gas may similarly be purchased in a heavy steel cylinder, or it may be made in an acetylene generator which generates the gas at low pressure from the reaction between carbide and water These gases pass first through pressure regulators, which can be set for the proper gas pressures to be used on the particular job being undertaken, thence to a blowpipe, whose function is to mix these gases thoroughly and deliver them in a fine-pointed stream at a tip whose shape renders it suitable for directing the flame against the weld Gas welding equipment can be quite dangerous, and safety precautions in the use of the equipment should be strictly observed In use, the operator lights the blow-pipe by opening the oxygen valve slightly, and the acetylene valve more The gas is ignited by passing the tip near an open flame, or with a special igniter, and the flame is then adjusted by

experience to the proper character. By regulating the acetylene flow a reducing, neutralizing, or oxidizing flame may be produced The flame is then brought by the welder to play on the edges to be welded, these having been previously prepared, and brought to the proper relative positions and clamped. The metal, let us say steel, is heated to a temperature such that the metal becomes fluid, or nearly so In some cases the weld metal can come from the parts being welded, as in a lap weld, but there are cases where a rod of welding metal must be introduced into the hot regions so that it will melt and fuse with the two edges which are to be joined by welding Oxides will form at the weld, and in connection with other impurities will produce a **slag** which, if included in the weld, would render it inferior Also, bubbles of gas included in the weld or during solidification will cause a porous, weak weld **Flux**, properly applied in moderate quantities, furnishes a means of eliminating these defects Fluxes are of importance in welding of cast iron, stainless steel, and aluminum alloys, but in the case of steel the slag readily floats to the surface, and does not tend to be included in the weld Gas welding is difficult, to say the least, when thin sections are to be welded, and consequently other methods of welding, such as the shot welding, have been used on thin sheet metal

Electric arc welding utilizes heat generated in an **arc** to melt the metals so that they will unite in fusion In carbon arc welding, one **electrode** of the arc is carbon and the other is the piece being welded Extra metal is supplied by holding a rod of the metal in the arc This system is suitable for building up metal and filling in holes, but the metallic arc method is the type generally employed to join edges As this constitutes the principal application of arc welding, the metallic arc welding system will be described Welding by this method is usually done with low-voltage **direct current** This is produced by a special **generator**, driven by a standard motor Insofar as it is possible to do so, electrical characteristics are incorporated into the generator which will cause it to maintain a stable arc, even though the arc resistance varies due to changing temperature or arc length One terminal of the generator is connected to the part to be welded, the other to an electrode—a metal rod which in melting supplies the metal which is used to fuse the pieces together This electrode is held by a spring clip in a handle which is held and guided by the welder As the welding continues, the electrode is consumed, and must be replaced at regular intervals When this welding equipment is put in use, the generator is started, and an arc is struck between the metal electrode and the work Then the electrode is separated at the proper arcing distance and carried along the seam to be welded Welding skill consists of maintaining this arc of uniform length and carrying it along the seam at exactly the right rate of speed The eyes must be protected from the intense light emitted from the electric arc, and the welder wears or uses a shield having an eyepiece of dark glass, which will filter out the harmful rays Welds may be made on vertical, horizontal, or inclined surfaces, even overhead—a feat that is not readily accomplished with gas welding Protection of the molten metal from oxidation may be had if the arc is surrounded by an atmosphere of inert gas. Coated welding rods are often used to provide such an atmosphere, although they are not always essential to good welding The bead of a weld is cast steel, and consequently the weld itself has a structure which is different from the steel pieces which were welded By subsequent annealing, the weld is improved However, unannealed welds, properly made, have high tensile strength. In both the gas and arc methods of fusion welding, the design of the structure should be made with due regard to the peculiarities of a welded construction. Methods which have been evolved over long years of riveted construction, or production by castings, may need to be not only revamped, but even discarded, and a theory of welded design originated. In particular, the expansion and contraction of the parts as they are heated by the welding must be allowed for, and jigs or clamps designed to hold the parts in correct alignment during welding Special attention must be given to this factor when, in quantity production, interchangeability of units is desired In some cases joints must be reinforced by **gusset plates** In addition to design, a strict procedure control is necessary for duplication of results in welding Much depends upon caliber of the welders, and experience and periodic tests of their product are deemed necessary. The welding rods must be selected with due regard to the work being welded, as must also the welding equipment itself In quantity production it is necessary to organize the welding technique to the point of specifying procedure and of setting up a routine system of tests of the welds

Although **riveting** is still considered to be most reliable for highly stressed thin sheets, especially those to be found in a primary structure, methods have been developed for welding sheets too thin to be treated by fusion These methods are known variously as spot welding, shot welding, etc. They all come under the general head of resistance welding, the basic principle of which is that if two thin sheets are placed together between the points of a pair of electrodes, the resistance between the contact surfaces will be great enough to cause the metal to fuse in a spot directly under the electrodes By manipulation of electrode pressure, voltage, and length of time of the power applications, the welder may adjust his equipment to obtain the best results, that is, a positive junction without burning or undercutting of the sheets If the process is not carefully manipulated, the welds may be weak, or only partially formed, they may be porous, or the sheet may be fused to the electrode This method of welding requires a machine to time the power impulses and adjust the electrodes A seam consists of a row of spot welds placed about one-half inch apart, and the process is, of course, applicable to a lap-welded joint A spot welder may be made automatic to the point that the lap may be fed into it, and the welder automatically adjusts its rate of travel along the same, so that as the parts emerge from the welder, the row of spot welds is completed This is a very inexpensive way of joining parts, but it is not as yet accepted for union of primary structural members, and of those subjected to vibration or shock

Despite the manifold advantages of welding, the reliability and durability of riveted joints and the loss of ductility in unannealed welded joints have tended to equalize these two methods in the minds of designers Much riveting and casting still goes on, even though emphasis is laid today on the properties of welded construction, and even though an ever-increasing amount of equipment is being produced by this modern method (F T.M)

WELS. Pisces, Teleostei A **catfish**, *Siluris glanis*, found in European rivers east of the Rhine It is a large fish, attaining commonly a length of six feet, and a maximum of twice that figure (A W L)

WELSBACH MANTLE. This is a gauze made out of **thorium** and **cerium** oxides which is used for gas mantles The heat derived in the combustion of the gas is converted by this mantle into light energy (R K S)

WENTLETRAP. Mollusca, Gasteropoda A marine **mollusk** with a white shell of elongated conical form, with many convex whorls bearing prominent ribs Also called spiral staircases. The two hundred species are widely distributed (A W L.)

WERNERITE. The mineral wernerite is a **silicate** of **calcium** and **aluminum** which contains also some **soda** and **chlorine.** In can be considered as an **isomorphous**

mixture of two molecules corresponding to the following compositions

$CaCO_3 \cdot 3CaAl_2Si_2O_8$, called meionite, and
$NaCl \cdot 3NaAlSi_3O_8$, called marialite

Its **tetragonal** crystals are coarse and thick, often very large It occurs also in massive forms It has a distinct prismatic **cleavage;** subconchoidal fracture, is brittle; hardness, 5–6, specific gravity 2 66–2 73, luster, vitreous to rather dull, color, white to gray, red, green, or blue, translucent to nearly opaque Wernerite is found in the **metamorphic rocks**, particularly those rich in calcium; also in contact metamorphic deposits in limestones It has been found in **basic** igneous rocks, probably as a secondary mineral Notable localities are Lake Baikal, Siberia, Arendal, Norway, and Madagascar In the United States it is found in Massachusetts, New York, and New Jersey Grenville, in the Province of Quebec, Canada, is an important locality Wernerite is named in honor of A G Werner, a famous German mineralogist (1749–1817) (E S C S)

WESTON CELL. Standard Cell.

WET-AND-DRY-BULB THERMOMETER. Hygrometers.

WHALE Mammalia, Odontoceti and Mystacoceti A marine animal of completely aquatic habits The whales vary to a considerable degree in structure, as is indicated by their classification in two orders Whales 20 feet long are among the smaller species Individuals 60 to 80 or 90 feet long have been recorded among several of the large kinds

The whalebone whales (**Mystacoceti**) live on small marine animals which are separated from the water by the sievelike whalebone fringes of the jaws The toothed whales (**Odontoceti**) include some actively predacious species Species of both orders were once widely sought for their oil and whalebone, but the latter has long been supplanted by manufactured products and the oil has given way for many uses to petroleum oils Sperm oil is still valued as a fine lubricant and sperm whales are killed also for a waxy material, spermaceti, used in the manufacture of cosmetics The peculiar substance call ambergris is formed in the intestine of the whale and is used to make the odor of **perfumes** more persistent

Whales are specialized for life in the ocean by the formation of the pectoral appendages into paddlelike flippers and by the complete loss of hind limbs The tail is expanded horizontally into a pair of broad lobes, the flukes, which serve as a powerful swimming organ The **respiratory system** is also highly specialized The lung capacity is great and the nostrils are located high on the head, so that very little of the animal need be exposed to enable it to breathe In some species they are combined to form a single opening The whales are without hair, which would be useless to animals living always in the water, but they have a thick layer of fat, the blubber, as an insulation against the cold of the surrounding water Much of the oil secured from their bodies is from the blubber, but the sperm whale also has an enormous cavity in the head filled with oil

The various kinds of whales are briefly mentioned under the two orders (A W L)

WHEAT. *Triticum sativum* and other species Gramineae Wheat is an annual plant producing the most valuable of cereal grains used by the white race The plants grow either as summer annuals, seed being planted in the spring and the harvest gathered in the fall of the same year, or winter annuals, the seed then being planted in the fall and growing until stopped by cold weather, developing during that time an abundant root system which insures rapid growth in the springtime, the mature crop being ready for harvest in early summer

When wheat seeds germinate a small primary root system is formed by the development of the hypocotyl or seed root This primary root system lasts but a short time, being soon replaced by a system of **adventitious roots** arising from the lowermost nodes of the stem and extending outward and downward to fill the soil with an extensive fibrous root system The stem of the wheat plant is from two to four feet tall and usually hollow, although some species have solid stems. The dried stems form wheat straw, frequently used in the manufacture of straw board The leaves are of the ordinary grass type The **inflorescence** is composed of very short-stemmed **spikelets** attached alternately on opposite sides of a zigzag axis Each spikelet has from two to eight flowers In certain varieties known as bearded wheats the **lemma** of the flower bears a long bristle or **awn** Most species of wheat, particularly those grown in temperate climates, are close-pollinated Durum wheat and primitive species are cross-pollinated Evidence indicates, also, that wheats grown in hot dry climates are cross-pollinated The fruit or grain of cultivated wheat varies somewhat according to the species In many kinds of wheat the fruit separates readily from the surrounding floral **bracts**, while in a few kinds the lemma and **palea** tightly enwrap the grain The grain bears at its apex a tuft of short hairs called the brush, a distinct groove along the side which was against the palea, and an **embryo** situated in the basal part of the grain In section, a wheat grain shows several very distinct layers Externally there is a layer several cells thick called the **pericarp**, or **ovary** wall Within this is a layer two cells thick, the testa, which is formed from the inner integument The outer integument was absorbed during the development of the grain Next is the **nucellus**, a single cell in thickness These three layers constitute some 8% of the grain, and make up the substance which is called bran Within these is the **endosperm**, which forms the bulk of the grain, the outermost layer of cells of the endosperm is the aleurone layer In the basal portion of the endosperm is the so-called germ, or embryo, from which the new plant may grow

There are several ways of classifying wheats Botanically they are separated according to the structure of the spikelet, the number of **florets** and the nature of the parts of the flower Among the kinds of wheat recognized in this classification are einkorn, spelt, emmer, durum, and common wheat Again, if the palea and lemma adhere to the grain, the wheat is classified as spelt wheat, while if the grain readily separates from these two parts it is naked wheat If one turns to the grain itself there are hard wheats, in which the grain is horny and has a high **protein** content, and soft wheats with starchy grains The nature of the soil in which the wheat is grown and the climate have considerable effect on the nature of the grain Hard wheats are separated into hard spring wheat, hard winter wheat, and durum, the latter being especially rich in protein content

While a considerable quantity of wheat is used directly as food for domestic animals, the greater part is ground into flour This milling of wheat is a very carefully controlled process The first step is the thorough cleaning of the grain, removing therefrom any other substance During this process the brush of the grain is removed The cleaned grain is then moistened slightly in order to soften the outer layers so that they may be more easily removed subsequently The moistened grain is then passed between iron rollers The first of these are corrugated and break up the grains. Each successive pair of rollers grind the grain into finer and finer particles. Early in this grinding the coarse flakes of bran are removed, and disposed of as such or ground up separately The ground grain is passed through fine bolting silks which insure a very even grade of fineness of the flour particles Every precaution is taken in flour mills to prevent the accumulation of dust particles in the atmosphere, since these may form very dangerous explosive mixtures

Flour is classified according to the amount of the grain included in the final product, into Graham flour, which contains the entire grain; whole wheat flour, which contains all the grain except about half of the bran; and straight bread flour, which results when all the bran is removed early in the grinding process. Wheat flour is used extensively in making breads, crackers, and pastries. Because it is so highly glutinous that pastes made from it will support their own weight, durum wheat is used in making macaroni. In making this product a thick viscous paste or dough is prepared. This is forced, under great pressure, through holes in metal dies. Metal pins may project into the hole in the die, causing the dough which is forced through to emerge as a hollow tube. As they emerge, the tubes or strings are cut into suitable lengths and hung up to dry. Durum wheat alone has the necessary properties for making macaroni and similar substances. If any other wheat were used the product would break apart from its own weight. In addition to flour and macaroni, much wheat is used in making breakfast foods. The familiar puffed wheat results from heating wheat grains under pressure and suddenly releasing the pressure; the grain expands rapidly. Some wheat is used for making whiskey and certain varieties of beer. (R.M.W.)

WHEATEAR. Aves, Passeriformes. A bird (**Aves**), *Oenanthe oenanthe*, related to the thrushes and bluebirds. It nests in the northern part of Europe and in Alaska, and is widely distributed in the Old World and occasionally in the United States during its southern migrations. (A.W.L.)

WHEAT MIDGE. Insecta, Diptera. A minute **fly** whose **larva** develops in the growing kernel of wheat. Introduced from Europe into Canada early in the nineteenth century, the species was troublesome in New York about the middle of the century but has not been serious since. Cultural methods are an adequate protection. They include crop rotation, fall plowing to bury and destroy the larvae, and the destruction of all debris from infested fields. (A.W.L.)

WHEATSTONE BRIDGE. One of the simplest and best-known **bridge** networks for measuring electrical **resistances**. Referring to Figure 1, let R_1 be the unknown

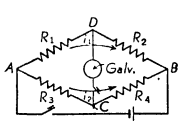


Figure 1.

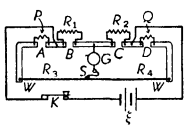


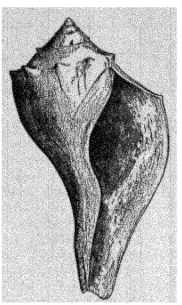
Figure 2.

Sketches of simple and four-gap Wheatstone bridge circuits.

resistance and R_2 a known resistance, preferably not very different from R_1, in terms of which R_1 is to be measured. R_3 and R_4, called the ratio arms, are two other resistances which may be varied continuously or by very small stages and the values of which are known, either in ohms or relatively to each other. From C to D is the bridge proper, containing a **galvanometer**. To measure R_1, the resistances R_3 and R_4 are adjusted until the galvanometer shows no current, which means that C and D are at the same potential. It then readily follows from the **law of potential drop** that $R_1 : R_2 = R_3 : R_4$, and hence $R_1 = R_2R_3/R_4$. Figure 2 shows a "slide-wire" form having a graduated resistance wire and four gaps. The **Carey-Foster bridge** is a special type of Wheatstone bridge. (L.D.W.)

WHEEL-AND-AXLE. Machines.

WHELK. Mollusca, Gasteropoda. A moderately large marine **mollusk** with a spirally coiled shell. It is used as a bait in the cod fisheries and in Europe is eaten. (A.W.L.)



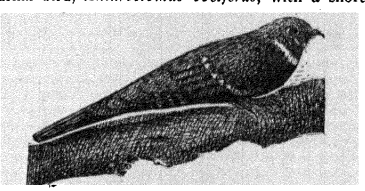
Fulgur, the whelk. (From U.S.B.F. Report, 1897.)

WHIMBREL. Aves, Charadriiformes. Northern shore birds (**Aves**) with long legs and a long curved beak. Related to the curlews and plovers. The name is European; the species that occur in North America are called here the Eskimo (*Phaeopus borealis*) and Hudsonian (*P. hudsonicus*) curlews. (A.W.L.)

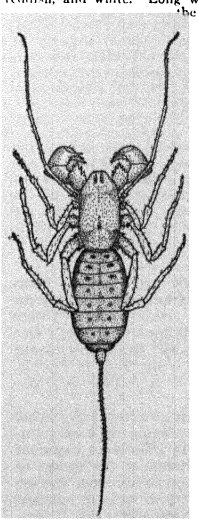
WHINCHAT. Aves, Passeriformes. A small European bird (**Aves**) related to the bluebirds and thrushes. It nests in the far north and winters in Africa. (A.W.L.)

WHINSTONE. A popular British term for **basic**, fine-grained **igneous rocks** belonging to the basaltic group and including **diabase**, **dolorite**, **spidiorite**, also **greenstone** and the **lamprophyres**. Synonym for **trap** or trap rock. (R.M.F.)

WHIPPOORWILL. Aves, Caprimulgiformes. A nocturnal bird, *Anthrostomus vociferus*, with a short beak



Whippoorwill, *Antrostomus vociferous*. Mottled grayish, reddish, and white. Long wings, conspicuous bristles around the mouth.



Whip scorpion.

and wide mouth, adapted for taking insects in flight. Its call has been likened to the words used in its name. Often the three syllables are repeated over and over scores of times without cessation. One of the **nightjars**. (A.W.L.)

WHIP SCORPION. Arachnida, Pedipalpi. A large **arthropod** whose abdomen bears a whiplike posterior portion, although some species of the same order lack this terminal filament. The **pedipalps** are large and strong, either chelate or simple. The first pair of legs are modified as slender many-jointed sensory appendages. They are tropical animals, only a few species entering the southern part of the United States.

In the southwest many fears and superstitions are associated with these unpleasant looking animals, which are called vinegarones (also spelled vinegar roan and vinegaroon). They discharge a dis-

agreeable, sour-smelling solution, but are entirely harmless to man (A W L)

WHISTLER. Mammalia, Rodentia An animal related to the woodchuck A **marmot.** Its range extends from Alaska to Montana and Washington. (A.W L)

WHITE ANT. Isoptera.

WHITE DWARFS. In the article on **giant and dwarf stars** it was shown that more than 99% of the observed stars may be classified either as super giants, giants, or main sequence stars A few stars do not fit into this general scheme at all and form a unique and little understood class known as the white dwarfs. The first star of this class to be discovered was the companion star to **Sirius** The **orbit** of the pair has been computed, and from it the mass of the companion was computed and found to be about the same as that of the sun Its **absolute magnitude** was known and the **luminosity** found to be about 1/360 that of the sun. On the ordinary giant and dwarf hypothesis such a star should be in the dwarf M-type **spectral class** having low brightness per unit area However, when its spectral class was finally determined it was found to be of class F and hence hotter than the sun and brighter per unit area From the brightness per unit area and the intrinsic brightness, the diameter can be computed, and it is found to be about 30,000 miles, or of planetary dimensions This means that we have an object of stellar mass and planetary dimensions, and an unbelievably great density, of the order of magnitude of 30,000 times the density of water At such a density a cubic foot of this stellar material would weigh 935 tons

This star is one of the general class known as white dwarfs, all with spectral classes between A and F The total number of such stars is not known, for they are all apparently very faint and cannot be detected as white dwarfs except by spectrographic analysis, which is difficult for faint objects Furthermore, their intrinsic brightness is so small that only the closer ones would be observed at all (the few known at present are all within 15 **light years** of the sun)

The problem of the internal constitution of objects of such great density is as yet far from completely solved The best hypothesis is that the material consists of atomic nuclei stripped of all external **electrons** and tightly packed together by gravitational compression Such matter would be in a state much like a single huge molecule, or crystal (W.K G)

WHITEFISH. Pisces, Teleostei A lake fish of the **salmon** family, genus *Coregonus* The several species are excellent food fishes and the common whitefish of the Great Lakes is among the most important in the inland fisheries of the United States Several species are known by various distinctive names, among them pilot-fish, whiting, cisco, bluefin, and tullibee (A W.L)

WHITE FLY. Insecta, Homoptera A minute sucking insect related to the phylloxerans and scale insects. The adult has four wings and is mealy white In spite of their small size these insects are important pests One species, *Asterochiton packardi,* attacks strawberry plants, one, *Dialeurodes citri,* is a pest of citrus fruits in Florida, and two attack both flowers and vegetables in greenhouses.

Cyanide fumigation is recommended for the control of the greenhouse species, while spraying with oil emulsions is effective against others. In Florida an ingenious method of spraying with an infusion of the spores of fungi has been devised. Three species of fungi live on the immature insects and destroy them in large numbers when the colonies are once inoculated (A W L)

WHITE LIGHT. Color.

WHITENOSE. Pisces, Teleostei. A common fish (Pisces), *Moxostoma anisurum,* of the Great Lakes and Ohio River basins, related to the redhorse It reaches a length of seventeen inches and is a good but not an important food fish. (A.W.L.)

WHITETHROAT. Aves, Passeriformes. A European **warbler.** The common species, *Sylvia cinerea,* is gray-brown above and whitish below, and the lesser whitethroat, *S curruca,* is gray above with dark brown ear coverts and tinged with pinkish on the breast (A.W.L)

WHITE WHALE. Mammalia, Odontoceti. A small species related to the **narwhal.** The **beluga** (A W.L.)

WHITING. Pisces, Teleostei 1 Marine fishes (*Menticirrhus*) of the **drum** family. One occurs on the Atlantic coast from Maryland to Brazil and another, called the silver or surf whiting, is found from Virginia to Texas 2 A member of the **cod** family found on the Atlantic coast of North America Also called the silver **hake** and stock-fish (A W L)

WHOOPING COUGH. (Pertussis) An acute contagious disease of childhood, caused by a small bacillus, first identified by Bordet and Gengou in 1906 Nearly 50% of the cases occur during the first two years of life, and most of the mortality occurs during this time During the first year of life the mortality rate is at least 25%

The incubation period of whooping cough is from five to fifteen days

The symptoms of the first week are mild and are those of a **bronchitis** Diagnosis during this stage is difficult unless there is a history of exposure Instead of subsiding, however, the coughing becomes more frequent, occurring in paroxysms, terminating in the characteristic whoop Several exhausting paroxysms may occur together until a small amount of mucus is coughed up, giving immediate relief Vomiting may occur after these paroxysms This stage of the disease averages between three and six weeks, while the intensity and severity of attacks slowly diminish The serious complication and that responsible for most of the mortality is broncho-pneumonia Hemorrhage may occur from the congestion of the paroxysms of coughing and most frequently occurs from the nose, although it may also occur in the lungs, ears, or in the brain Convulsions occurring in this disease probably result from the congestion of the brain brought on by coughing Middle ear infection is common and tuberculosis follows whooping cough not infrequently The disease is most contagious soon after its onset

During the past few years prophylactic results against this disease have been obtained by use of the Sauer vaccine This is best given during the first year of life, and should be given as a routine to all infants in view of the mortality and complications of whooping cough

Treatment is difficult and consists in treatment of the cough and keeping up the nutrition, which is interfered with by the frequent vomiting after the paroxysms of cough. **Oxygen** has been used to advantage in severe cases (R S M)

WHYDAH BIRD. Aves, Passeriformes A brilliantly colored and long-tailed **weaver bird** of Africa The several species constitute the genus *Vidua.* (A W.L)

WIDGEON, WIGEON. Aves, Anseriformes. A **duck** with a relatively small beak, widest at the base. The European species is occasionally taken in the United States, in addition to a native species called the baldpate and sometimes the American widgeon. A third species occurs in South America. All belong to the genus *Mareca.* (A W.L)

WIEDEMANN-FRANZ LAW. The most casual observation reveals that at ordinary temperatures the metals which are the best electrical conductors are also the

best conductors of heat. (See **Thermal Conduction**) In fact, if we calculate the ratio of the thermal conductivity (in calories per centimeter per second per degree) to the electrical conductivity (in reciprocal ohms-centimeters) for a number of metals at 0° C, we get results like the following copper, 0 00000156, platinum, 0 00000143, lead, 0 00000169, etc., all in calorie-ohms per degree per second The ratio appears to be nearly constant

The Wiedemann-Franz law states that the ratio of the thermal to the electrical conductivity for all metals is proportional to the absolute temperature T, and in the above units equal to $5\,345 \times 10^{-9}$ T For 0° C (273° absolute) this gives 0 00000146 calorie-ohm per second per degree, which is very close to the observed value for platinum The Wiedemann-Franz formula is theoretical and its coefficient involves both the **Boltzmann constant** and the electronic charge For most metals the ratio as observed is a little higher than that given by the formula, doubtless because of thermal conduction due to other causes than electronic activity (L D W)

WIEN'S LAWS. From a study of the **spectral energy distribution of thermal radiation**, W Wien, in 1896, arrived at three laws relating to the radiation from a **black body**

(1) The wave length λ_m of the spectral distribution, for which the radiation has greatest intensity, is inversely proportional to the absolute temperature of the black body:

$$\lambda_m T = c_1$$

Thus as the temperature rises, the "peak" of the distribution curve is displaced or shifted toward the short-wave-length end of the spectrum This is commonly called Wien's "displacement law" The value of the "displacement constant" c_1 is about 0 2884 centimeter-degree

(2) The emissive power of the black body within the maximum-intensity wave-length interval $d\lambda$ is proportional to the fifth power of the absolute temperature

$$dE_m = c_2 T^5 d\lambda.$$

Subsequent work by Planck and others gives the value of the constant c_2 as about $1\,302 \times 10^{-4}$ erg/cm^3 sec deg^5

(3) Wien's third law is an attempt to express the spectral energy distribution of the radiation from the black body at temperature T, as follows.

$$dE_\lambda = A\lambda^{-5} e^{-B/\lambda T} d\lambda,$$

in which $dE\lambda$ is the emissive power within the wave-length interval $d\lambda$ and A and B are constants to be empirically determined

The first and second laws are in accord with thermodynamic theory and with **Planck's equation**, and also agree very accurately with experiment The third law is empirical, but is almost identical in form with **Planck's equation** and agrees with it closely except for short wave lengths (L D W.)

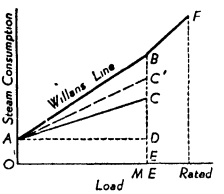
WILDCAT. Mammalia, Carnivora *Lynx* Any of five species of **cats** found in North America, related to the Canada lynx but of slightly smaller size One species, also called the bobcat, is found in forested regions throughout the United States and southern Canada, and extends into Mexico It is now confined to wilder areas (A W L)

WILDEBEEST. Gnu.

WILD RICE. Rice.

WILLANS LINE. A characteristic curve for the **steam turbine** is that of steam consumption per kilowatt-hour versus load in kilowatts From this curve the Willans line, conveying information of great value, can be plotted. The Willans line shows total steam consumption at each load In conjunction with the load curve it can be used to find total **steam** required per day or any other period of time The steam-rate curve for all turbines will exhibit a node corresponding to the most efficient load This point will be observed on the Willans line as a break on the nearly straight slopes on each side of it This is the load point at which the first overload valve opens. The slope of the Willans line is a result of the combined effect of the various losses in the steam turbine

For the sake of comparison with the ideal turbine, the Willans line of an ideal turbine is shown in line *OC* in the figure The line *OC'*, parallel to *AB*, would be the Willans line of a turbine having stage efficiencies less than those of the ideal turbine (100%) but, at the same time, having no no-load losses The **steam rate** of such a turbine would be constant at all loads up to the most economical The line *AB* represents the steam consumption of an actual turbine under specified operating conditions Practically all steam consumption curves are straight lines between the no-load and most economical load points Above the most economical load performance varies In general computers assume that the steam rate at full rated load is 5% greater than at the most economical load, when the latter is about 80% of the rated load The end point of the Willans line, *F*, is usually joined to *B* by a straight line unless the overload characteristics of the particular turbine are known (F T M)



Willans line

WILLEMITE. The mineral willemite is an **orthosilicate** of zinc, Zn_2SiO_4, occurring in **hexagonal** prisms, as masses or scattered grain It has a good basal **cleavage**, conchoidal fracture, is brittle, hardness, 5 5, specific gravity, 3 9–4 2, subvitreous luster, usually some shade of yellow, yellowish green, green, or reddish brown, but may be colorless, white, or blue to nearly black, transparent to opaque Much willemite is strongly fluorescent in yellow or yellowish green hues Willemite occurs associated with other zinc materials in Belgium, Algeria, the French Congo, South West Africa, and Greenland In the United States, except for three occurrences, one in Colorado, one in New Mexico, and one in Utah, Sussex County, New Jersey, is the only locality in this country for willemite and is the only one in which that mineral is found in quantity Here it is found associated with **zincite** and **franklinite**, forming an important ore of zinc It was named by the French mineralogist, Michel Lévy, in honor of King William the First of the Netherlands (E S C S)

WILLET. Aves, Charadriiformes A North American wading bird, *Catoptrophorus semipalmatus*, long legged and with a long straight beak They are mottled grayish above and white below Closely related to the sandpipers. (A W L)

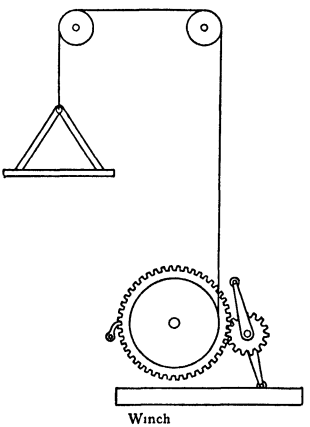
WILSON CHAMBER. Cloud Track.

WILSON EXPERIMENT. The theory of the **electromagnetic field** in dielectrics requires that if a dielectric move across a magnetic field, an electric polarization should take place at right angles to the field and to the motion, just as in a conductor, likewise moved, electric induction is set up. The question was tested by H. A Wilson in an experiment which has become classic A hollow cylinder of dielectric material, coated on its inner and outer cylindrical surfaces with metal, was rotated about its axis in a magnetic field whose lines of force were parallel to the axis The metal coatings were connected to a sensitive electrometer, which registered a charge, reversing with the reversal of the field, and hav-

ing both the sign and the magnitude required by the theory (L D W)

WIMSHURST MACHINE. Static Machines.

WINCH. A mechanism arranged to hoist by manual or mechanical power through the medium of a rope, cable, etc, winding on a drum is a winch The winch is provided with means for stepping up the torque obtainable and a brake for lowering the load However, the brake is sometimes omitted in the simplest winches The setup of a winch used for hoisting is shown in the accompanying figure The hoisting rope passes up and



Winch

over two sheaves, so that a load may be hoisted from a position adjacent to the winch The hand power is applied at a crank or cranks, which are attached to a shaft bearing a pinion gear This pinion engages with a large gear attached to the winding drum On the winding drum there is a brake, generally of the band type, which is brought into play when a load is to be lowered A high-capacity winch may have a double reduction gear, instead of the single gear illustrated Winches are necessarily slow moving, and they are not ordinarily economical for other than intermittent hoisting jobs. (F T M)

WIND GAP. Gap.

WINDHOVER. Falcon.

WINDOW PANE. Turbot.

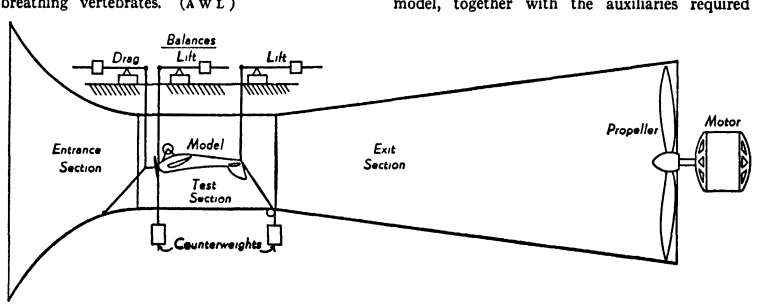
WINDPIPE. The trachea, in the respiratory system of air-breathing vertebrates. (A W L)

WINDS. Since only slight horizontal variations in the density of the air can occur ordinarily, and the total volume of the atmosphere is substantially constant, it is evident that a wind is necessarily a circulation, that is, any movement of the air in one direction must be offset by a return current elsewhere. All such movements are the result of thermal convection due to the heat of the sun

The winds may be roughly classified into three types (1) Winds which are in a sense permanent, including the easterly trade winds of the tropics and the westerly winds prevailing in the temperate zones (2) Seasonal winds, such as the monsoons of the Indian ocean, which blow northward toward the warm Asiatic continent in summer, bringing heavy rainfall to India, and which pour southward over the Himalayas from the cold plateaus in winter (To such may be added the diurnal land and sea breezes, which have similar origin but on a much smaller scale) (3) Local winds and storms, which temporarily interrupt the more general air movements prevailing at the time Among these are the great cyclones and anticyclones characteristic of North American climate, ocean cyclones (including hurricanes or typhoons), thunderstorms, tornadoes, waterspouts or ocean tornadoes, and the very cold mistrals, chinooks, and blizzards These local winds are all of the vortex type The cyclone, for example, is generated over a large, heated land area, where the air is warmed to lower than average density Air accordingly moves inward along the ground, rises in the central region, and returns outward at high altitudes, the movement being given at the same time a rotary character because of the deflection of the air masses by the rotation of the earth (producing a counterclockwise whirl in the northern hemisphere, clockwise in the southern) The cyclones of the United States are carried in a northeasterly direction by the prevailing north-temperate westerlies, so that weather conditions experienced, say, in Iowa one day may be looked for in Wisconsin the next The same is true of the anticyclones formed over cold areas, but with high pressure and with the direction of the local air currents reversed Hurricanes, tornadoes, waterspouts, etc, are similarly formed but in varying circumstances and on different scales

The winds are practically all confined to a very few miles vertically above the earth's surface Above this lies the stratosphere, believed to be a region of almost perpetual calm (See **Atmosphere**) Air currents at high altitudes are commonly studied by means of small pilot balloons, released for the purpose and watched through telescopes (L D W)

WIND TUNNEL Aerodynamic data upon which are founded the rational design of heavier-than-air craft, are obtained in large measure from tests made by blowing air past a stationary model which is supported so that the air forces acting on it may be measured The conduit which contains and directs the air across the model, together with the auxiliaries required for its



Simple wind tunnel

operation, is known as a wind tunnel. The auxiliaries mentioned are a **blower** or **propeller**, a return duct, a honeycomb, and corner vanes Besides heavier-than-air research, the wind tunnel is used to obtain data on **airship** hulls, automobile shapes, and other cases where air reactions are important Theoretically, the reaction of air upon any shape or object is the same, whether the object be moving through still air, or whether the object is at rest, and the air moving past it Actually, however, there are some differences, arising largely from the fact that the air in a wind tunnel has a certain degree of **turbulence** not present in a calm atmosphere Furthermore, model tests may not be applied directly to full scale designs without certain corrections. Chief among these is the scale correction The relative size of a molecule of air and a wind tunnel model is much different than the relative size of a molecule of air and the actual airplane The fact that molecular density against the airfoil is not in proportion in the model introduces the scale effect If a model test were to yield lift and drag coefficients which could be used directly in airplane design, the scale effect would have to be absent Scale is usually measured by **Reynolds number.** This criterion shows that either the velocity in the wind tunnel must be vastly increased, or the model must be as large as the actual airplane, in order to get the same scale If the model is one-tenth actual size, the velocity would have to be ten times actual flying velocity As this is impracticable, models have been tested at lower scales than **airplanes** operate, and corrections for scale have had to be applied Considerable knowledge as to the magnitude of scale effect, and means for correcting it, have been devised from tests in a variable density wind tunnel This special type is arranged so that compressed air having pressure of several atmospheres, and a corresponding high density, can be blown over the model The advantage here is that by increasing the density of air sufficiently, a small model may be tested at reasonable tunnel velocities, and yet have the Reynolds number of a magnitude comparable to that of a full sized airplane Besides scale and turbulence, corrections must be made for shape of the wind tunnel walls, tunnel wall interference, and aspect ratio.

The wind tunnel is used to measure the drag of all sorts of objects, particularly components of aircraft, and to measure the drag and lift forces of complete model aircraft It is also employed to test for stability and balance of the same The principal classifications of tunnels are once-through and return-circuit types Another classification is open or closed test section The air is usually blown by a propeller driven by a variable speed electric motor The models most frequently tested are those having a wing span varying from two to three feet This means that the tunnel must have a thirty- to fifty-inch width at the test section However, tunnels are built in a variety of sizes, ranging anywhere from six inches to sixty feet at the throat

Ordinarily, a tunnel has a nozzle to give something like constant acceleration to the air, and direct it into the test section, which is a constant area section in which the models are mounted Passing the test section, the tunnel is slowly enlarged in order to recover the pressure head In a once-through tunnel, the propeller is mounted at the end of the diverging section In a return-circuit tunnel it may be mounted there or in the return circuit. The materials from which tunnels have been constructed are wood, plaster, concrete, and steel The sections employed have been circular, octagonal, hexagonal, square, and rectangular The models are supported from a balance, which can be of a suspension wire type (Goettingen), or a rigid post-like support (National Physical Laboratory) In either case the purpose of the balance is to maintain the model in a predetermined attitude with respect to the wind stream, and quantitatively measure the air forces which arise therefrom (F T M)

WING. For the use of this term in aeronautics, see **Airfoil.** In zoology, a wing is a broad thin appendage used to support the animal in the air, either through its resistance to air currents or by muscular movement against the air. The support may be accompanied by the progress called **flight** or may sustain the animal in one spot The latter action is called hovering

Wings and flight have been developed in only four groups of animals the extinct pterosaurs, a group of **reptiles**, the **insects**, the **birds**, and the **bats**, an order of mammals Other animals progress through the air to a limited extent, but they merely coast, supported by extended surfaces of various kinds, this form of locomotion is known as gliding and is considered with flight

Only the insects have developed wings independent of their other appendages In this class there are two pairs at the maximum, attached dorsolaterally to the second and third segments of the thorax They are developed as sacklike outgrowths of the body wall whose upper and lower walls become closely apposed and relatively very thin to form a light membrane Some rigidity is conferred by the cuticula of the wing membrane and additional support is provided by thick-walled tubes called veins or nervures running through the structure The principal veins follow the courses of tracheae which are functional during the developmental stages, but others of a supplementary nature may be present The number and arrangement of the veins have been of the greatest importance in the classification of the insects

Insect wings are modified in some orders beyond the changes of shape, venation, texture, and vestiture which do not interfere with their use in flight Examples are the **elytra** of beetles, the **tegmina** of grasshoppers, and the **halteres** of flies

The wings of bats are thin folds of skin extending between elongated digits of the front legs, along the sides of the body to the hind legs, and in some species thence to the tail They are admirably adapted to flight but they have the one great weakness of presenting a greatly extended surface from which the radiation of heat may take place, hence the activities of bats are limited to warmer climates and warmer seasons of temperate regions The **pterodactyls** had similar wings, but the problem of radiation was not the same to them since they were presumably cold-blooded.

The wings of birds, like those of bats and pterodactyls, are supported by the skeleton of the pectoral appendages In this group, however, they are no more than modified pectoral appendages The extended surface of the bird's wing is made up of large stiff feathers and the supporting skeleton is reduced in size and complexity The resulting advantage in the lightness of the wings and in their presenting no radiating surface greatly extends the radius of activity of birds No climate is too cold for them, and no season too severe They are among the most widely distributed of all living things

The wings of bats retain short clawed appendages on the anterior margin, but those of birds are wholly transformed into organs of flight except in the young **hoatzin**, which uses similar clawed digits in climbing The only other noteworthy modification of birds' wings is found in the **penguins**, where they are small paddles with greatly reduced feathers, useless for flight but effectively developed for swimming Reduction to a vestigial state has also occurred in various flightless species, such as the **ostrich** and the **kiwis** (A W L)

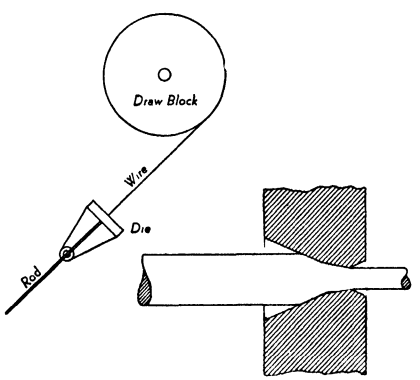
WING WALL. Abutment.

WINTER EGG. A form of egg produced by some invertebrates, usually in the fall It has a thick protective shell and in species with a complex life cycle, such as the **aphids,** it is produced by the sexual generation Such eggs usually pass through the winter before hatching, but similar eggs may be produced at the beginning of other unfavorable seasons, as periods of drought. (A W L)

WINTERGREEN. Heath Family.

WIRE. A wire is defined as a slender rod or filament of drawn metal If covered with electrical **insulation,** it is called insulated wire There are manifold uses of wire in the present day and time Among the more important uses are fencing, woven and barbed type; binding of extra strong nature for heavy packages, spring stock, ropes and hawsers, electrical **conductors** or resistors, and stock for forming various small light-weight parts, such as mouse traps, egg beaters, triggers, latches, etc The materials from which wires are drawn are wrought iron, steel, annealed copper, aluminum, and phosphor bronze Wires are sized by the areas in circular mills or American wire gage See **Gage.** Despite the arguments in favor of one system using the diameters in mills as the size numbers, the American wire gage is commonly used in gage numbers from 40 to 0000 Descending gage numbers indicate increasing wire sizes Electrical conductor is usually annealed copper wire, although aluminum has been used for transmission lines, and iron for resistance wires Most low voltage electrical conductors are insulated Rubber compound and varnished cambric are the principal materials for insulating wires The standardizing agency in the field of electric wiring is the National Electric Code (F T M)

WIRE DRAWING. The term "wire drawing" has two separate and distinct meanings First, it is descriptive of the action whereby a rod is reduced to a wire by being pulled forcibly through a round die which reduces



Wire drawing

its diameter and increases its length (See figure) Secondly, wire drawing refers to a similar action occurring in fluid flow through a small aperture The usage in the second case is derived from the first Wire drawing as applied to a **fluid** is usually employed in discussions of the flow of **steam** or **gas** through the **valves** of engines When the valves are partially open, the small area through which a fluid flows causes a reduction of pressure which is known as wire drawing The description below refers entirely to the production of wires

To make a wire, the metal is first prepared as a rod by rolling It is then treated to give it a surface coating which will act as a lubricant during its passage through the die The method of applying the lubricant gives rise to the wet and dry process of wire drawing In the dry process the wire is dipped in an emulsion of hydrated lime (See **Calcium**), and dried in baking ovens Then just before it is passed into the die it passes through a greasing operation The combination of lime film and grease provides the lubricant between the rod and the die during the drawing process In the wet process the rod is first dipped in a solution of copper sulfate, which results in a thin coating of copper in the wire It is then dipped in a vat containing a fermented mixture made from meal and yeast Upon being withdrawn from this vat, it is fed wet to the die The liquor, together with the thin copper deposited in the salt bath, lubricates the rod in the wet drawing process

Drawing consists of pointing the rod and threading it through the die It is then gripped by pinchers and drawn a short distance by hand power applied through a draw bar Then the end is clamped in a vise on a revolving drum called the drawblock This drum is revolved slowly by power applied through a geared shaft, and in so revolving continues to pull the wire through the die until the rod has been completely reduced When the stock is passed through the die it is elongated and reduced in cross-section The elongation is known as draft, and may amount to from 10 to 40 times the length of the original rod Sometimes more than one draft is necessary to finish the wire In such cases it is removed from the block and started through another smaller die

The dies are the most essential part of wire drawing They are made of chilled cast iron, steel, or diamond, the latter used only for fine wire A typical cross-section of a die is shown in the figure The hole through the die is tapered, and the part where the reduction in wire size occurs is reamed to a very smooth finish Two tapers are employed, one in which most of the reduction takes place, the other one of smaller taper, in order to ease the wire down to the exact size at exit from the die. The initial part of the tapered hole is not machined, as it serves only as a region for application of the lubricant to the rod A plan of a draw bench which is the production unit in wire drawing, is also given (F T M)

WIRELESS TELEGRAPHY. Wireless, or radio telegraphy is carried on by flashing through space from the transmitting station a series of electro-magnetic waves which are intercepted and interpreted by a receiving station as dots and dashes A trained operator or a machine can then transcribe this code into words comprising the message Wireless telegraphy is thus a form of **radio communication** Historically, it antedates radio telephony and **television,** but it came after the land telegraph, the telephone, and the submarine cable had become commercially successful The pioneer work in electro-magnetic phenomena accomplished by Maxwell and Hertz was further developed by Marconi, who, after a rapid series of successes in extending the range of wireless communication, in 1901 sent the letter "S" across the Atlantic The immense usefulness of a new method of communication, thus envisaged, lent such impetus that this method of communication was soon on a commercial footing At first it was not possible to compete commercially with the older established wired communications, and the spread of wireless telegraphy was largely confined to marine service, where, of course, wired communication was impossible The remarkable effect attending removal of the isolation formerly attending ships at sea, coupled with dramatic maritime rescues wrought through the medium of the new wireless telegraphy, displayed to the world its need of radio, and gave some small indication of the future it might expect

From these beginnings have grown all radio communication The field of wireless telegraphy itself has expanded to include governmental, military, and naval services, shore-to-shore transoceanic telegraphy and amateur communication, as well as the ship-to-ship or ship-to-shore service. Although some of the early workers in the field of electro-magnetic radiations experimented with short waves (i e, high **frequency** radiations), the developing industry turned towards the use of long waves, for reasons too lengthy to be detailed here, and until recently most wireless telegraphy was conducted

on frequencies of 10 to 500 kilocycles (the kilocycle equals 1000 cycles per second) Increasing appreciation of the advantages of high frequency or short wave transmission where long distances are involved, has led to the utilization of the short wave field by wireless telegraphy High frequency transmission is attended by certain advantages, among which might be mentioned the lower power consumption for equivalent distances, less trouble from static interference, and greater number of words which may be transmitted On the other hand, magnetic storms affect short waves more than they do the long, and fading is more prevalent

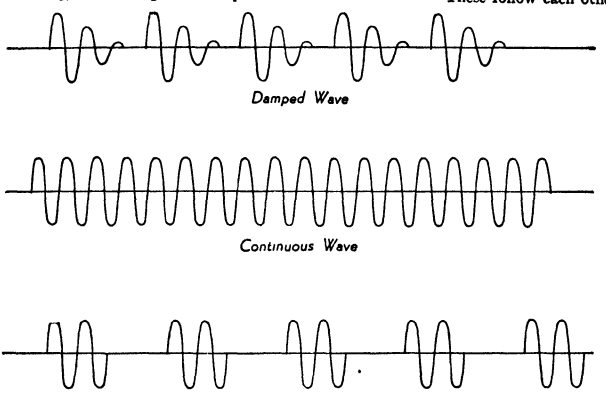


Figure 1 Wave forms

The Continental Morse Code, which is the standard in use today, conveys intelligence by means of certain combinations of dots and dashes

Continental Morse Code

A . –	B –	C – .	D – . .
E .	F . –	G – –	H . . .
I . .	J . – – –	K – . –	L . – . .
M – –	N – .	O – – –	P . – – .
Q – – . –	R . – .	S . . .	T –
U . . –	V . . . –	W . – –	X – . . –
Y – . – –	Z – – . .		
1 . – – – –	2 . . – – –	3 . . . – –	4 . . . . –
5	6 –	7 – – . . .	8 – – – . .
9 – – – – .	0 – – – – –		

To send these dots and dashes by means of electromagnetic waves, one of two systems may be employed One is called the damped-wave (spark) and the other the continuous wave (c w) In each case the code is sent by interrupting or altering the character of the train of waves sent off the antenna However, the methods of production are different, as are also methods of reception

Spark telegraphy is produced by sending from the transmitting **antenna** groups of high frequency, highly damped waves similar to those graphed in Figure 1 These follow each other at the rate usually of a thousand per second. When these waves are impressed on the antenna of the receiving station they may be caused to produce, on the diaphragm of an earphone, a series of pulls setting up an audible vibration having a frequency equal to the number of wave trains per second The number of these wave trains sent out uninterruptedly may be controlled by an operator manipulating a telegraph key, and the resulting interrupted train of waves will create in the earphones of the receiving operator a series of dots and dashes from which he can interpret the message A simple arrangement of a spark transmitter and receiver is shown in Figure 2 A source of high frequency alternating current, such as an **alternator,** is connected to a spark gap by means of a step-up **transformer.** A **condenser** is connected around the gap When the alternator circuit is closed by operating a key, each alternation of current charges the condenser highly enough to break down the spark gap through which is then discharged an oscillatory current This current flowing through the primary of the oscillation transformer sets up in the antenna circuit a highly damped oscillatory current which radiates electro-magnetic waves of the wave form shown in Figure 1 Since one of these damped wave trains is sent out for each alternation of current in the alternator circuit, a 500 cycle alternator (commonly used) produces them at the rate of 1,000 per second On the receiving end the antenna is conducted to ground by antenna tuning inductance and capacitance This might be called the

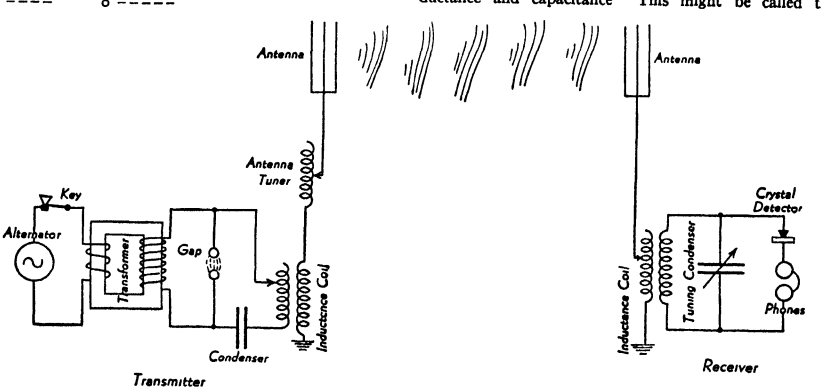


Figure 2 Simple spark telegraphy circuit

open circuit of the receiver. The closed circuit is tuned to the antenna circuit by means of a variable condenser. Across the condenser are connected the detector and earphone receiver. The detector may be a simple crystal type valve, or a vacuum tube. In the case of the crystal receiver, as diagrammed, detection is made possible by the physical property of certain crystals (galena commonly used) of passing current better in one direction than in the reverse. As a result, the oscillating current occurring in the tuned circuit at the rate of 1,000 groups per second creates a monotone signal in the receiver, whose diaphragm will respond to the pull exercised by the unidirectional pulse passed by the detector. In practice, unless the power of the transmitting station is very low, it is necessary to operate the main key magnetically by the operator's key Also, a simple spark gap is not satisfactory It does not tend to quench rapidly, and would not be adequately cooled Spark transmitters actually employ synchronous rotating spark gaps or a special form of spark gap known as the quenched gap

Continuous wave telegraphy operates on a somewhat different principle In its simplest form, a source of high frequency current is connected to the antenna through a circuit, including a key, by means of which the continuous waves sent out by such an arrangement may be interrupted This intentional interruption on the part of the transmitter operator, however, should not be confused with the interrupted continuous wave system, which is received similarly to the spark wave, but which may be produced by more modern means The transmitter for the continuous wave is simpler than for the damped wave, but the receiver is more complex, for the following reason A train of continuous waves impressed on a receiver of the type shown in Figure 1, would create simply two clicks for each group of waves, and dots and dashes would be inseparable This is because the dot or dash transmitted consists of groups of continuous waves instead of a number of finite damped trains The crystal detector enabled the earphone diaphragm to respond to the group frequency of the wave trains To receive continuous wave telegraphy, the principle of heterodyning is employed Since the incoming signal is of constant amplitude, it is necessary to produce a beat or amplitude variation before audibility of the signal can be achieved By impressing on the incoming signal an alternating voltage of a frequency which is produced and controlled in the receiver, the result is a current having an amplitude varying, and so producing a "beat," or in other words, a wave train having a beat frequency equal to the difference between the incoming signal and the locally generated signal The detector will then produce a series of pulses in the earphone, the frequency of which is the beat frequency of the circuit This wave action is shown in Figure 3

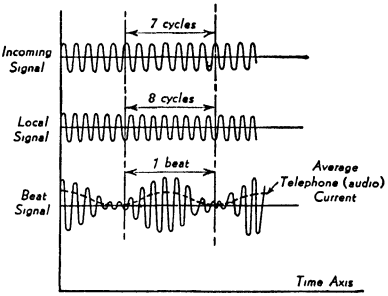


Figure 3 The heterodyne action

Continuous wave transmission was accomplished originally by extremely high frequency alternators of special construction, such as the Alexanderson or Goldschmidt type, or by means of the Poulsen arc, once extensively employed by the United States Navy These had certain limitations of power output or range of frequency Furthermore, enormous strides have been made in the development of the vacuum tube for many services The three element **vacuum tube** may be the means of producing a source of high frequency oscillations, in fact, for the short and ultra short wave wireless telegraphy, it is the only type available Further development of the triode tube and short wave telegraphy will tend to render other methods of generating high frequency continuous waves obsolete A simple circuit suitable for transmitting continuous wave signals is shown in Figure 4

Manual operation of the radio telegraph employing a hand operated key at the transmitting end and earphones at the receiver, is satisfactory for a great many services However, there are instances where limitations in speed of transmission of messages, caused by the inability of even trained and competent operators to receive more than approximately forty words a minute

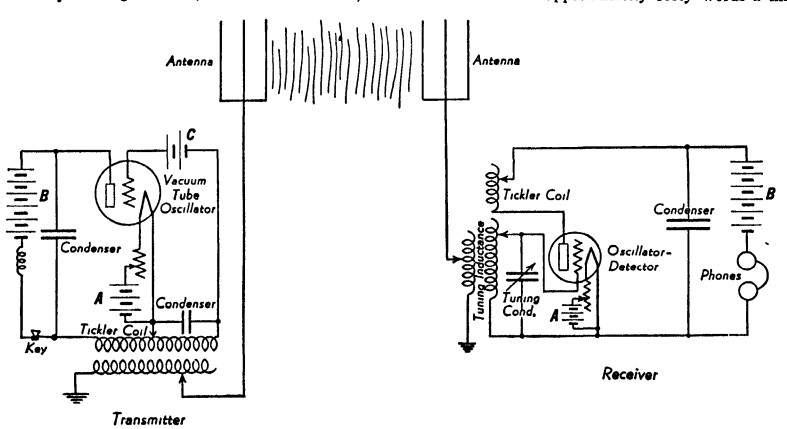


Figure 4. Simple continuous wave circuit.

do not fully develop the possibilities of either the investment or of the channel allotment Particularly, in point-to-point commercial wireless telegraphy automatic transmitting and receiving equipment is justified In one system the message is typed out on a machine having a keyboard similar to a standard typewriter Operation of this machine perforates a roll of paper which is then fed into an automatic transmitter, in which the perforations in the tape create an action which takes the place of the manual keying of the hand-operated transmitter. Since the perforation of the tape, and its use occur in two different machines, there need not be any equality of the speed of perforating the roll, and the speed with which it is then fed through the automatic transmitter Several perforating machines might be employed to supply messages to one automatic transmitter, so the limitations imposed by an operator's speed of typing need not affect the transmitter As a result, the latter can be made to transmit over 200 words per minute This greatly increases the use to which a point-to-point wireless telegraph system may be put Naturally, reception of such high speed signals must also be the function of a machine A commonly used system has an ink recorder in which movement of the pen is controlled by the incoming signal and a record of dots and dashes is made upon a continuous roll of paper Operators may then transcribe this ink record into the original message (F T M)

WIREWORM. Insecta, Coleoptera. Slender hard-bodied **larvae** of the **click-beetles.** They live under bark and in logs or in the ground Among the latter species are some important crop pests which damage the roots of **grass** and **grains,** and a few other crops including **potatoes** and **cotton.** The corn wireworm is one of the most widely known, often destroying entire fields.

The hard bodies of these worms render them immune from repellent substances that can be used in the soil, but crop rotation including clover, **soy beans, buckwheat,** flax, or some other species not subject to attack, is an effective method of avoiding serious loss. (A W L)

WIRING. Wiring consists of running the necessary electrical **conductors** from distribution panels to such lamps, plug-in sockets, motors, ovens, etc, as may be served from the distribution center. The interpretation given here to wiring includes the field of interior wiring, only Wiring must meet so widely differing service conditions that different types have been developed The conditions which may vary in different installations are average quantity of **current** flowing, light or heavy power service, need for finished appearance or concealment of wiring, presence of moisture or fumes, different structural types of buildings in which wiring is installed, and time of installation, i e, during construction or in old buildings Other factors which bear on the development and use of different types of wiring are the money which can be expended on wiring, and the possible loss which might result from electrical fires These factories have brought about the creation of the following methods of wiring:

1 Exposed knob and cleat wiring (mill type).
2 Concealed knob and tube wiring
3 Raceway wiring
4 Armored conductor wiring (BX)
5 Rigid iron conduit wiring

The first two of these methods involve suspension of the conductors a certain distance apart (minimum 5 inches), or their enclosure in flexible loom, when as at switches and fixtures, they must converge However, knob wiring, wherein the insulators are supported on porcelain knobs or cleats, or in tubes where they pass through holes in beams and walls, very definitely insulates the conductors from one another, and eliminates contact with anything but the porcelain insulation. Of course, when poorly installed, and not taut, the conductors may sag between insulators and may create a very definite fire hazard. Even when installed perfectly, little can be said for the decorative appearance of open wiring, so that it is limited to industrial buildings, garages, sheds, and other places where appearance is not a primary consideration. Knob and tube wiring installed in residences is inexpensive, although it must be done during construction of the building. If well installed, it is as good as any method of wiring, except possibly the rigid iron conduit

Raceway wiring is to be thought of as a type whose maximum usefulness is in the field of wiring installation subsequent to construction, where the opening of partitions or ceilings for the purpose of introducing concealed wiring is impossible or undesirable Raceway wiring is surface wiring, with the wires concealed in wooden or metal raceway which is attached to the surface of walls or ceilings A wooden raceway is provided with a molded decorative cover which may be worked into a semblance of decoration in a room The same cannot be said for a metal raceway, but it is of small size as compared to the wooden raceway, less conspicuous and is frequently used for surface wiring of offices and mercantile establishments In raceway wiring, the base is installed and the wires laid therein, complete from outlet to outlet, then the cover is applied

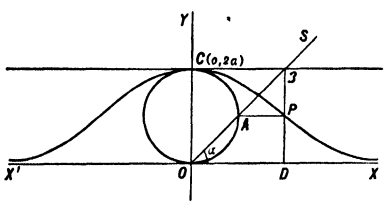
Flexible armored conductor is probably used more nowadays for residence wiring than any other type The armored conductor consists of two rubber covered wires (three conductor cable is also commercially produced) covered with a spiral serving of craft paper over which is laid a double spiral steel sheath The flexibility of the latter permits the armored cable to be bent, although if too small a radius of bending is attempted, the sheath will be damaged Armored cable is not moisture proof unless it is of a special type having a lead sheath between armor and the conductor. However, it is approved for wiring in dry locations, such as residences The cable must be continuous from outlet to outlet, and is generally employed in connection with iron outlet boxes, to which it is attached by special clamping connectors It does not need to be held by **insulators,** and may be passed through holes bored in beams or joists without the aid of insulating bushings

Rigid iron conduit is the best method of wiring, also the most expensive It is superior in durability, is moisture proof, and fireproof, reliable, safe, and mechanically strong While it is not the intention here to give details of conduit wiring (there are standard handbooks treating that subject), some of the general principles are stated Although the conduit is an ordinary water pipe smoothed on the inside, there is little in common between the installation of conduit and of water pipe, unless it be that junction of adjacent lengths is made by screwed couplings in both cases To understand the differences let it first be noted how wires are installed in a conduit. A run of conduit having been installed complete and unbroken between the terminal points, the wire is drawn in as follows A fish tape or wire, a tempered steel wire of rectangular cross-section, is pushed through the conduit until its end appears at the farther end A draw line is then attached to it and by withdrawing the fish tape, the line is drawn through the conduit The wires are in turn attached to the draw line and drawn into position This method of installation requires (1) that the conduit interior be smooth and uninterrupted, (2) that the bends be of long radius and limited in number If the conduit were not smooth internally there might be difficulty in pushing the fish tape through it, moreover, the roughness would doubtless damage the insulation on wires being drawn in When conduit is cut and threaded the ends should be reamed to remove burrs. Ordinary pipe elbows are not used in conduit wiring The pipe itself is bent to a long radius or long radius elbows are used. Due to the snubbing action of bends on wire being drawn through the conduit, not more than four equivalent 90°

bends are permitted between pulling points, and many prefer to limit the number to three. In size, conduits smaller than ½ inch iron pipe size are not to be used, while conduits larger than 4 inches are seldom required. Fiber ducts or tunnels are favored over the large iron conduit. Manufacturers have developed, in place of ordinary pipe elbows, tees, etc, lines of special conduit fittings designed to satisfy all requirements for outlets, junctions, etc (F T M)

WISENT. Mammalia, Artiodactyla The European **bison.**

WITCH OF AGNESI. The witch (of Agnesi) is a plane curve wh.ch may be defined geometrically as follows Place a circle of radius a with its center on the



Witch of Agnesi

Y-axis and passing through the origin; draw any line OS cutting the circle at A and cutting the tangent at C at B, draw BD perpendicular to the X-axis and AP parallel to the X-axis, and let BD and AP intersect at P As OA rotates about O, the point P describes the witch

The **parametric equations** of the witch are

$$x = 2a \cot \alpha, \quad y = 2a \sin^2 \alpha$$

The equation in **rectangular coordinates** is:

$$x^2y + 4a^2y - 8a^3 = 0,$$

or

$$y = \frac{8a^3}{4a^2 + x^2}.$$

(L L S.)

WITCHES' BROOMS. The malformations known as witches' brooms are formed in many different kinds of woody plants. Many of them are caused by the presence of *Exoascus*, an **ascomycete**, which grows parasitically in the tissues of the plant A bud infected by *Exoascus* is stimulated to rapid growth So are the lateral buds of this shoot The result is a bush-like mass of branches The leaves of these infected branches are commonly dwarfed and fall earlier than the other leaves of the plant The stems contain a much greater amount of **parenchymatous** tissue than is found in the normal branches. No reproductive parts are found on the brooms.

Witches' brooms are formed on fir trees, here they are caused by *Aecidium elatinum*, one of the **rusts.** A rust, *Gymnosporangium*, also causes the formation of witches' brooms on white cedars Hackberry trees are often conspicuously covered with witches' brooms In this plant they are caused by a mite, *Phytoptus*, which attacks the plant (R M.W)

WITHERITE. The mineral witherite is **barium carbonate**, $BaCO_3$, crystallizing in the **orthorhombic system** It is interesting to note that at 811° C it changes to the **hexagonal** system, and at 982° C it appears to become **isometric.** It has a rather imperfect prismatic **cleavage;** uneven fracture; hardness 3–3 7, specific gravity, 4 2–4 35; luster, vitreous to resinous; color, white to yellowish or grayish; streak, white; transparent to translucent Witherite is not a common mineral, being found in veins, and often associated with **galena** as at Alston Moor, Cumberland, England Associated with **barite** at Freiberg, Saxony, and at Lexington, Kentucky. Named in honor of Dr William Withering, an English botanist. (E S C S)

WOLF. Mammalia, Carnivora A large doglike animal belonging to the family Canidae, containing the jackals and domestic dogs, the various wild dogs, and the foxes. The wolves are closely related to the domestic dogs and are supposed to be the ancestral stock of the latter. The relatively few species are found in Europe, Asia and North America, with the one exception of the Antarctic wolf of the Falkland Islands, a species somewhat smaller than the coyote, with a less bushy tail, black at the middle and tipped with white. The kaberu, also called the Abyssinian wolf, is related to the jackals

Of the true wolves of the genus *Canis*, the **coyote** or prairie wolf of North America is the smallest form Seven species ranging over various limited areas from Canada to Texas and from Iowa to California are known indiscriminately as coyotes They are more cowardly animals than the larger wolves and in settled areas often persist as annoying predators, robbing poultry roosts and catching small game

Wolves are now common only in the wilder parts of the continent and are entirely exterminated in well settled regions The North American species are the gray (*Canis lycaon*), southern (*C floridanus*), lobo or timber (*C nubilis*), and Texas red (*C rufus*) wolves, and the American jackal (*C frustror*) of Texas and Oklahoma (A W L)

WOLFFIAN DUCT Urogenital **system.**

WOLFRAM. Tungsten.

WOLFRAMITE. The mineral wolframite, **tungstate** of iron and **manganese,** is an **isomorphous** mixture of tungstate of iron, $FeWO_4$, and tungstate of manganese, $MnWO_4$, the amounts being variable The pure iron tungstate is called ferberite and the manganese tungstate, hubnerite It has been proposed that the name ferberite be applied to mixtures of not less than 80% $FeWO_4$ and not more than 20% $MnWO_4$, and that the term hubnerite be given to mixtures of not less than 80% $MnWO_4$ but not more than 20% $FeWO_4$ Wolframite would thus include the minerals of intermediate composition, and its formula would be written $(Fe,Mn)WO_4$. Wolframite is **monoclinic,** usually appearing in tabular, columnar or bladed crystals, sometimes quite large; also may be massive Its hardness is 5–5 5, specific gravity, 7 1–7 5; color, gray, reddish brown, brown or black; streak, reddish brown to black, luster, submetallic, opaque, occasionally magnetic Wolframite is found associated with **apatite, cassiterite, quartz, fluorite,** etc, in **granites** and **pegmatites.** Often with **scheelite,** $CaWO_4$, and sometimes as a **pseudomorph** after that mineral Wolframite is found in Czechoslovakia, Rumania, Saxony, Cornwall in England, New South Wales, Bolivia, and in the United States at Trumbull, Connecticut, Luna and Lincoln Counties, New Mexico. It also occurs in small quantities in Nevada and Utah

Ferberite, which has monoclinic tabular crystals, sometimes massive, resembles wolframite, and occurs in Spain and in Boulder County, Colorado

Hubnerite crystals are monoclinic, often long fibrous or bladed, may be massive; resembles wolframite and is found in Peru, the Black Hills, South Dakota; San Juan County, Colorado, White Pine County, Nevada, and Lemhi County, Idaho. (E S C S)

WOLLASTONITE. The mineral wollastonite is **calcium** metasilicate, $CaSiO_3$, which is found as tabular or short-prismatic **monoclinic** crystals This mineral has a hardness of 4–5, specific gravity, 2 8–2 9; color, yellowish, reddish or brownish, to gray, white or colorless; luster, vitreous to pearly; transparent to translucent. Wollastonite in the main is formed by the action of contact **metamorphic** processes on limestones at relative

high temperatures (600°+ C). Its common associates, **diopside, vesuvianite, garnet** and **epidote,** suggest this origin. Some of the more important foreign localities are in the copper mines of Rumania, in the lavas of Monte Somma and Vesuvius, in Finland and Mexico In the United States it is found in Essex and Lewis Counties, New York, Keweenaw County, Michigan, and Riverside County, California Wollastonite was named in honor of the English chemist, William Hyde Wollaston (E S C S.)

WOLVERINE. Mammalia, Carnivora. A stoutly built short-legged animal, *Gulo luscus,* of northern North America, ranging from the mountain forests of Colorado and Pennsylvania to the Arctic It is over three feet long, with large feet, a short bushy tail, and shaggy fur. Also known as the glutton, and by the Canadian French name carcajou

The wolverine is noted as a vicious killer and as a despoiler of camps It not only damages foods that it cannot eat but steals objects that it cannot use and so makes itself a general nuisance to campers and trappers in the northern woods Since it climbs, gnaws, and digs with great facility, protection of supplies against its attacks is difficult Wolverines eat dead animals as well as prey that they kill, and often rob trap lines

A second species of wolverine, *G luteus,* of slightly smaller size and different proportions, has been recognized, extending southward in the Sierra Nevada of California (A W L)

WOMB. The mammalian **uterus. Reproductive system.**

WOMBAT. Mammalia, Marsupialia *Phascolomys* Stoutly built pouched animals of Australia and Tasmania, broad of body and with short thick legs They have a pair of chisel-like incisor teeth in each jaw, like the rodents, and have similar food habits They live in burrows or in crevices among rocks Several species are known (A.W L)

WOOD. TIMBER. LUMBER. These three terms are rather confusedly used, with several different meanings, often of local use The word wood is frequently applied to fuel, which in this case means forest products cut to a size suitable for burning in stoves Again, especially in the plural form, the word refers to a stand of growing trees, especially if the stand covers a considerable area The word may also apply to finished products such as boards, joists, and beams, all called wood In botanical language, the word wood means that part of the stem, trunk, or branches, which is composed of the water-conducting **xylem** cells and associated fibers, especially in perennial plants in which these cells form a considerable mass, as in trees, shrubs and vines

The word timber is also applied to standing trees, especially in the phrase standing timber, meaning trees large enough to be commercially valuable Another common phrase is timber-land Timber also means prepared forest products, especially any large beams, or coarse products **Lumber** has a similar meaning, but is used in a rather broader sense, applying generallly to any forest products such as boards, planks, beams, etc

Practically all plants yielding wood of any value are **gymnosperms** or **dicotyledonous angiosperms.** Among **monocotyledons** only certain **bamboos** and **palms** have any appreciable use, and that largely restricted to the regions in which these plants grow

It is worthy of note that forests have a very great value to man in addition to their yields of wood For a forest is a very important factor in conserving water, preventing it from rapid running off, and so tending greatly to reduce the possibility of disastrous floods This retention of water is due to several factors, one because the roots themselves tend to form hollows in which water stands and settles, to move slowly through the ground another because the increased supply of humus accumulating in the ground under the trees acts as a sponge absorbing and retaining water.

In North America there are several types of forests, distinguished mainly by the kinds of trees which are most numerous in any kind In eastern North America three main regions are recognized There is the Northern Forest, occupying the northernmost tier of states from Minnesota east, and reaching downward in the mountains to Virginia and Tennessee. The dominant trees of this forest are **coniferous,** with white pine the most valuable species Other coniferous species are hemlock, fir, and spruce Hardwoods such as oaks, maples and birches are important trees of this northern forest The southern forest occupies the region bordering the Atlantic and Gulf of Mexico and extending from the southeastern corner of Virginia into the eastern part of Texas This also is a forest dominated by coniferous trees, mostly species of pine Hardwood trees of this forest include red gum, ash, and tupelo Between these two forests and extending west into the prairie region is the hardwood forest, in which are found oaks, black walnut, hickory, and basswood In the western half of the country there are two regions, one, the Pacific forest, occupying the states bordering the Pacific ocean, and composed largely of Douglas fir, redwoods and several species of pine, all trees frequently attaining tremendous size Occupying higher elevations in the western mountain states is the Rocky Mountain forest, containing such trees as Douglas fir, Engelman spruce, several pines, aspen, red cedar, and many others Including the southernmost tip of Florida and the southern borders of Louisiana and Texas is a forest of an entirely different type, the tropical forest, which occupies vast regions of land in central and South America, as well as the West Indies

Woods are divided into two main classes, softwoods and hardwoods, distinguished not so much by the nature of the wood as by the trees Softwoods are those obtained from **coniferous** trees such as pines, spruces, hemlocks and firs, hardwoods come from **deciduous** trees, and include such trees as oaks, ashes, maples, basswood, poplars, gums, as well as many tropical trees It will be seen that the relative hardness of the wood is not an indication of its classification, since many hard pines, which are softwoods, are much harder than the softwood of the bass, the poplar and the tulip tree, all of which are classed as hardwoods Softwoods are much more extensively used by man, being employed widely in building work Hardwoods are used for furniture, interior finish, and for products demanding special wood structure

The structure of wood is a very important factor in determining its ultimate use The woody tissue of any plant is composed entirely of cells of various kinds, the majority of them being elongated and thick-walled In **gymnosperms,** from which come the softwoods, these cells are **tracheids,** elongated cells in the walls of which there are many **pits.** These tracheids vary in size and in the thickness of their walls, those which are formed during the season of most active growth, in the spring, being larger and having thinner walls than those formed later The hollow center, or lumen, of the spring-formed wood is much larger than that of the summer wood As a result of this variation in cell size and structure, the wood of the tree is made up of distinct concentric layers of cells, often very sharply distinct These are the annual rings By counting them one may obtain an accurate knowledge of the age of the tree In addition to the tracheids there are in the gymnosperm wood other cells which extend in narrow radial bands outward towards the surface of the stem These are the ray cells which collectively form the rays of the wood In softwoods the rays are not conspicuous, in many they are very minute In hardwoods the cellular structure of the wood is more complex Tracheids are present and resemble those of the softwood in appearance In addition there are many vessels These are composed of many cells arranged in vertical rows extending considerable distances

along the stem It is characteristic of vessels that there is no cross wall separating the component cells Pits are found in the lateral walls of the vessels In hardwoods, there are also many fibers, slender elongate cells with thick walls, in which there are only a few small pits Compared with those of softwoods, the rays of hardwoods are very large and often form a conspicuous feature of the wood All these cells in both hard and soft woods are formed by the **cambium** cells When first formed, all wood cells contain **protoplasm** Very early in their development, the protoplasm of the vessels, fibers and tracheids is lost, the cell becoming void of any living contents Only the ray cells and any **parenchyma** cells which may remain retain their protoplasm Therefore the greater part of the woody tissue of the tree is dead For some time this wood functions, it being the region through which water and dissolved mineral matter passes up through the stem Wood thus functioning is called sapwood It is usually pale in color As the stem increases in size, changes occur in the cells, and there is less and less **ascent of sap.** Their walls frequently become much darker in color, often the lumina of the cells becomes filled up with various solid substances When this condition obtains the wood is known as heartwood The separation between sapwood and heartwood is usually quite distinct, it does not necessarily coincide with an annual ring, but may form a very irregular region The appearance of the heartwood differs greatly in different woods, in some it is never distinct from the sapwood, in others it forms a small mass in the center of the stem, while in others it includes almost the entire stem In color heartwood ranges from white through yellows, reds, greens, browns, and even black in different trees, often it is streaked and mottled with different shades of color

The first step in the preparation of wood is cutting it into suitable dimensions Usually this means that the felled trunks, known as logs, are cut into lengths varying from two or three feet to sixteen feet or more, depending on the use to which the wood will be put. These logs are then sawed into boards, planks, or larger pieces The manner in which a log is sawed is often a very important factor in the value of the product, since many woods are valuable for their grain, which differs according to the way the wood is cut The word grain, applied to wood, has many meanings Commonly it refers to the appearance of the wood when finished This is determined by the nature of the cells composing the wood and their arrangement In many woods, especially the softwoods, the cells are all parallel so that the wood splits easily Such wood is said to have a straight grain In other woods, the cells are oriented in various directions Such woods split with great difficulty, and are called cross-grained woods Wood composed mostly of small thick-walled cells, with few vessels, is called fine-grained wood, in contrast to that having many vessels, usually of large diameter, known as coarse-grained wood The rays of the wood often form an important feature of the grain, since when they are large they may appear in the form of distinct flakes or streaks in the surface of the wood The size and appearance of these flakes is greatly changed by the method of sawing the wood

The commonest way of sawing is called plain sawing In this, successive boards or planks are cut from the log, beginning at one side and cutting successive pieces through the center to the opposite side In those woods in which grain is of little value, especially those with very small rays, this method of cutting is entirely satisfactory, for it is quickly and easily done In other woods, especially those in which the rays are large and form a conspicuous feature of the finished wood, it is not so satisfactory, since variation results This variation is largely due to the nature of the rays, which extend directly outward from the center to the surface of the wood, and have little thickness compared to their other two dimensions Consequently the first cuts will be across the rays, which will then appear as narrow linear streaks in the wood. When boards near the center are cut, the ray will be nearly parallel to the cut and so appear as an irregular broad patch on the surface, adding greatly to the beauty of the wood Methods of cutting have been devised which increase the number of boards which show these radial cuts These methods are known as quarter-sawing There are many of these, all having as their object the cutting of the greatest number of radial cuts most economically Another important feature of the grain of wood, which can be changed by the method of cutting, is found in the annual growth increment, which forms the annual rings of the cross-section In sawed woods these annual layers appear as lines or streaks, often elaborately twisting

Another important step in the preparation of wood is drying or seasoning This may be done either before or after the log is cut into boards During this process much of the water which is present in the wood, both in the lumina of the cells and in the cell walls, themselves, is lost As a consequence there is a certain amount of shrinkage of the wood, which is greater tangentially than in the other dimensions As a result, the wood on drying tends to check or crack longitudinally, especially in large pieces of wood For most purposes, undried wood, known as green wood, is entirely unsatisfactory, it will twist, warp, and crack as it dries, it cannot easily be glued, or finished, and it is more subject to attacks of fungi and boring insects There are two methods of seasoning woods The older method was to pile the wood in such a manner as to secure the maximum exposure to air, separating each piece from the next by narrow strips of wood, or by other means, and leaving the piled-up wood to dry slowly. This is called air-drying or air-seasoning To dry wood in this way requires a month or more for boards an inch thick and several years for very large sticks, especially if the wood be a hardwood containing much water Naturally the climate greatly effects the time required, wet seasons causing very slow drying Recently much of the wood used, especially that used in making furniture, interior finish, shingles, etc, has been dried artificially in large rooms, heated artificially By this method it is possible to dry wood in a few days instead of months or years. The product is also much drier and better fitted for use This method is known as kiln-drying of kiln-seasoning Properly prepared wood has the following properties which give it its special value It possesses great strength and incompressibility, yet is flexible, giving without breaking, and elastic, recovering after bending Many woods have special properties which particularly fit them for special uses

The uses made of wood are so numerous that only those of the greatest importance can be named Immense quantities of wood, both hard and soft, are used in the pulp and paper industry In construction work other large quantities are used, and in a variety of ways Poorer grades of lumber are much used in making forms in which concrete work is poured Scaffoldings and other framework also use quantities of the cheaper kinds of lumber Wood is still a most important material for the construction of dwellings and other buildings For the framework and for the rough finish of the walls and floors, the poorer kinds of wood are mostly used For the outer parts, such as shingles and clapboards, and for the interior finish materials and floors, better grades, often of special kinds of wood, are used. Shingles, for example, are mostly cut from red cedar, which is very resistant to the weather Floors are made from hard pine, from maple or oak, and a few other woods which do not splinter easily and which resist heavy wear favorably Nearly all the woods used in construction work are softwoods, which are light in weight, durable and easy to work.

For cabinet work and furniture an entirely different group of woods is used. Most of these are hard woods, selected for their fine grains, or for their color, or because

fashion and the whims of fancy happen to give them popularity Many of the woods used for this purpose are tropical woods difficult to obtain and so of great value In early days furniture was made from solid pieces; later it became the custom to use thin pieces of wood glued to a background of a different wood These thin pieces were called veneer. There were several reasons for using veneer One of course was economy, since an expensive wood would yield many more pieces of veneer than it would boards Another reason was found in the fact that it was often difficult to fashion things from the hard dense woods used They would split or crack easily, whereas when glued to a more easily handled more suitable wood they became usable Finally, and very important, was the fact that often veneers could be obtained showing a beautiful grain which could rarely be obtained otherwise So veneering became important

There are three ways of cutting veneer wood They may be sawed like any board this method is wasteful since much material is wasted in the cut, as sawdust, it cannot produce very thin pieces, and it does not give the best grain in many cases An advantage is found in the high polish which may be given veneers cut by this method A second method of cutting veneers is slicing In this method the short piece of wood, called a bolt, from which the veneers are to be cut, is moved up and down against a heavy stationary blade This method has an advantage over sawing in that it allows much thinner veneers to be cut As in sawed veneers, sliced veneers are limited to the size of the bolt from which they are cut, which is frequently a factor against them The third method and the one used in cutting nearly all the veneers in the United States, is rotary-cutting. In this method the bolt is revolved against the knife, the veneer coming off in a thin sheet of any width desired In order that the wood may be more easily cut and the veneer handled better, the bolt from which it is to be cut is usually soaked in water or steamed for some time before cutting, both by the slicing and the rotary method After cutting, veneers are pressed flat and dried, in which condition they may be held indefinitely They are commonly glued to some softwood when they are used

Another way in which veneers are used is in the making of plywood This is made by gluing together three or more layers of veneer, the grain of each layer being at right angles to the one above it Plywood is very resistant to blows and not easily cracked or broken For which reason it is much used in making boxes, crates and panels designed for various purposes

In addition to these major uses of wood, there are many others, each of which uses immense quantities Cooperage is one of these There are two kinds, slack and tight, each producing a barrel or container suited for a special purpose Slack cooperage produces barrels, kegs, tubs, etc, which are used as containers for vegetables, for nails, and for many other things Formerly flour was mostly shipped in barrels of this sort Tight cooperage produces containers which are tight, the staves fitting very close together, and the heads being very closely fitted. Woods used in tight cooperage must not have large pores. White oak, in which the pores are completely plugged, is especially suitable. If other woods are used, they must be coated with a film of paraffin which will plug the pores Quantities of wood are used in the manufacture of charcoal, which is extensively used in making steel, explosives, and carbon dioxide gas, and also as a filter in the manufacture of sugar. Charcoal is made by allowing a closely packed pile of wood to burn with insufficient air, as a result of which the volatile materials are driven off and the carbon of the wood left Millions of cords of wood are used for fuel each year in the United States; much of this is waste wood which would be of little value for any other purpose. Large quantities of light softwoods, especially basswood, are used in making excelsior, in this the wood is first scored and then stripped off in thin pieces by knives. Excelsior is largely used to pack around glassware and dishes, and as a stuffing for mattresses and upholstery of the cheaper grades Other uses of wood are railroad ties, poles, and posts, piling, all of which call for woods which will resist rotting and the attacks of various animals

The following woods have properties which particularly fit them for special uses. Lignum-vitae, the heaviest of all woods, is a dark greenish-brown fine-grained wood with an oily appearance It is obtained from *Guaiacum officinale*, a small tree native in tropical America The wood of another species, *Guaiacum sanctum*, is also used Both trees have compound leaves and showy flowers borne in clusters in the axils of the leaves The fine-grained wood with its much-crossed fibers is used in making pulley sheaves, and as bushing around the propeller shafts of steamships, as well as for bowling balls and mallet heads The wood contains a resin, guaiacum, which was formerly highly esteemed as a valuable medicine used in the treatment of social diseases Today it is of slight importance as a drug. Rosewood is obtained from *Dalbergia nigra* and other species, natives of South America It is a hard close-grained wood with a pleasant fragrance Formerly it was much used as a cabinet wood Sandalwood is obtained from trees native in the East Indian region It is a firm-textured wood of dull yellow color, which darkens with age Like rosewood, sandalwood has a characteristic aromatic odor The tree, *Santalum album*, is interesting because it is a parasite on the roots of other plants Satinwood is obtained from *Chloroxylon Swietenia*, and other species, natives of India and Ceylon The wood has a golden yellow color and a brilliant luster which makes it a valuable cabinet wood Several species of walnut, particularly *Juglans regia* of Europe and Asia and *Juglans nigra* of North America, yield dark brown woods of great value They are much used in furniture making, and in interior finish in houses, and also because when once dried they are not subject to any changes through swelling or shrinkage, they are particularly favored as material from which to make gun and rifle stocks Walnut is capable of taking a very high polish Another dark heavy wood which is much used in furniture making is ebony, the wood of *Diospyros Ebenum*, and other species The sapwood of the tree is soft and creamy white and of little value, the heartwood is very dark, often black, and hard There are many other less well known woods, which are frequently used in furniture making

See also **Cedar, Mahogany, Oak.** (R M W)

WOODCHUCK. Mammalia, Rodentia. A large heavy bodied animal of the northern hemisphere Woodchucks have short stout legs and are powerful burrowing animals, penetrating many feet into the ground They also climb readily, although somewhat clumsily They eat vegetation of many kinds and sometimes become troublesome in fields and gardens

North America has three species of woodchucks, the common woodchuck (*Marmota monax*), the yellow-bellied woodchuck (*M flaviventris*), and the whistler (*M caligata*) The first occurs from Kansas to Georgia, northward to Alaska and Hudson Bay The second ranges from the Rocky Mountains to the Pacific and the third is also western, ranging from Montana and Washington to Alaska The names **marmot** and groundhog are also generally applied to them The Old World species are widely distributed in Europe and Asia, where they are more commonly called marmots

The flesh of woodchucks is eaten but it is inferior to that of other common **rodents.** While its flavor is good it is coarse in texture as compared with that of squirrels and rabbits (A W L)

WOODCOCK. Aves, Charadriiformes. A woodland bird (**Aves**), *Scolopax minor*, of the northern and eastern part of the United States, related to the snipes. It has

a long straight beak and short neck, tail and legs, and its mottled brown plumage is a fine example of protective coloration Of limited interest as a game bird. (A W L)

WOOD-HEWER. Aves, Passeriformes. A small brown bird (**Aves**), of a family found only from Mexico to southern South America. The family includes more than two hundred species, mostly limited to the temperate parts of the continent Among them are the **oven birds** and several other groups (A W L)

WOOD HOOPOE. Aves, Piciformes An African bird (**Aves**), of a family closely related to the true hoopoes The wood hoopoes differ in the metallic gloss of the plumage and the long wedge-shaped tail Also called chatterers. (A W L)

WOODLOUSE. Crustacea, Isopoda Small terrestrial **crustaceans** of oval form, somewhat flattened They live under bark and debris near the surface of the ground, in decaying vegetation, and in other sufficiently moist situations, and are common in gardens Also called sowbugs These forms constitute the families Porcellionidae and Oniscidae, and in the closely related family Armadillidiidae are found the pill bugs The latter are able to roll themselves into almost perfect spheres when disturbed The numerous species vary in color from gray to brownish and blackish (A W L)

WOODPECKER. Aves, Piciformes A bird (**Aves**) whose beak is adapted for chipping wood and whose feet are formed for gripping the bark of trees The tail is composed of stiff feathers and is used as a brace against the surface to which the bird clings Woodpeckers excavate deep holes in trees as nests and deposit white eggs whose shells are like translucent china They also dig into decaying wood for the insects contained in it The capture of insects is facilitated by the sharp barbed tongue and sticky saliva Both the barbed tongue and the stiff tail are lacking in a few genera

Woodpeckers are well represented in all regions except the Australian They vary from the diminutive piculets of South America and Asia to the great ivory-billed species, which attain a length of eighteen inches North America has more than a score of species, including the flickers and sapsuckers Of these the red-headed (*Melanerpes erythrocephalus*) and downy (*Pyrobates pubescens*) woodpeckers and the flickers are widely known and the large pileated woodpecker (*Ceophloeus pileatus*) or cock-of-the-woods of northern and western forests and ivory-billed woodpecker (*Campephilus principalis*) of southern localities are among the rarest (A.W L)

WOOD RAT. Mammalia, Rodentia A moderately large **rodent**, more common in the western states but represented by a few species in other sections They are well and unfavorably known from their habit of invading houses and camps and carrying away anything edible They differ from true rats in the shorter furry tail and the larger eyes and ears Ten species have been described, all in the genus *Neotoma*.

These animals are also called pack rats and trade rats, the latter from their habit of replacing what they take with some other object. (A W L)

WOOD'S METAL. Alloys.

WOOLLY BEAR. Insecta, Lepidoptera. The densely hairy **caterpillar** of a **moth** of the family Arctiidae. Most hairy caterpillars belong to this family and most species of the family have hairy larvae (A W.L.)

WORK. Work may be regarded as the transfer of **energy** from one body to another; or, in a slightly different sense, as energy in process of transfer While there are numerous instances of energy transfer whose mechanism is unknown (by radiation, for example), in all cases open to direct observation the process appears to involve two essential factors: (1) the exertion of a force by one body *A* upon another body *B*, and (2) the motion or displacement of *B* in a direction in which the force has an effective component (not necessarily in the direction of the force itself). Thus, the wind may exert a force upon a sail in the direction north-northeast, while the boat actually moves straight north, that is, at an angle of 22° 30′ with the force But if the force is *F*, it has a component in the direction of motion, equal to *F* cos 22° 30′ or 0 9239 *F*, and work is therefore done.

It would be logical to define the measure of work as the quantity of energy transferred But custom has it just reversed, we fix upon a measure of work and define the unit of energy as that transferred when unit work is done The quantity of work itself is defined as the product of the displacement (say in feet) by the component of the force (say in pounds) in the direction of that displacement, thus giving rise to composite work units such as the **foot-pound**, or the **erg** and the **joule**. Thus, it comes about that we also commonly express energy in foot-pounds, ergs, or joules

It should be made clear that the displacement is not necessarily caused by the force when work is done. Thus, if one throws a tennis ball against the rear of a rapidly receding truck, it cannot be said that this causes the truck to move Nevertheless the ball does work on the truck which it would not do were the truck standing still; and as a result the ball rebounds with less energy than from a stationary surface (L D W)

WORK FUNCTION. The general meaning of this term, much used in connection with electronic phenomena, may be made clear from the following application Imagine an electron trying to escape from the heated, negatively charged filament of a radio tube It moves about readily enough within the metal, where there is no general electric field, but upon leaving the interior and receding from the positive atomic nuclei of the metal, the electron must necessarily experience a backward jerk which robs it of some of its **kinetic energy**. The work function, which expresses this lost energy, is characteristic of the metal Once outside the surface, the negative surface charge helps the fugitive electron along, but it always has less speed and less kinetic energy than it would have had but for the parting jerk Photoelectric emission involves the same thing A somewhat analogous case is that of molecules escaping from a liquid in evaporation, they are likewise slowed down (by cohesion), the lost kinetic energy manifesting itself as **heat by vaporization**. Electronic work functions are commonly expressed in **electron-volts**. (L D W)

WORKING STRESS. Factor of Safety.

WORLD LINE. Relativity.

WORM. A word without exact scientific limitations. Applied to creeping animals of the invertebrate phyla with long slender bodies, but also to some flatworms with broad thin bodies and only inaccurately to wormlike forms such as some of the insects Scientifically it embraces four phyla· **Platyhelminthes** or flatworms, **Nemertea** or ribbon worms, **Nemathelminthes** or roundworms, and **Annelida** or segmented worms (A.W.L.)

WORM GEAR. Screw Gear.

WORMWOOD, OIL OF. Volatile oils.

WOU-WOU. Mammalia, Primates. The gray or silver gibbon of Java.

WOUND. Any break in the continuity of a bodily surface, internal or external, caused by an outside injury or force.

An operative wound is one that is made surgically to expose an organ or portion of the body.

An aseptic wound is a clean wound which is not infected by pathogenic organisms. Such a wound is said to heal by primary intention.

An infected wound is one which is infected with pyogenic organisms. Such a wound heals by secondary intention, by adhesion of granulating surfaces, or by third intention, by filling of the wound with granulation tissue.

A lacerated wound is one in which the tissues are torn.

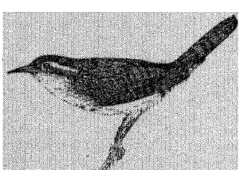
A contused wound is one in which crushing and bruising has occurred.

A punctured wound is a deep wound, small in diameter, made by a pointed object.

An incised wound is one made cleanly, as by a knife or other cutting instrument. (R.S.M.)

WRASSE. Pisces, Teleostei. Marine fishes (**Pisces**) found among rocks and coral reefs in tropical and temperate seas. Many are beautifully colored. Some of the larger wrasses are excellent food fishes. The name applies generally to members of the family Labridae. Two species of the Atlantic coast are known as the cunner (blue perch, chogset, bergall), *Tautogolabrus adspersus,* and the tautog (oyster-fish, black-fish), *Tautoga onitis.* (A.W.L.)

WREN. Aves, Passeriformes. A small bird (**Aves**), related to the larger thrashers. Distinguished by its long curved beak and often sharply erected tail. Several species habitually build their nests about dwellings or in bird houses. From this habit the widely distributed and vociferous little house wren, *Troglodytes gedon,* has become widely known and the Bewick wren, *Thryomanes bewicki,* a more musical species, has introduced himself to many residents of the eastern states. The Carolina wren, *Thryothorus ludovicianus,* also frequents human habitations. North America is the home of a dozen species and Europe and Asia also have representatives of the group, but it attains its greatest diversity in South America. (A.W.L.)



Carolina wren, *Thryothorus ludovicianus.* Bright reddish brown above; wings and tail barred with black. A long white line over eye. Underparts, creamy buff.

WRIST. The slender part of the forearm at its attachment with the hand, especially the region containing the group of small carpal bones between the radius and ulna of the arm and the metacarpals of the hand. (A.W.L.)

WROUGHT IRON. Wrought iron is a ferrous material aggregated from a solidifying mass of pasty particles of highly refined metallic **iron,** with which, and without subsequent fusion, is included a minutely and uniformly distributed quantity of **slag.** This definition of wrought iron indicates that it is a material made of two components; one, iron of a high degree of purity, the other, slag (chiefly silicate of iron). In the finished product the slag is distributed through the iron in threads and fibers, of which there is an enormous number. The slag imparts to the wrought iron a fibrous structure, quite different from the crystalline structure of cast metals. Wrought iron has made for itself a name as a metal which has resistance to corrosion, and which is exceptionally suitable for structural purposes where the structure is subject to shock. Wrought iron also can be readily worked, forged, machined, welded, galvanized, etc. Among the many applications of wrought iron might be mentioned tubes, pipes, and tanks.

Wrought iron has been made for centuries, but until comparatively recently, its production involved a large amount of hand labor. In former years, wrought iron was produced in the puddling furnace, wherein molten iron was refined with the aids of oxidizing agents, which resulted in the production of an iron silicate, slag. In this process the furnace temperature towards the end of the heat run is maintained high enough to keep the slag in molten condition, but low enough for the iron to become pasty. The workman thoroughly mixes the slag with a spongy iron, producing a sponge of iron and slag. This working is known as rabbling. When this process is complete, the sponge is taken from the furnace with tongs, and put in a squeezing machine, which presses out the surplus slag. The resulting product is then collected and hammered into blooms or rough bars of the wrought iron. Much arduous and tedious work has to be applied to produce a comparatively small sponge with the puddling process. The rabbling process requires a large amount of labor, yet this system continued to be used to produce wrought iron until comparatively recent years.

In the Byer's process, a modern wrought iron manufacturing method capable of large output, the pig iron is melted in a cupola, then refined in a **Bessemer** converter. The slag is independently produced in a tilting **open hearth** furnace. When the molten slag is ready it is poured into a large ladle and carried to a processing machine where the liquid refined iron from the converter is slowly poured into it. The temperature of the slag is maintained at a value which is sufficiently lower than the melting point of iron that, as the iron is poured into it, the iron rapidly assumes a semi-solidified form. The pouring of iron into the slag is attended by certain mechanical oscillations and relative movement which is designed to produce a uniform distribution of iron in the slag ladle. When all the iron has been poured into the slag, it lies in the bottom of the ladle as a spongy slag-iron mixture over which the excess slag floats. This excess is poured off, and the sponge is dumped into a press which ejects still more slag and squeezes the sponge into a boom which can be finished in a **rolling mill.** (F.T.M.)

WRYBILL. Aves, Charadriiformes. A new Zealand bird (**Aves**), whose beak is asymmetrical. The terminal half of the organ bends to the right. The bird is said to seek its food, consisting of insects and other small animals, by reaching under the edges of stones. This habit is apparently well served by the peculiar adaptation. (A.W.L.)

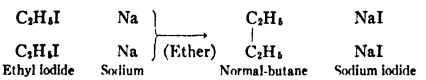
WRYMOUTH. Pisces, Teleostei. A marine fish (**Pisces**), related to the blennies. Found off Cape Cod. The name applies to all members of the family Cryptacanthodidae. (A.W.L.)

WRYNECK. Aves, Piciformes. A bird (**Aves**) related to the woodpeckers but with soft tail feathers. The name is from the curious habit of turning and extending the head displayed by the European species. The few known members of the group are found in Europe, Asia, and Africa. (A.W.L.)

WULFENITE. The mineral wulfenite is **lead molybdate** corresponding to the formula $PbMoO_4$, analyses showing that a part of the lead may be replaced by calcium. Wulfenite crystallizes in the tetragonal system usually in thin tabular forms, but is also found massive. It is a brittle mineral; hardness, 2.75–3; specific gravity, 6.5–7; luster, adamantine to resinous; color, yellowish to green or red, may be whitish or grayish; transparent to translucent. Wulfenite is a secondary mineral found in association with other lead minerals such as **galena, pyromorphite,** etc. It is believed to have been formed,

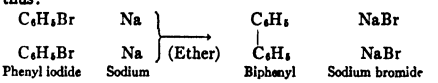
at least in part, by the action of waters containing molybdenum salts on cerussite, anglesite, pyromorphite, etc. Especially important foreign localities are in Yugoslavia, Czechoslovakia, Morocco, French Congo, New South Wales and Mexico In the United States it has been found in Phoenixville, Pennsylvania, and in the Organ Mountains, New Mexico; Yuma County, Arizona; Box Elder and Salt Lake Counties, Utah; and in Clark and Eureka Counties, Nevada. Wulfenite was named in honor of F. X. von Wülfen, an Austrian mineralogist of the eighteenth century. (E S C.S)

WURTZ - FITTIG - FRANKLAND REACTION. **Sodium** metal was used by Wurtz as reagent for the preparation of paraffin **hydrocarbons** by treating alkyl iodide in ethereal solution, thus:

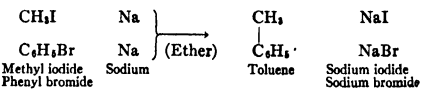


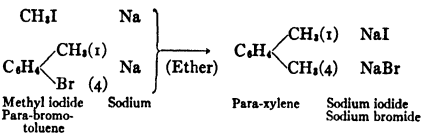
The method has been applied to the preparation of paraffin hydrocarbons as high in the series as hexacontane ($C_{60}H_{122}$). The alkyl radicals may be the same or different in the **iodide** or iodides taken.

Sodium metal was also used similarly by Fittig as reagent for the preparation of hydrocarbons by treating aryl **bromide** or iodide in the presence of dry ether, thus:



When alkyl iodide and aryl bromide are taken, the hydrocarbon is of the mixed alkyl-aryl type, thus:





The method has been applied to the preparation of substituted benzene hydrocarbons containing as many as four alkyl-groups (durene, $C_6H_2(CH_3)_4(1,2,4,5)$ and isodurene, $C_6H_2(CH_3)_4(1,2,3,5)$)

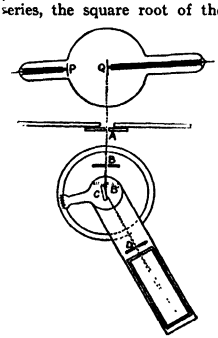
Frankland introduced the use of **zinc** instead of sodium to accomplish similar reactions. (R.K.S.)

X

X-RAY SPECTRA. We know that it is possible, by means of the grating effect of a crystal, to analyze a beam of non-homogeneous **x-rays** into its various wave lengths, thus forming a **spectrum**, and to measure the relative intensities of its various components (See **X-ray Spectrometer**). When **cathode rays** of sufficient energy fall upon a specimen of some element, as the metal "target" of an x-ray tube, the resulting x-rays, thus analyzed, are in general found to consist of a continuous spectrum (somewhat analogous to the radiation from a heated solid) with an intensity maximum and an upper frequency limit at frequencies dependent upon the speed of the cathode rays. Upon this may be superposed certain groups of much sharper maxima, which may be regarded as rather diffuse spectrum lines. These are characteristic of the material of the target, not of the incident cathode rays; except that if the cathode rays are produced below a certain voltage, some groups of lines do not appear at all.

As in the case of ordinary **diffraction-grating** spectra with light, each spectrum line may appear in two or three different orders, of which only the first need be considered. There are then recognized, in the spectrum of each element, several distinct line series; viz, the K, L, M, and N series (perhaps more); which are believed to be due to electron transitions ending in as many distinct quantum or energy states. The lines in any series correspond to "drops" to these respective states from various higher states or levels; the greater the drop, the greater the frequency of the resulting line (See **Quantum Theory**). There is a definite relation between the frequencies of the lines for a given element and the lower frequency limits or edges of the absorption bands of the same element for x-rays (See **Absorption Spectrum**).

If attention is fixed upon the strongest line of any one series (say the K series) as produced by different heavy elements, it is observed that the higher the **atomic number** of the element, the higher the frequency of this line, and if one plots a curve with these variables as coordinates, the result is a **parabola**. In fact, as we pass from one element to the next in the atomic-number series, the square root of the frequency of the selected line always increases by the same amount. This is known as Moseley's law. (L.D.W.)



A Bragg x-ray spectrometer. (Diagrammatic.)

X-RAY SPECTROMETER. X-ray **spectroscopes** or spectrometers, of which there are several designs, all utilize the **diffraction-grating** effect of crystals in analyzing x-rays The Bragg spectrometer, one of the earliest types, is quite simple (see figure). The rays enter through a pair or a succession of slits *A*, *B*, which limit them to a narrow parallel beam, and fall upon a suitable crystal *C* mounted on a prism table at the center of a graduated circle. The table, with the crystal, can be rotated so as to vary the angle of incidence. On another arm is mounted an **ionization chamber**, which the reflected rays enter through a set of slits *D*. As the crystal is rotated slowly, this second arm is rotated just twice as fast, so as to keep the axis *CD* always at the same angle with the reflecting planes of the crystal as the fixed incident beam *AC*. Thus, when any of the x-rays are reflected, they enter the chamber and produce an electrometer deflection proportional to their intensity. By plotting the electrometer readings against wave lengths as computed from **Bragg's law**, it is possible to exhibit the distribution curve and the contours of the spectrum lines. In more modern forms, the spectrum is progressively recorded on a photographic plate or film as the crystal rotates, and the instrument is then an x-ray spectograph. (L.D.W.)

X-RAYS. It was in 1895 that Professor Wilhelm Roentgen, of Wurzburg, Germany, discovered the x-rays, quite by accident, while experimenting with a **Crookes tube**. He observed the fluorescence of a barium platinocyanide screen which happened to lie near the tube, and traced the effect to something which emanated from the spot where the **cathode rays** struck the tube wall. Putting the tube in a pasteboard box made no difference; so it was not **light** or **ultraviolet radiation** that caused the fluorescence. Investigations followed rapidly, and within only a few weeks the x-rays were being used by surgeons to examine the bones of living people.

It was soon found that x-rays arise wherever cathode rays encounter solids; that "targets" for high **atomic weight** yield more copious x-rays; and that the greater the speed of the cathode particles, the more penetrating, or the "harder," the x-rays are. Special tubes were designed for producing x-rays. The earlier tubes were of the Crookes type, depending on the conduction of ionized gas. Those most used now are thermionic, of the Coolidge type, with a hot-wire cathode operating in a high vacuum; a construction which permits the passage of very high-speed electrons under voltage control, the quantity of them, and the intensity of the resulting x-rays, being regulated by the filament temperature.

Early experiments indicated that x-rays are something essentially different from light, an erroneous conclusion based upon the failure to observe regular reflection, refraction, or diffraction. We now know that this failure was due to the extremely short wave length of the rays, the range of which extends from the extreme ultraviolet into the **gamma-ray** region, that is, from 10^{-7} to 10^{-9} centimeters. The early theories attributed x-rays to the sudden stopping of the cathode-ray electrons; but the discoveries of Barkla, Moseley, Bragg, and others have shown that they arise in the atoms of the bombarded substance and that they have wave lengths and spectra quite analogous to visible **atomic spectra** (See **X-ray Spectra**).

There are three principal means of detecting x-rays: the fluorescent effect, the photographic effect, and the ionizing effect. The only method at first available for distinguishing radiations of different wave length was to measure their penetration or their **absorption coefficient** in various substances. The discovery of the x-ray **diffraction** or grating effect of crystals, by von Laue, Friedrich, and Knipping, in 1912, made it possible to analyze the rays and measure their wave lengths very much as light is studied with the **spectroscope**. When x-rays of given wave length are incident upon a crystal turned in various directions, the layers of atoms, at certain angles of incidence, reflect wave trains in phase with each other which, if caught on a photographic plate, produce a "Laue pattern." While the matter is not as simple as in the case of light incident on a dif-

fraction grating, it is nevertheless possible to interpret such patterns in somewhat the same way as a line spectrum, and to deduce the wave length from it. A unit convenient for expressing x-ray wave lengths is the "x-unit," which is 10^{-11} centimeters or 0.001 angstrom. (See **X-ray Spectrometer, Bragg's law,** and **Crystal Structure.**)

X-rays are used in medicine to photograph various organs and tissues of the body, or to view them directly (by projecting the x-rays onto a fluorescent screen—fluoroscopy). X-rays are also used in the treatment of certain forms of **cancer,** certain skin diseases, and other pathological conditions. (L.D.W., R.S.M.)

X-UNIT. X-rays.

XANTHINE. Alkaloids.

XANTHOPHYLL. Pigments in plants.

XANTUS BECARD. Chatterer.

XENIA. The name xenia is given to that phenomenon in which, two plants having been crossed, the characters of the male parent appear at once in the seed. Ordinarily the characters of neither parent are recognizable so early. Xenia is particularly well shown in **corn** plants There there is a conspicuous **endosperm,** the outermost layer of which is the aleurone layer. This endosperm results from the fusion of a male **nucleus** with a female fusion nucleus in the process of **fertilization.** The endosperm therefore is of **zygotic** nature. In corn it is frequently distinctly colored, with yellow dominating over white. It is possible therefore to pollinate a white-grained corn with a yellow parent, all the grains resulting from the cross being yellow. Red or purple colors often occur in corn, usually in the aleurone layer, and are dominant over colorless aleurone. So again crosses may be made showing directly the effect of the male parent on the seed.

In some plants the influence of the male element is more extensive, involving tissues which are of female origin. This phenomenon is known as metaxenia. (R.M.W.)

XENOBLAST. A term proposed by Becke in 1903 for metamorphic crystals with undeveloped **crystal faces.** Compare with **idioblast.** (R.M.F.)

XENOCRYST. A term proposed by Sollas in 1804 for crystals, usually corroded, which are foreign to the **magma** from which the **igneous rock** in which they occur has crystallized. (R.M.F.)

XENOLITH. A fragment, large or small, of a foreign rock included in an igneous mass The term is derived from the Greek, meaning stranger and stone. Xenoliths, both large and small, are best displayed at the contacts or margins of **batholiths.** (R.M.F.)

XENON. Symbol: Xe. Atomic number: 54. Atomic weight: 131.3. Density: 5 851 grams per liter, 0° C., 760 mm., or 4.53 when air equals 1.00. Melting point: —112° C. Boiling point: —107.1° C. (**Isotopes:** page 238.)

Xenon is a colorless, odorless gas, of negative chemical properties with ordinary materials. Discovered by Ramsay and Travers, in 1898, in ordinary **air** to the extent of 1 part xenon in about 11,000,000 air. (R.K.S.)

XEROPHYTES. These are plants which are adapted to grow in regions in which there is a decided lack of water, as in deserts. Plants growing in such localities have become modified in various ways which enable them to survive. Since the greatest problem is the lack of water, xerophytes must be so formed as to avoid excessive loss of water. There are several factors which reduce water loss. In many of these plants the leaves are greatly reduced in size or are completely lost, as in most Cacti and many Euphorbias. Most of the water lost to the plant passes through the **stomata** of the leaves and stem epidermis. In many xerophytes the stomata are sunk deep in small pits. The number of stomata is often reduced and also their size. As a further protection against loss of water the epidermis may be covered with a very thick cuticle.

The sap or xerophytic plants has properties which make it hold water tenaciously, tending to reduce loss. Many xerophytes have a fleshy habit, so that greater space is available for storage of water. Sometimes the root is tremendously swollen, in others the stem becomes the enlarged part, while in many it is the leaves. Often the leaves form dense tufts which cause great reduction of free surfaces.

Xerophytes are extremely tolerant of prolonged drought. Some may be kept free from water for several years, yet revive and grow when supplied with water. Most of these plants cannot stand too much water. quickly rotting under such conditions. Many species of xerophytes are covered with thorns. This is commonly assumed to protect them against grazing animals. (R.M.W.)

XIPHOSURA. The horseshoe or king crabs, a class of the phylum **Arthropoda** containing only a single genus, *Limulus*, with five species, one found along the Atlantic coast of North America from Florida to Nova Scotia and the other four on the eastern coast of Asia. They are animals of ancient lineage, showing no important change from **fossils** of the **Triassic.**

King crabs are distinguished by the following characters: 1. The **cephalothorax** is covered by a continuous arched plate of horseshoe shape. 2 Six segments of the abdomen are fused to form a continuous piece, hinged to the cephalothorax. 3. The abdomen bears a long caudal spine, the **telson.** 4. The appendages of the cephalothorax include six pairs associated with the mouth, five of them chelate. The five posterior pairs have the basal segments formed for crushing food. 5. The appendages of the abdomen are six pairs of broad plates bearing gills and used in swimming. 6. There are two large compound eyes and two smaller median eyes.

These animals burrow in sand and mud near the shore, feeding on small animals. They come to shore to deposit their eggs in sand. They are of little economic importance but have been used as food for pigs and domestic fowls, and to a limited extent as fertilizer. (A.W.L.)

XYLEM. The **cells** composing the woody tissues of higher plants are xylem cells. They have undergone extreme modification during their development, becoming greatly elongated and having much-thickened walls. Xylem cells include **tracheids, vessels, fibers,** and **parenchyma.** (R.M.W.)

XYLENE. Hydrocarbons.

Y

Y-CONNECTION. Three-phase alternating current equipment is wound with three wires whose currents differ 120° in **phase.** These three windings can be connected either in Y or **delta.** In balanced electrical condition, voltages and currents are the same in all coils. In the Y-connections one end of all three coils is connected in a common joint, and leads from each of the other ends constitute the three-phase line. The Y-connection is preferred for alternators because of the usefulness of the neutral point, and because the line voltage is the $\sqrt{3}$ times the phase voltage. The ability to bring out a neutral point and ground it either through resistance or reactance, is advantageous because it aids in working out protection and selectivity of control of parallel alternators. (F.T.M.)

YAGUARONDI. Jaguarondi.

YAK. Mammalia, Artiodactyla. A species of **ox,** *Poephagus grunniens,* found in Tibet and as a domestic animal in other parts of Asia. It is a large animal, attaining a height of well over five feet and a weight of more than 1000 pounds The horns are large, and are of the characteristic curved form usually found in oxen, with smooth surfaces The animals are marked chiefly by the long hair that clothes the flanks, legs, and tail, drooping almost to the ground.

Like other domestic cattle, yaks are important as a source of meat, milk, hides, and hair. (A.W L.)

YAM. Sweet potato.

YAPOK. Mammalia, Marsupialia. *Chironectes.* An **opossum** found from Guatemala to Brazil. It differs from other members of the group in its aquatic habits, resembling the mink and otter in this respect. The hind toes are webbed. (A.W.L)

YAW. Airplane.

YAWS (Frambesia, Frambaesia). An infectious tropical disease principally affecting the skin. The disease is caused by a **protozoan** organism, *Treponema pertenue.* This organism is practically indistinguishable from that of syphilis, and was first discovered in 1905 by Castellani. It is believed that yaws is a modified kind of syphilis, much less severe, and non-venereal in nature.

The symptoms resemble the cutaneous lesions of syphilis, and the treatment is identical with that of syphilis. The Wassermann reaction is also positive as with syphilis. (R.S.M.)

YEAR. The year is the longest natural unit for measuring **time.** Several different kinds of year are in use, but all of them depend upon the same phenomenon—the revolution of the earth about the sun. The variations between the different kinds of year arise from the use of different reference points external to the earth relative to which the revolution period is measured.

The sidereal year is the revolution period of the earth about the sun from a given star back to the same star again. Its length, expressed in mean solar **days,** hours, minutes, and seconds, is $365^d\ 6^h\ 9^m\ 9.^s5$ ($365\,^d25636$) and from a purely mechanical point of view this is the true revolution period of the earth.

For general living purposes the sidereal year has no particular significance, and for this purpose the time required for the earth (or apparently the sun) to pass from the vernal equinox back to the vernal equinox again is used. Such a year is $365^d\ 5^h\ 48^m\ 46.^s9$ ($365.^d24220$) in length, the difference between this and the sidereal year being due to **precession.** This is the year which is the basis of practically all ancient and modern **calendars.**

A third type of year, which is seldom used, is the period for the earth to pass from some point in its **orbit** (e.g., perihelion) back to the same point again. This year is $365^d\ 6^h\ 13^m\ 53.^s0$ ($365.^d25964$) in length, differing from the other two because of the fact that the line of apsides of the earth's orbit is slowly moving at the rate of 11″ per year. (W.K.G.)

YEASTS. Saccharomycetales. Yeasts are unicellular **Ascomycetes** in which no **mycelium** develops, and presumably are degenerate forms. They possess two methods of reproduction; one is the asexual process known as **budding;** the other a reduced type of **ascus** formation. In this the contents of a single cell divide to form four or eight cells; this would then be an ascus resulting from the transformation of a single cell. In some species a fusion of two cells occurs prior to ascus formation.

Yeasts are of great economic value, because of their ability to cause fermentations when present in solutions of **carbohydrates.** As a result of their activities the carbohydrates are broken down to **alcohols** and **carbon dioxide.** Yeast is therefore used in producing wine from grape juice, cider from apple juice, and beer from sprouted barley, as well as grain alcohol from various sources.

A similar process occurs in bread making. Yeast plants, obtained in the form of yeast cakes, are mixed in the dough; immediately the yeast acts on the carbohydrates present, producing alcohol and carbon dioxide. After the process has gone on for a sufficient time the dough is kneaded and presently baked. Kneading serves to break up the bubbles of carbon dioxide which have formed. These are the cause of the many small holes present in raised bread. Any alcohol present is driven off in the baking process. (R.M.W.)

YELLOWBIRD. Aves, Passeriformes The American **goldfinch,** *Astragalinus tristis,* and the yellow **warbler,** *Dendroica aestiva.* Only the male of the former species is yellow, and it has the crown and wings black and the tail marked with black. The yellow warbler is more generally yellow in both sexes. The name yellowbird is not commonly used. (A.W.L.)

YELLOW FEVER. An acute infectious disease which at present exists only in West Africa and certain parts of South America. Its geographical extent has been gradually limited by proper sanitary measures. Yellow fever is not contagious but is transmitted by the bite of a domestic **mosquito,** the female *Aëdes aegypti,* which has bitten a yellow fever patient during the first few days of the attack. Twelve days after biting an infected patient, the mosquito is then able to infect a non-immune person. During the eighteenth and nineteenth centuries yellow fever was seen in North America and Europe, being transmitted by mosquitoes breeding in the open water tanks of sailing vessels.

The organism causing yellow fever is classed as belonging to the group of filterable **viruses.** The virus can retain its potency for considerable time if kept in the dried and frozen state in a vacuum. The principal work on yellow fever has been done by the West African Yellow Fever Commission of the Rockefeller Founda-

tion Noguchi has done a great deal of the experimental work The mortality of this disease is high, 60% of cases resulting fatally.

The symptoms are characterized by a sudden onset, after an incubation period of from three to six days, of acute prostration, fever, slow pulse rate, body pains, and jaundice The **kidneys** are particularly involved Vomiting is uncontrollable Due to bleeding throughout the gastrointestinal tract and the bringing up of the old blood, the "black vomit" characteristic of this disease is produced

Failure of the kidneys usually indicates a rapid fatal termination Death usually occurs on the fourth or fifth day The crisis occurs in seven to eight days and patients that survive this period usually get well

Complications are rare

Malaria is difficult to differentiate from yellow fever. Weil's disease or infectious **jaundice** may give the same clinical picture

There is no specific treatment for yellow fever. A vaccine is used prophylactically against the disease Prevention of yellow fever consists of measures toward the destruction of the breeding of mosquitoes. (R S M)

YELLOW-FIN. Pisces, Teleostei A species of **trout**, *Trutta macdonaldi*, found in the upper part of the Arkansas River (A W L)

YELLOW-JACKET. Insecta, Hymenoptera A small black and yellow **wasp** that builds its nest of paper, either in a hole in the ground or under some object near the ground The use of partly decayed wood in making the paper gives these nests a brownish color Several species are known (A W L)

YELLOW-LEGS. Aves, Charadriiformes An American bird (**Aves**) related to the snipes and sandpipers Two species, the greater (*Totanus melanoleucus*) and lesser (*T flavipes*) yellow-legs, are widely distributed over North America and migrate into South America The latter is occasionally seen in Europe (A W I)

YELLOW-THROAT. Aves, Passeriformes *Geothlypis* A North American **warbler** distinguished by its bright yellow front with a black patch through the eyes and along the side of the head Known as the Maryland yellow-throat in the eastern and central states and in its western varieties as the western, Pacific, tule, and salt-marsh yellow-throat It frequents low thickets and marshes (A.W L.)

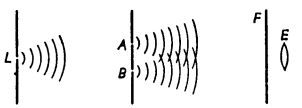
YIELD POINT. The minimum unit **stress** at which a structural material will deform without an increase in the **load** is called the yield point (See **Ultimate Strength** and **Elasticity**) (C W C)

YOLK GLAND. A portion of the **reproductive system** of the female by which yolk is secreted In some animals called the **vitellarium** (A W L)

YOLK SAC. An accessory embryonic membrane formed in the **vertebrates** as an enveloping structure around the yolk of the egg It is connected with the mid gut of the **embryo** and serves for the absorption of nourishment during embryonic life, and in some species, notably the fishes, after the individual has become active The wall of the structure is composed of the same **germ layers** that form the gut, a lining endoderm, and a covering of splanchnic mesoderm In the latter blood and blood spaces develop at an early period, later forming a network of vitelline vessels from which blood flows into the body of the embryo by way of a pair of large omphalomesenteric veins. Branches of the arterial system of the body extend into this plexus, completing a cycle for the transportation of the absorbed food to the developing body

The yolk sac persists even in the **mammals**, where yolk is usually not present In these forms it serves for the absorption of materials from the surrounding uterus during early development and is involved in the development of the circulatory system It soon becomes a vestige, however, as its functions are taken over by other membranes (A W L)

YOUNG'S INTERFERENCE EXPERIMENT. In 1801 Thomas Young made the epochal discovery of the interference of light waves, by means of an experiment which has become classic Light from a narrow slit L falls on a plate in which are two parallel slits, A, B, very close together, so that from the further side of the latter there emerge two exactly similar wave trains



Light from single source L gives rise to two wave trains at A and B, which produce interference fringes on screen F

(See figure) These overlap in the region beyond AB and produce **interference** If a screen F is placed at some distance from AB, alternate bright and dark bands or fringes appear on it, parallel to the two slits If a translucent screen is used (or in the case of white light, a plate of colored glass acting as a color filter), these bands may be viewed by means of a magnifier beyond it at E, or better, a low-power micrometer eyepiece, with which the width of the band-interval can be measured

It is easy to show from the elementary theory of interference that if $AB = s$, if the distance from AB to F is x, and if the wave length of the light is λ, the distance on the screen between any two consecutive dark bands or any two consecutive bright bands is $b = x\lambda/s$ Therefore if b, s, and x are measured, we have at once a means of determining the wave length $\lambda = bs/x$

Other devices have proved more satisfactory than the pair of slits, such as Young's "biprism," Fresnel's mirrors, or Lloyd's mirror, each of which produces a double virtual image of the slit L to serve as the two wave-train sources A and B (L D W)

YOUNG'S MODULUS Elasticity.

YPSILOID CARTILAGE. A cartilaginous structure associated with the pelvic girdle in some of the **salamanders** It is a Y-shaped projection from the pubis. (A W L.)

YTTERBIUM. Symbol Yb Atomic number 70. Atomic weight. 173 04 Melting point: 1800° C Type of compound Yb_2O_3 Color of salts colorless Discovered by Urbain in 1907 A member of the **yttrium** sub-group of the rare earth metals (R K S)

YTTRIUM. Symbol Y Atomic number: 39. Atomic weight. 88 92. Density. 3 80 Melting point: 1490° C. Type of compound: Y_2O_3 Color of salts: colorless. Discovered by Mosander in 1842.

Yttrium occurs in a few uncommon minerals, e g, **gadolinite** (35%–45% Y_2O_3), **xenotime** (55%–65%), **fergusonite** (25%–45%), **euxenite** (15%–35%).

The yttrium sub-group of the rare earth metals consists of the elements yttrium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium The **potassium** sulfate compounds of all of these elements are relatively soluble in water. Yttrium is the most abundant member of the sub-group but not so abundant as are nine of the ten members of the **cerium** sub-group. (R K S)

YUCCA BORER. Insecta, Lepidoptera. A giant **skipper**, *Megathymus yuccae*, whose **larva** bores in the stem and root of yucca plants. Several species of these insects are known, expanding from two to three and a half inches in the adult stage. They are limited in distribution to the southern states and south into Central America with the exception of one that has been taken in central Colorado and western Nebraska. (A.W.L.)

YUCCA MOTH. Insecta, Lepidoptera. A small **moth**, also commonly called the pronuba moth from the name of its genus. It lives in the flowers of yucca, depositing its eggs in the ovary of the plant and then **pollinating** the flower. The developing larva eats the seeds, but since many more are formed than it is capable of consuming, the exchange is beneficial to the plant. Several species of these moths are known. All belong to the same genus, whose early name, *Pronuba*, has been supplanted by another, **Tegeticula.** Yuccas are also frequented by moths of the genus **Prodoxus**, which are of no service in pollinating the flowers. They are called false yucca moths. (A.W.L.)

Z

ZEBRA. Mammalia, Perissodactyla. An animal of the genus *Equus* related to the asses and quagga, distinguished by the complete or nearly complete transverse striping of the body and legs. The stripes vary in the several species from white to yellow-brown, alternating with dark brown to black. All of the zebras occur in the southern half of Africa. (A.W.L.)

ZEBU. Mammalia, Artiodactyla. The common domesticated **cattle**, *Bos indicus*, of India, characterized by the highly developed **dewlap** and by the sharply defined hump on the withers. Similar cattle are found in China and Africa, and they have been introduced into the Americas for hybridization with range cattle. In southern Texas and Brazil these crosses are promising, since the humped cattle are more tolerant of heat and more resistant to insect- and tick-borne diseases. In America the zebu has been known also as Brahman cattle. (A.W.L.)

ZEEMAN EFFECT. An effect of a magnetic field upon the structure of the spectrum lines of a gas when subjected to its influence. The phenomenon, sought unsuccessfully by Faraday and finally observed by Zeeman in 1896, consists in the splitting up of each line into two or more components. In the simpler cases, when the source is viewed at right angles to the field, there are three components, of which the middle one has the same frequency as the unmodified line. This component is plane-polarized to vibrate parallel with the field, while the two side components vibrate at right angles to the field. When the source is viewed in the direction of the field, there are only two components, displaced in opposite directions, and circularly polarized in opposite senses. (See **Polarized Light.**) These phenomena constitute the so-called "normal" Zeeman effect.

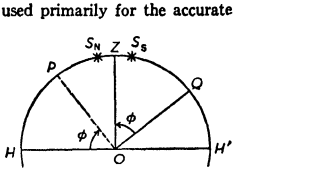
With most lines, however, the number of components is greater, in some cases reaching twelve or fifteen. They are symmetrically arranged and symmetrically polarized. The displacements, as in the simpler case, are proportional to the magnetic field intensity H, and are always expressible, in wave numbers, as rational multiples of the displacement in the normal effect, which is $4.67 \times 10^{-5}H$ (reciprocal centimeter), a quantity known as the "Lorentz unit." The Zeeman effects observed in **sun spots** give valuable information as to the magnetic conditions in those areas.

Closely related to the Zeeman effect are two others, the Paschen-Back effect, produced by very strong magnetic fields, and the Back-Goudsmit effect, observed with elements having a nuclear magnetic moment, such as **bismuth.** (L.D.W.)

ZENITH. The point on the celestial sphere directly overhead is the observer's **zenith.** The astronomical zenith is defined as the point where the plumb line extended up from the surface of the earth will intersect the **celestial sphere.** Owing to the fact that the plumb line may be affected by local gravitational effects, such as large mountains in the vicinity, the geographical zenith is the point where a line perpendicular to the surface of a smooth earth would intersect the celestial sphere. The angular distance between the astronomical and geographical zenith is the station error of the point on the surface of the earth. Because of the fact that the earth is an oblate **spheroid** rather than a perfect sphere, neither the plumb line nor a perpendicular to the surface of the earth will pass through the geometrical center of the earth unless the observer is either at one of the poles or is on the **equator.** The geocentric zenith is defined as the point where a line extended from the center of the earth through the observer will intersect the celestial sphere. The angular distance between the astronomical and geocentric zenith is the reduction of **latitude** for the observer. (W.K.G.)

ZENITH TELESCOPE. This instrument, as the name implies, is designed for use at or very close to the **zenith.** A telescope is mounted in the same manner as the **meridian circle**; i.e., in the **altazimuth** form with the azimuth so fixed that the instrument is always in the plane of the meridian. In place of the accurate circles for measuring altitude which are to be found on the meridian circle, this instrument carries a very accurate level so adjusted that the bubble is in the center of the tube when the telescope is pointing at the zenith. The **reticle** of the instrument carries in addition to the set of wires parallel to the meridian, as in the meridian circle, two wires parallel to the axis of rotation; i.e., perpendicular to the meridian. One of these wires is fixed and, when the instrument is in proper adjustment, with the level bubble in the center of the tube, the fixed wire is in the plane of the prime vertical; i.e., passes through the zenith. The other wire may be moved by means of a fine screw which is parallel to the meridian. The head of this screw is accurately calibrated so that the distance of the movable wire from the zenith wire may be determined in seconds of arc

The zenith telescope is used primarily for the accurate determination of terrestrial **latitude** by what is commonly known as Talcott's Method. In the figure we have a representation of the **celestial sphere** drawn in the plane of the observer's meridian $HPZQH'$. HOH' is the plane of the **horizon,** Z is the astronomic **zenith,** P the pole of rotation, and Q the direction of the **equator.** HP is the **altitude** of the pole and hence is, by definition, the astronomic latitude of O. Inspection of the figure shows that QZ, the **declination** of the zenith, is also equal to φ.



For the purpose of determining QZ a pair of stars, S_s and S_n, are selected which have approximately the same **right ascension** and hence will cross the meridian within a short time of each other. The declinations of the stars are so selected that one will pass just south of the zenith and the other just north. Such pairs of stars, known as Talcott pairs, have been selected and their declinations accurately determined by various observatories. Of course for the selection of the proper pairs to be used for a particular station the latitude of that station must be approximately determined in advance by any of the methods discussed under latitude.

At the time that one of the stars is approaching the meridian the observer watches in the eyepiece of the zenith telescope and, when the star appears, he sets the movable wire upon the star and keeps it there until the star has crossed the meridian. The reading of the screw gives the distance that the star is north or south of the zenith, either S_nZ or S_sZ, depending upon which star is observed first. The second star is then observed and

the other zenith distance determined in the same manner. From the value of the measured zenith distances and the declinations of the stars the value of the declination of the zenith can be accurately determined and hence the latitude.

The great advantage of this method is that both stars are observed close to the zenith and hence the correction for **astronomical refraction** is very small in either case. Furthermore, since one star passes north and the other south of the zenith, the refraction corrections practically neutralize each other The measurement of the zenith distance by means of the screw can be very accurately made. The disadvantages of the method are that it requires the use of the accurately adjusted fixed instrument, and the declinations of the stars must be very accurately known

Observations of this character are constantly being made at various stations all over the world for the purpose of determining the **variation of latitude.** This is also the method used by the Coast and Geodetic Survey for the determination of latitude of their fundamental stations. (W K G)

ZEOLITE GROUP. To the zeolite group of minerals belong a number of hydrous **silicates** of **aluminum** which also ordinarily contain **sodium** or **calcium,** but rarely they may carry **barium, strontium, magnesium, potassium,** etc These minerals are not related crystallographically as they occur in the **isometric, orthorhombic, hexagonal,** and **monoclinic** systems, but they are all characterized by the presence of water, up to 10% or 20%, which is easily released with the application of heat. They are all rather soft minerals, hardness between 3 5 and 5 5, of low specific gravity, 2 0 to 2.5, and they will decompose readily upon treatment with acid, most of them yielding a gelatinous mass The easy fusion, together with the rapid expulsion of water, is responsible for the name of this interesting group, it is derived from the Greek words to boil and a stone, hence zeolite, "a boiling stone" The zeolites are secondary minerals, usually found filling fissures and cavities in the more **basic igneous rocks** as **basalt, gabbro,** etc, but occasionally in the more **acidic** types as **granite** or in **gneisses.** The following members of the zeolite group are described under their own headings· **Analcite, chabazite, heulandite, natrolite, phillipsite, stilbite, thomsonite, scolecite,** and **harmotone** (E S C S)

ZERO. The number zero has the fundamental properties expressed by the formulas

$$a + 0 = a, \quad a \cdot 0 = 0,$$

and

$$0/a = 0, \quad \text{if } a \neq 0,$$

where a is any number.

Division by zero is not defined and is not a permissible operation (L L S)

ZERO EXPONENT. Powers and Exponents.

ZERO OF A FUNCTION. A zero of a **function** of one variable is a value of the **variable** which gives the value **zero** to the function

A zero of a function $f(x)$ is a **root** of the corresponding **equation** $f(x) = 0$ (L L S)

ZEUGLODON. Eocene.

ZINC. Symbol· Zn Atomic number: 30 Atomic weight: 65 38 Density. 7.1 Hardness 2.5 Melting point: 419.4° C. Boiling point: 907° C. (Isotopes: page 238)

Zinc is a bluish-white metal, malleable and ductile at 150° C., but at 180° C it changes rapidly so that at 205° C. it may be easily powdered; remains lustrous in dry air but is slightly tarnished in moist air or in water; burns upon heating to vaporization with a bluish flame forming zinc oxide; soluble in acids—slowly when pure but rapidly on contact with **copper** or **platinum;** soluble in alkalis. Discovery prehistoric

Zinc is one of the four most largely produced and utilized metals. Used (1) as a protective coating for iron and steel ("galvanized iron"), (2) as a constituent of various **alloys,** especially brass, (3) as plates for primary **batteries,** e.g, dry cell, (4) as a reducing agent of wide range of application in inorganic and organic chemical reactions.

Zinc occurs chiefly as sulfide (**sphalerite,** zinc blende, ZnS), carbonate (**smithsonite,** $ZnCO_3$), or oxide (**franklinite,** iron-zinc-manganese oxide) The sulfide ore is roasted to form the oxide The oxide is mixed with **carbon** (coal) and heated to 1200° C Zinc vapor is condensed outside the reaction chamber, and cast into blocks called spelter A low-temperature process employs roasting of the sulfide preferably to the sulfate, which is later extracted with water, and zinc metal obtained by **electrolysis.**

Acetate Zinc acetate ($Zn(C_2H_3O_2)_2 \cdot 2H_2O$), white crystals, soluble Used as a mordant in dyeing textiles, as a wood preservative, and medicinally.

Carbonate. Zinc carbonate ($ZnCO_3$), white insoluble powder, by grinding smithsonite, or by reaction of zinc salt solution and **sodium** hydrogen carbonate solution Used as a pigment and medicinally

Chloride. Zinc chloride ($ZnCl_2$), white, soluble, fusible (melting point 365° C) solid, formed by reaction of zinc oxide, carbonate, or metal with **hydrochloric acid** solution, and evaporating. Used in a great variety of ways, such as a wood preservative, in soldering fluxes, as a mordant in dyeing textiles, in adhesives and cements, in fluids for embalming and taxidermy, zinc ammonium chloride ($ZnCl_2 \cdot 5NH_3 \cdot H_2O$), white solid

Chromate Zinc chromate, "zinc yellow" ($ZnCrO_4$), yellow solid, insoluble, formed by reaction of zinc salt solution and **sodium** chromate solution. Used as a pigment

Dichromate: Zinc dichromate ($ZnCr_2O_7$), orange-red solid, insoluble, formed by reaction of **chromic acid** and zinc hydroxide Used as a pigment

Hydroxide Zinc hydroxide ($Zn(OH)_2$), white, gelatinous precipitate, formed by reaction of zinc salt solution and alkali hydroxide solution, but soluble in excess of either **sodium** or **ammonium** hydroxide, and soluble in acids

Nitrate Zinc nitrate ($Zn(NO_3)_2 \cdot 6H_2O$), white, deliquescent crystals, soluble, formed by reaction of zinc oxide, carbonate, or metal with **nitric acid.**

Oxide Zinc oxide (ZnO), white, insoluble powder, formed (1) by burning zinc vapor in air, (2) by igniting zinc carbonate, hydroxide, or nitrate Used (1) as a paint pigment, (2) in compounding rubber, (3) in pharmaceutical and cosmetic preparations, (4) in white printing inks, (5) in ceramic glazes, (6) in dental cements

Peroxide Zinc peroxide (ZnO_2), white precipitate, formed by reaction of zinc chloride solution and **barium** peroxide, followed by recovery of the precipitate. Used as an antiseptic in medicine and in cosmetics

Phosphate: Zinc phosphate ($Zn_3(PO_4)_2 \cdot 4H_2O$), white precipitate, formed by reaction of zinc salt solution and **sodium** triphosphate solution Used in dental cements, and in medicine

Sulfate· Zinc sulfate, white vitrol ($ZnSO_4 \cdot 7H_2O$). white crystals, soluble, formed by reaction of zinc oxide, carbonate, or metal with **sulfuric acid,** or by roasting the sulfide ores at a relatively low temperature, and later extracting with water and crystallizing Used (1) in preserving wood, glue, and skins, (2) in the manufacture of lithopone pigment, (3) as electrolyte for zinc plating, (4) as a mordant in dyeing textiles, (5) in medicine as an emetic and mild disinfectant.

Sulfide: Zinc sulfide (ZnS), white precipitate, by reaction of zinc salt solution and a soluble **sulfide** This reaction is applied in the preparation of lithopone by

mixing solutions of zinc sulfate and barium sulfide, the product formed being a mixture of zinc sulfide and barium sulfate. Lithopone is used as an important paint pigment.

Stearate: Zinc stearate ($Zn(C_{18}H_{35}O_2)_2$), white insoluble powder, formed by the reaction of zinc salt solution and **sodium** stearate solution. Used in medicine (1) as a non-irritant powder and in skin diseases, (2) in paints and linoleum as a dryer, (3) in cosmetics.

When zinc salt solutions are ignited with **cobalt** nitrate solution, a green cobalt zincate is formed (R K S)

ZINC BLENDE. Sphalerite.

ZINCITE. The mineral zincite is a **zinc** oxide corresponding to the formula ZnO Its **hexagonal** crystals are rare, as it usually occurs massive, foliated, or in coarse to fine grains When the crystals are observable it reveals a perfect cleavage parallel to the base of the prism. The fracture is conchoidal Its hardness is 4–4 5, specific gravity, 5 4–5 7, luster, subadamantine to vitreous, orange yellow streak, color, red to orange yellow, translucent to opaque Zincite occurs in considerable quantities at Franklin Furnace, New Jersey, with **willemite** and **franklinite** Zincite has been found in Poland, Tuscany, Spain, Saxony, Tasmania, and elsewhere Except at Franklin Furnace, it is not an important ore of zinc. (E S C S)

ZINC POISONING (Brass founders' ague). This industrial disease is caused by inhalation of fumes from **zinc** oxide It is characterized by chills and fever accompanied by profuse sweating It develops in individuals working with zinc, such as smelters, metal refiners, galvanizers, etc There is no treatment, and the disorder lasts only a day or two and apparently leaves no after effects (R S M)

ZIRCON. The mineral zircon, **zirconium** silicate is commonly found in square **tetragonal** prisms, although sometimes assuming pyramidal or irregular forms It may be found as grains in sands and gravels It is without good **cleavage**, is brittle, with a conchoidal fracture, hardness, 7 5, specific gravity, variable from 4 2 to 4 8, luster, adamantine, brilliant, color, green, yellow green, golden yellow, red, red brown, brown, and blue It is said that the colorless stones have been produced by heating the brown ones, to imitation diamonds The name zircon comes from an Arabic word ***zarqun***, meaning vermilion, or perhaps from the Persian ***zargun***, meaning golden colored These words are corrupted into jargoon, a term applied to the light-colored zircons The yellow zircon is called hyacinth, from a word of East Indian origin In the Middle Ages all yellow stones of Indian origin were called hyacinth, but today it is restricted to the yellow zircons.

Zircon occurs in the **igneous rocks of acid** type, such as **granites** and **syenites**, e g, the zircon syenites of southern Norway It is sometimes found in **gneisses** and **schists**, and is common in river gravels Foreign localities are the Ural Mountains, Trentino, Monte Somma, and Vesuvius, Arendal, Norway, Ceylon, India, Siam, at the Kimberley mines, South Africa, Madagascar, and in Canada in Renfrew County, Ontario, and Grenville, Quebec In the United States zircon is found at Litchfield, Maine, Chesterfield, Massachusetts; in Essex, Orange, and St Lawrence Counties, New York, Henderson County, North Carolina, the Pike's Peak district, Colorado; and Llano County, Texas (E S.C S)

ZIRCONIUM. Symbol Zr Atomic number· 40 Atomic weight· 91 22. Density· 6 44. Melting point: 1900° C (Isotopes: page 238.)

Crystalline zirconium of high purity is a white, soft, ductile, and malleable metal, but that of 99% purity, when obtained at high temperature, is hard and brittle. Amorphous zirconium is a bluish-black powder At about 500° C zirconium burns in air; heated in **hydrogen** forms hydride; heated in **nitrogen** a nitride; and heated in **chlorine** the tetrachloride. A mixture of **hydrofluoric** and **nitric acids** dissolves the metal. On the laboratory scale, zirconium metal may be produced by the reduction of the chloride, oxide, or potassium zirconium fluoride with **sodium** metal Discovered by Klaproth in 1789

Zirconium occurs in **zircon** (zirconium silicate, $ZrSiO_4$), and **baddeleyite** (zirconium oxide, ZrO_2)

Hydroxide· Zirconium hydroxide, white precipitate, formed by reaction of zirconium salt solution and with alkali hydroxide solutions, e g, **sodium** hydroxide

Oxide· Zirconium oxide (ZrO_2), white solid, obtained by the ignition of the hydroxide, nitrate, or sulfate, and used as a furnace **refractory**, and in ceramics

Salts· (1) Normal For example, zirconium chloride ($ZrCl_4$), which hydrolyzes readily, (2) zirconyl For example, zirconyl chloride ($ZrOCl_2$), and (3) zirconate. For example, sodium zirconate (Na_2ZrO_3). (R.K.S.)

ZOANTHARIA. Actinozoa.

ZODIAC The zodiac is a belt on the celestial sphere which extends for an angular distance of 8° either side of the **ecliptic** This belt is divided into 12 sections, each 30° long, which are known as the signs of the zodiac These signs indicate the position of the sun for each month in the year and are named for the zodiacal **constellations** which occupied the signs about two thousand years ago Due to **precession** the sign of **Aries** has moved back into the constellation of **Pisces**, so that the signs and constellation names no longer agree

Since the **planets** all lie relatively close to the ecliptic their paths along the celestial sphere will lie in the zodiac It is a common practice with makers of almanacs to indicate the positions of the planets by the sign of the zodiac in which they are to be found The signs of the zodiac, or houses of the planets, also play an important part in the pseudo science of **astrology** (W K G)

ZODIACAL LIGHT. The zodiacal light is a faint glow which appears extending along the **ecliptic** or **zodiac** from the vicinity of the sun It may best be observed in the western sky in the spring after the sunset twilight has completely disappeared, or in the eastern sky in the fall just before the morning twilight appears. It is so faint that it is completely masked by moonlight. The zodiacal light decreases in intensity with distance from the sun, but on very dark and clear nights it has been followed completely around the ecliptic In fact, the work of Van Rhijn at the Mount Wilson Observatory indicates that the illumination is not confined to the ecliptic, but presumably covers the entire sky, being responsible for about 60% of the total skylight on a moonless night There is a slightly increased illumination of the zodiacal light on the ecliptic directly opposite the sun known as the **gegenschein.**

Photographic observations of the spectrum of the zodiacal light indicate that it is composed of reflected sunlight The amount of material necessary to produce the intensity of the zodiacal light is amazingly small. Calculation indicates that the zodiacal light could be accounted for, if, inside the orbit of the earth, there were particles a millimeter in diameter of the reflecting power of the moon, and each one five miles from its neighbors

Observational studies indicate that the material producing the zodiacal light is located in a lens-shaped volume of space centered on the sun and extending well out beyond the orbit of the earth. Each individual particle, unless small enough to be held away from the sun by **radiation pressure**, must be moving about the sun in its individual orbit. The intensification of the reflected light at the point directly opposite the sun might be explained either by a concentration of the reflecting particles in this region, or by the fact that directly opposite the sun the particles would be in full **phase.** (W K.G)

ZONE PLATE. This is a curious piece of **diffraction** apparatus, useful in illustrating certain aspects of the **Huygens' principle.** It consists of a transparent plate on which is a pattern composed of a very large number of concentric, opaque, circular rings with open spaces between them They might be made by drawing on glass a system of circles whose radii are proportional to the square roots of the consecutive integers, and then covering every other annular space between these circles with black paint Actually the rings must be so finely spaced that the design is first drawn to a large scale on white paper and a much reduced photograph of it then made on a glass slide There should be two or three hundred of the rings When finished, they look much like a set of **Newton's rings.**

A plate thus prepared, when placed across a beam of light, acts like a converging lens with its optical center at the center of the ring system It will produce a faint, inverted, real image of a bright object, such as a candle If there are N opaque rings and the radius of the outermost is R, then the focal length (See **Mirrors and Lenses**) for light of wave length λ is $l = R^2/N\lambda$. (L D W)

ZOOCHLORELLA. A green plant cell (**alga**) living in the tissues of various animals, including flatworms, coelenterates, sponges, and one-celled species The association is a true symbiosis (**animal association**) Yellow or brown symbionts of the same habits are called zooxanthellae (A W L)

ZOOECIUM. The body wall of the individual in colonies of **Bryozoa** The zooecium acts as a sheath into which the polypide, consisting of the alimentary tract with the tentacles, can be retracted when the animal is disturbed (A W L)

ZOOGEOGRAPHY. Also called chorology The distribution of animal faunas on the surface of the earth According to the prevailing characteristics of their faunas, several zoogeographical regions are recognized as principal divisions These are the Palaearctic region, including all of Europe, Asia south to the Himalayas, and Africa above Lat 20° N Some biologists include Greenland and Labrador in the same region, but they are usually regarded as part of the Nearctic region with the rest of North America Central and South America and the West Indies are in the Neotropical region. The Ethiopian region includes Africa and Madagascar The Australian region includes Australia, Tasmania, New Zealand, and many of the Pacific islands to the north and east The Oriental region includes all of Asia south of the Palaearctic, with the large adjoining East Indian islands and some of the smaller Pacific islands to the east Various subdivisions have been recognized by some writers

Later studies of animal distribution have attempted to correlate it with climatic conditions Merriam's classification of the North American fauna included three principal regions, boreal, austral, and tropical In the first the Arctic zone is limited to high altitudes and latitudes where the mean normal temperature of the six hottest weeks is 50° F at the lowest boundary. The Hudsonian zone ranges from this limit to a mean of 57° F, and the Canadian zone from this to 64° F The transition zone of the Austral has an upper limit, expressed as the sum of mean daily temperatures above 43° F., of 10,000. The Upper Austral extends from this limit to 11,500, and the Lower Austral to 18,000. Tropical regions have a total of 26,000; in North America they occur only in southern Florida

Still other attempts to classify the distribution of organisms in North America in relation to climatic conditions have resulted in the **isophanes** and phenomeridians of Hopkins' maps and in biotic areas based on rainfall, temperatures, and floral characteristics. In modern **ecology** these studies have become intricately associated with more detailed analyses of the relations of organisms to the environment, but for the more general needs of taxonomists and specialists in other fields of biology the older terms of distribution are still useful. (A W L)

ZOOLOGICAL GARDEN. More often shortened to zoo A place where animals are kept in captivity for public display and scientific study The term is also closely related to menagerie, referring to a collection of wild animals for exhibition

One of the most famous of the zoological gardens is that of the Zoological Society of London in Regent's Park, although most of the world's great cities have exhibits of some importance Dublin, Edinburgh, Antwerp, the Jardin des Plantes in Paris, and the Tiergarten in Berlin are among the leading European gardens In Africa the collection at Cairo is noteworthy, and in Australia several of the larger cities maintain such establishments The United States has a very large number of small and unimportant zoos and several that rank with the finest The best known are the national zoological park at Washington, D C, and the New York and Philadelphia zoological gardens

In all such exhibits the exotic mammals and the birds take a leading place, with reptiles next in importance Specimens are secured mostly by capture, although some wild animals breed freely enough in captivity to furnish a dependable supply The principal activities in the management of exhibits are for the maintenance of healthful conditions for the animals, including cleanliness and proper feeding Research on the habits of the animals exhibited and special studies according to the interest and training of the scientific staff are also a normal part of the work, and in the larger zoos the routine incidental to extensive public patronage becomes important (A W L)

ZOOSPORANGIUM. A zoosporangium is a **cell** in which motile **spores** called **zoospores** are formed (R M W)

ZOOSPORE. A zoospore is a motile **spore** or reproductive **cell** which develops into a new plant It is formed from the **protoplast** of the cell, usually by repeated divisions of the protoplast Zoospores are asexual (R M W)

ZOOXANTHELLA. Zoochlorella.

ZORAPTERA. An order of insects without a common name, made up of a few rare species found in the Oriental region, Africa, Central America, and the southern United States They live in small colonies and resemble **termites** in appearance, although they differ conspicuously in the form of wings As in the latter insects, some members of the colony are winged and some wingless (A W L)

ZOSTEROPS. Aves, Passeriformes. A small bird (**Aves**) of the Old World tropics All of the numerous species are birds of small size and quiet colors Their affinities are uncertain. The name is that of one of the included genera, used as an Anglicized common name (A W L)

ZUBR. Ox. The European **bison.**

ZYGOMATIC ARCH. A narrow bridge of bone extending, in the mammalian skull, from before the ear to the cheekbone, below the temple It is composed of a long process of the temporal bone extending forward and joining a short posterior process of the malar bone (A W L)

ZYGOMORPHIC. Flower.

ZYGOSPORE. A spore formed by the union of two similar gametes is called a zygospore. (R M.W.)

ZYGOTE. This is the cell which is formed from the union of two sex cells or gametes. In many of the algae the two fusing cells are identical. In many cases these two cells are actively motile, as is the zygote which they form by their union. In other cases the zygote is non-motile from the beginning. This is always true in the oögamous species of green algae and in all higher plants.

The zygote has at first a thin cell wall. Soon this thickens and becomes differentiated into layers. In the lower plants the zygote is often a stage in which the plant survives long periods of unfavorable conditions, such as drought or cold. (R.M.W.)